Chapter

Smart Built Environment Including Smart Home, Smart Building and Smart City: Definitions and Applied Technologies

Reyhaneh Karimi, Leila Farahzadi, Samad M.E. Sepasgozar, Sharifeh Sargolzaei, Sanee M. Ebrahimzadeh Sepasgozar, Mohsen Zareian and Akram Nasrolahi

Abstract

Technology, particularly over the past decades, has affected the cities and their components, such as building sectors. Consequently, smart building that has currently utilized various technologies which is incorporated into buildings is the core of the present chapter. It provides a comprehensive overview on smart cities, smart buildings and smart home to address what systems and technologies have been incorporated so far. The aim is to review the smart concepts in built environment with the main focus on smart cities, smart buildings, and smart homes. State-of-the-art and current practices in smart buildings were also reviewed to enlighten a set of directions for future studies. The Chapter is primarily focuses on 51 articles in smart buildings/homes, as per collected from various datasets. It represents a summary of systems utilized and incorporared into smart buildings and homes over the past decade (2010–2020). Additional to different features of smart buildings and homes, is the discussion around various fields and system performances currently utilized in smart buildings/homes. Limitations and future trends and directions is also discussed. In total, such building/home systems were categorized into 6 groups, including: security systems, healthcare systems, energy management systems, building/home management systems, automation systems, and activity/movement recognition systems. Furthermore, there are a number of surveys which investigated the user's acceptance and adoption of the new smart systems in homes and buildings, as presented and summarized thereafter in Tables. The present Chapter is a contribution to a better understanding of the functions and performances of such buildings/homes for further implementation and enhancement so that varying demands of smart citizens are fulfilled and eventually contribute to the development of smart cities.

Keywords: smart cities, smart buildings, smart homes, intelligence, automation, systems function

1. Introduction and research method

Technology over the past decades has significantly influenced cities, including building sectors to a great extend. The term "Smart" was recently coined and developed across all built environment segments - thanks to efforts made to set up highly-functional buildings and constructions. "Smart building" technologies are currently recognized as a promising solution to enhance flexibility and efficiency of built environment. Such buildings are thus recognized as the main core of diffenerent Smart city components i.e., Smart Infrastructure, Smart Healthcare, Smart Energy, Smart Mobility, Smart Technologies, Smart Construction, Smart Governance and Education, Smart Citizens, and Smart Transportation, as illustrated in **Figure 1**.

The present Chapter reviews the concepts of Smart Built Environment with the main focus on smart cities [1], smart buildings, and smart homes. State-of-the-art and current practices made in smart buildings are reviewed, and a set of directions for future studies are suggested. The main question to address is what systems and technologies have been utilized and incorporated in smart buildings/homes so far.

As such, a holistic view of the smart cities are provided. Papers related to Smart building, the existing definitions of Smart and transformations made over the past decades, how it was categorized, contributions made to the building sectors and current research reported in smart buildings are reviewed. Section 3 is focused on smart homes – the most recurrent concentration as the primary focus of smart buildings. How smart homes are defined and emerged are outlined and a timeline of evolvement are depicted.

A large body of literature (51 papers) in smart buildings and smart homes is reviewed, and practical benefits of smart homes are discussed. Articles were

