

Smart Buildings Technologies: a comprehensive review of software advancement and integration strategies

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Abstract

This research explores the rapidly developing of the two topics known as smart buildings and smart cities, that are the results of the quick development of cutting-edge technologies. With an focus on the practical applications of advanced technologies such as Internet of Things (IoT), Building Information Modeling (BIM) and Artificial Intelligence(AI) , this research offers an in-depth review of their vital role in evolving urban environments. The research focuses on the potential benefits they could bring to human and their built environment development, building management, energy efficiency, and urban design and planning. Particularly, BIM can become a powerful tool for smart cities, enabling data-driven decision-making, improving operations and maintenance, and transforming design and construction processes via thorough digital modeling.

In this paper, the merits of technologies implementations such as resource economy, sustainability, environmental viability, and enhanced quality of life—are highlighted . As a methodology for this research, bibliometric analytic from scopus data base have been used.

Even though smart cities smart cities have the potential to be revolutionary, but there are still challenges that need to be addressed, which includes security and privacy problems, socioeconomic inequality, large investment requirements, and technology vulnerabilities. The paper tries to understand the complexities of data ownership, ethical considerations, and cyber security risks, highlighting the possible dangers associated during hacking, data breaches, and viral assaults.

The paper explains about cyber security solutions for the challenges using the BIM and promoting the technology merits that are paving a way for Smart Cities.

Keywords: Smart cities; Building Information Modeling (BIM); Internet of Things (IoT); cyber security

INTRODUCTION

Urbanization in world have been facing various challenges and many researches are been conducted around the world to overcome the challenges. The few concepts like smart cities, smart buildings have become a ray of opportunity for the challenges that urban areas face in terms of security, infrastructure, monitoring and many more. The research towards smart developments will provide a sustainable development for the future generations. Abandoning conventional cities was never an option, but, enhancing them has always been a goal to many urban designers, urban planners and also policy makers. Smart cities have many merits like minimizing infrastructure costs, reducing carbon footprints, mitigating greenhouse gas impacts, and steering society toward sustainability which also aligns to the Kyoto protocol and Paris agreements objectives.

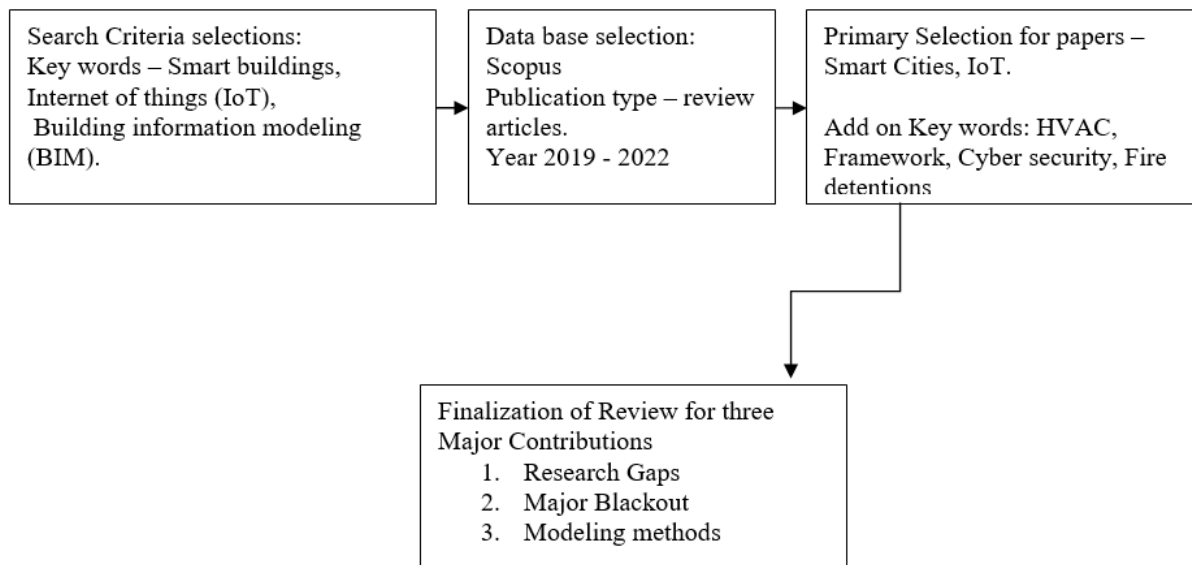
The emerging technologies like Building Information Modelling (BIM) and Industry 4.0 offers varied opportunities for constructing sector promoting new smart buildings and also energy efficiency policies and guild lines are released for renovating existing structures. The growth of urbanization in rapid pace needs intelligent solutions for green and smart built environment with carbon free transportation, social conscious governance, environmental stewardship, and quality of life (Padmanaban, 2021). The Internet of Things (IoT) play a vital role that helps in interconnecting physical equipments and objects to share and integrate data, but increased energy consumption challenge for the data transfer and storage must be effectively addressed (Waleed Ejaz, 2016). As we move toward smarter urban built

environment, the acceptance of technologies like BIM becomes influential (Ande Ruth, 2020). BIM is not exclusively a tool for new constructions but a catalyst for revitalizing existing structures which align with energy efficient practices of contemporary standards. Better maintenance, operations, and design in construction processes can be achieved by digital modeling , BIM data-driven decision-making options, fostering stakeholder engagement, cost reduction, and overall sustainability.

The Internet of Things (IoT) uses sensors, software, and internet protocols to share data effortlessly with networked physical devices. IoT technology plays a vital role in controlling infrastructures like security, lighting, ventilation, heating, and air conditioning, smart buildings make use of connected technologies, devices, data analytics, and automation for the objective of energy efficiency according and enhancing user comfort. For example, smart HVAC controls by analyzing and clearing a pattern that helps in maximize energy efficiency by detecting and resolving problems, setting consumption limits, and cutting power in unoccupied areas—especially during periods of high demand. Solutions and awareness regarding cyber security, data breaches have to be well researched and policies have to be drafted for sustainability and ethical technology usage for the development of smart cities (Chen, 2021).

METHODOLOGY

In this research paper the methodology used is bibliometric analysis, a systematic approach that helps the research area by minimizing the biased judgments of authors, and ensures the intelligibility and depth of the results. Extensively used to analyze research trends and analyze published articles in explicit areas, bibliometric analysis enables detailed conclusions to be drawn without the need for extensive literature review. The research articles are searched for the time period of 2019 to 2022 and primary selections of the papers are done on the bases of keywords like smart cities, IOT and then as an add on keywords HVAC, cyber security, and fire detention are used. The research papers found are approximately 121 and based on the research goals, the papers are selected and literature review has been done.



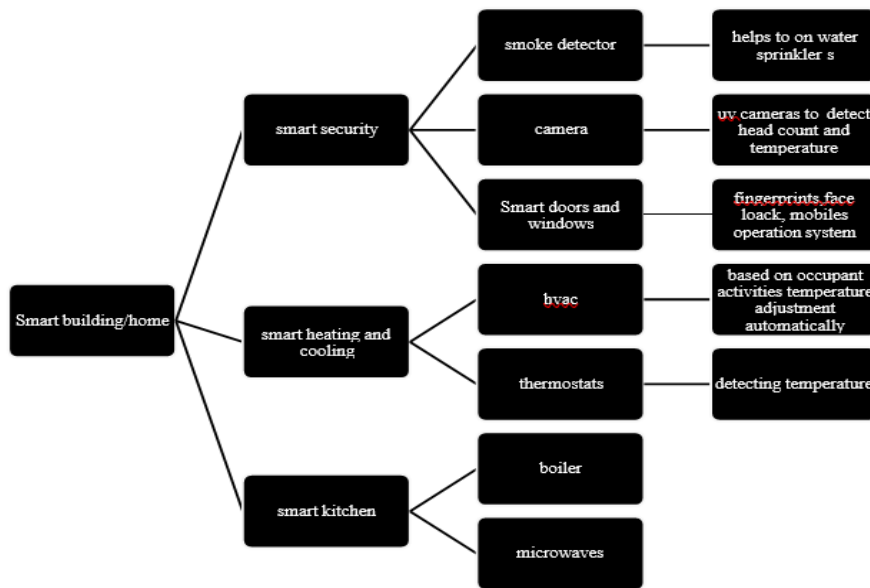
FINDINGS AND DISCUSSION

Smart Cities:

The cities where information, digital and communication technologies of the existing network and services are improved for the citizen's benefit and adaptable are known as Smart Cities. The smart cities should be adaptable, effective and sustainable for the citizens for long term benefits. Smart cities consists smart Infrastructure, smart transportation, smart health care, smart energy and many more. Industry 4.0 where BIM, IoT, AI, Big data etc play vital role in maintaining Smart city operations more efficient and accurate. Energy efficiency is major concern in the rapidly growing urbanization and the technological solution identified is IoT. IoT connected networks of physical devices control and operate according to the user (Waleed Ejaz, 2016) (Ashraf, 2021).