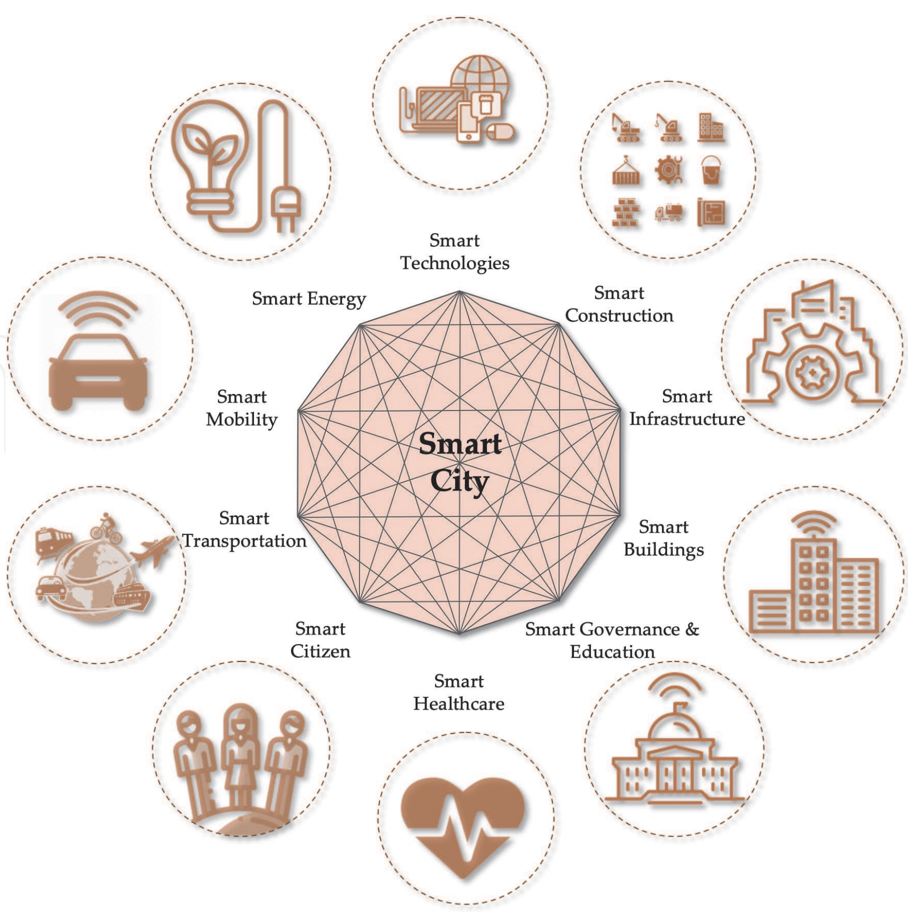

Figure 1.
Smart city components and the connections among them.