Smart Building Features:

Smart phones, tablets, computers etc serve as the central monitoring unit for the networked devices. Building Openings, electrical gadgets, heating and cooling devices, lighting and ventilations are some of the things that can be monitored and controlled. The user can create a smart home networks to schedule and control the home appliances to save energy. Additional benefits like improved lifestyle, personalized daily schedules can be seen. Demand Side management by incorporating smart grid helps in adjusting/shifting the power load according to the demand the user can operate. (Batov, 2015)



Smart Buildings - IoT

The IoT units, connect physical appliances by accessing the internet and play an important role in the evolution of smart building environment. These physical devices are helpful in monitoring and controlling the different systems within the building. Lighting, HVAC, Security and energy management can be done effectively by using IoT technology, as the IoT can collect the data from devices and analyze it. Sensors monitoring temperature, humidity, air quality aids in creating a more comfortable living environment (Verma & Surya Prakash, 2019). HVAC, lighting, waste and water recourse use monitoring contribute to energy and resource conservation. The Smart Building security can be enhanced by providing surveillance cameras and give access control systems to the owners. Smart Fire alarm systems and automatic watering systems; prove effective solutions for detecting and responding to buildings fires. The IoT technology of residential applications encompasses smart sensors, remote monitoring, energy management and data analytics of the systems. These measures, coupled with user behavioral patterns, reducing cost and decreasing carbon foot print. The data collected by the devices help in immediate optimization and also for decision making in building management (Arun Kumar, 2021).

How IoT's and BIM work

BIM (Building Information Modeling) and IoT (Internet of Things) come together to improve the functionality and efficiency of smart buildings. The capacity between these technologies lies in creating a digital twin of the building for for real-time monitoring and analysis by

incorporating IoT sensors, effortlessly integrated into BIM models. This integration is done to achieve the goals of resource and energy efficiency, allowing efficient maintenance to address potential issues before hand. Various data can be captured using IoT sensors. The data of building systems from HVAC and lighting systems helps in accurate depiction of energy usage and performance within the BIM model. This information empowers building and maintenance managers to maximize energy efficiency and identify possible opportunities for energy savings, reduce costs, and enhance the overall occupant experience. This combination of IoT and BIM results in the making of smarter buildings that are functional, secure, and energy-efficient (Karthick T, 2021)

Disasters and Pandemics mitigation

Smart buildings act as crucial players in disaster and pandemic scenarios by offering cutting-edge technologies to intimate and mitigate during emergency situations. Environmental management helps to alleviate the workload of the users like construction workers during construction and users during the occupancy. Ventilation, occupancy monitoring, touch free technology usage can make the administration work effectively and accurate. These practice align with government initiatives and guidelines, potentially reducing the human workforce in the required duties. For example in school these systems will help educators to focus on teaching rather than other monitoring duties. Several technologies helped in pandemic situation where wearable IOT based devices promoting physical distancing and temperature control intimating the user regarding the outsider temperatures. In one of the building context in South Korea, the building supervision is done by employing deep learning objects identification technology using BIM environment (Anastasi Giuseppe, 2021). This helped the building sector to work efficiently by automatically categorizing and quantifying column rebars. In this case study, the management aimed to improve building supervision effectiveness by identifying potential issues or failures with important components of the building, such as columns, beams to prevent from harm and collapse. These advanced practices successfully achieved damage protection in construction industry.

Cyber-attacks on smart cities and buildings

Virus attacks, data leaks of important information, unauthorized access along with occupants' lives are some of the vulnerable treats of smart building.. Emphasizing the role of artificial intelligence (AI) the users and government can achieve defense strategies involve securing networks, devices, and applications. AI-enhanced security cameras recognize faces, aiding in

intrusion detection, while AI guides smart home security systems, notifying users through mobile apps. IoT-enabled smart buildings contain secure router configurations, deep learning-based security, segregated IoT networks, and next-generation firewalls for protective measures. Implementing these technologies safeguards the user by ensuring the security and privacy of IoT-enabled smart buildings. Four-layered architecture, evaluating frameworks, and enhancing hardware/software security are advocated in research paper as cyber security solutions (Alkatheri Mohammed Saeed, 2021).

CONCLUSION

The evolution of smart cities and smart buildings concepts holds massive potential to change urban landscapes, urban planning, design, construction, and operations of built environment. The usage of Internet of Things (IoT), Building Information Modelling (BIM), and other advanced technologies created a unprecedented scope for enhancing sustainability, energy efficiency, safety, and overall quality of life in urban areas. The utilization of IoT devices, such as sensors and actuators, helps us to enables real-time monitoring and analysis of various indoor and outdoor environments like urban elements, from traffic flow to air quality. . The data from IoT devices and advanced technology analysis empowers municipal urban planners and construction sectors to reduce resource allocation and streamline operations. BIM technology enhances this by providing a digital depiction of structural and functional components of building, promotes stakeholder engagement throughout the lifecycle of the project. When combined BIM with IoT and united with promising technologies like artificial intelligence and machine learning, big data, data-driven decision-making enhances sustainability and improves the quality of life of the users. However, addressing challenges like data privacy, cyber security, interoperability are vital to fully realizing the transformative potential of these technologies in building smarter, more sustainable cities and buildings. The world needs careful planning, ethical guidelines by government and inclusive solutions to revolutions urban well-being in the years ahead.

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