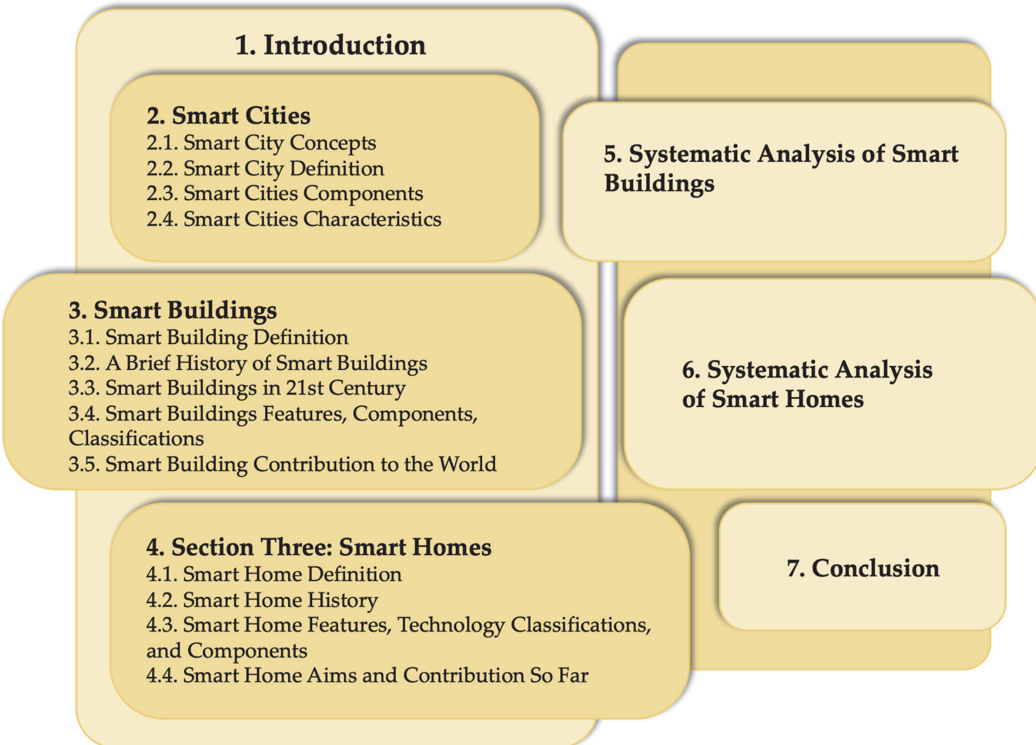

Figure 2.
The framework summarizing the main themes reviewed in this chapter.

extracted from a variety of datasets such as Elsevier, Springer and IEEE with the following keywords searched for relative papers: "smart building" and "automated building" for the part related to smart buildings and "smart home" and "automated home" for the part related to smart homes. as per published between 2010 and 2020. Different technologies utilized in smart homes, features, findings, and limitations were also discussed. Finally, potential research trends in the future advancement of smart home applications and components are outlined.

The most interesting findings of the present chapter are: (1) smart buildings and homes categories (functions): security, healthcare, energy management, building/home management, automation, and activity/movement recognition; (2) Suggestions made for future research can serve as a useful collection for students and researchers and assist with identifing gaps and developing ideas to address future research; (3) Finally, key findings of each article are summarized in Tables, therefore provide readers with key contributions made. **Figure 2** illustrates the framework on which the whole Chapter is organized.

2. Smart cities

Concepts, definitions, dimensions, and characteristics of smart cities are presented as follows.

2.1 Smart cities concepts

Originally traced back to the Smart Growth Movement in the late 1990s, the concept of Smart Cities has recently gained much attention and recognized as an important paradigm in intelligent urban development and sustainable socio-economic growth, [2]. Smart cities in the urban planners' is profoundly debated on the future of cities, the diffusion of smart city initiatives in countries with different requirements and contextual conditions (e.g., developed or developing nations) which makes it difficult to identify common definitions and trends on a global scale. In fact, a globally-agreed definition of the term Smart City or related attributes are still missing.

2.2 Smart cities definition

The term "smart city" was first coined in the 1990s in which the focus was on the impact of new ICT on modern infrastructures within cities. In the first few years of 21st century, the term "smart city" was recognized as an "urban labeling" phenomenon. Generally, in the most presented definitions of "smart city", there are several keywords that are repeated, including infrastructures, resources, efficiency, increasing the quality, data, and technology. This reveals, despite the lack of a unique definition for the concept of the "smart city", the nature of the definitions and the opinions around urban planning and management are in common. As expected in a smart city:

City managers can use city infrastructures and resources in an efficient way. The key feature of the smart city is monitoring and integrating "conditions of all of its critical infrastructures" as previously described [3]. Infrastrucure refers to "roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize own resources, plan preventive maintenance activities, and monitor security aspects while maximizing services to citizens". As earlier stated [4, 5] "A smart city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, add efficiencies, conserve energy, improve the quality of air and water, identify problems and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains". Another quote [6] also indicated "A smart city means uses all available technology and resources in an intelligent and coordinated manner to develop urban centers that are at once integrated, habitable, and sustainable".

Furthermore, a smart city is anticipated to use information for a dynamism in the economy and resource sustainability purposes. For instance, it was stated [7] that: "Two main streams of research ideas: (1) smart cities should do everything related to governance and economy using new thinking paradigms and (2) smart cities are all about networks of sensors, smart devices, real-time data, and information and communication technologies (ICT) integration in every aspect of human life". Another definition is [8] "a city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens". Smart city generally refers to the search for and identifing intelligent solutions which allow modern cities to enhance the quality of the services provided to citizens". Smart cities are profoundly dependent on big data [1, 9, 10], ICT to provide more efficient services to citizens, to monitor and optimize existing infrastructure, to boost collaborations among different economic actors, and to encourage innovative business models in both private and public sectors". **Figure 3** presents a typical network of a smart city including data server and connections to different buildings and infrastructrues.

The concept of "smart city" aimed to increase the efficiency of urban systems operations in urban environments. In the past century, increased poulations and habitats in cities made services to citizens inefficient. Furthermore, from a sustainability and carbon emission footprints perspective, the excessive use of limited resources has pushed the situation into a more hazardous and unsafe environement [11]. It is therefore of prime importance to seek for tools/plans for optimization

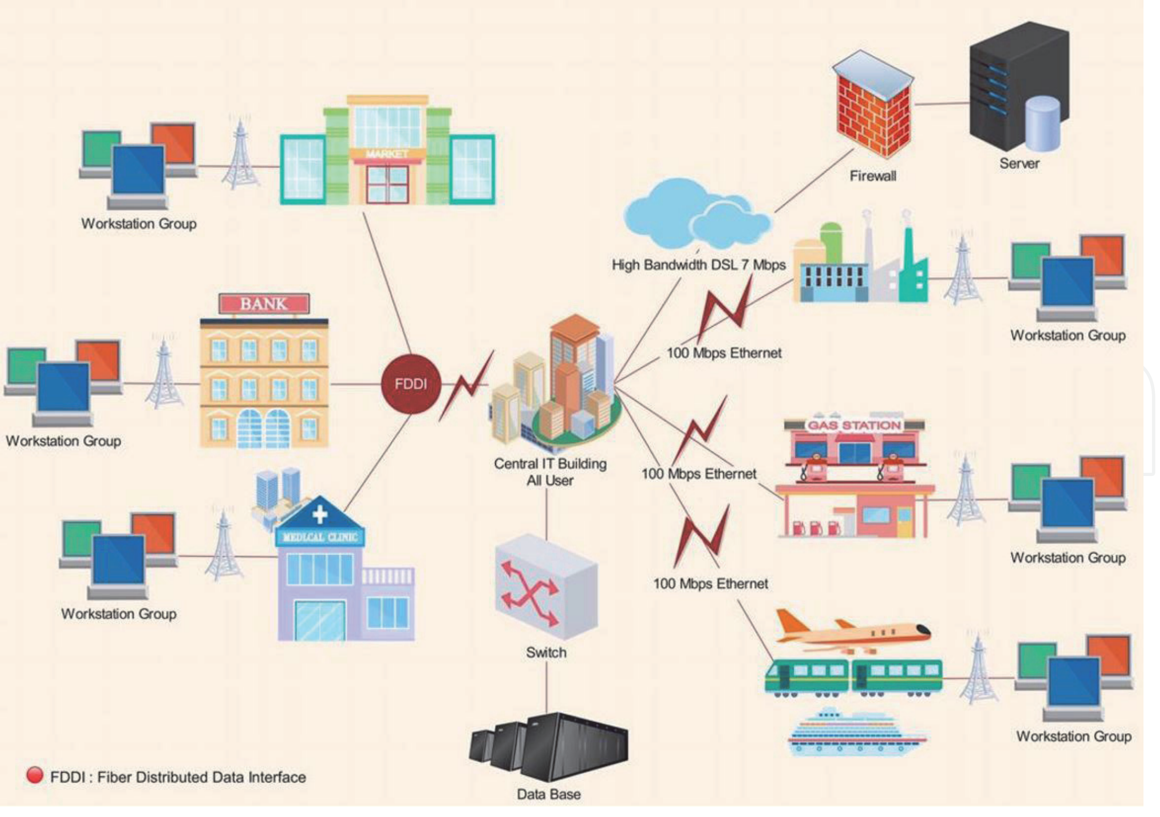

Figure 3.
A typical smart city network.

purposes of urban resources and infrastructures, where data and technologies are gathered in smart city.

2.3 Smart cities components

To clarify what constitutes a smart city, researchers have devided this concept into many features and components, to justify the complexity involved in smart city concept in a holistic way. Attempts made to delineate the features of a smart city

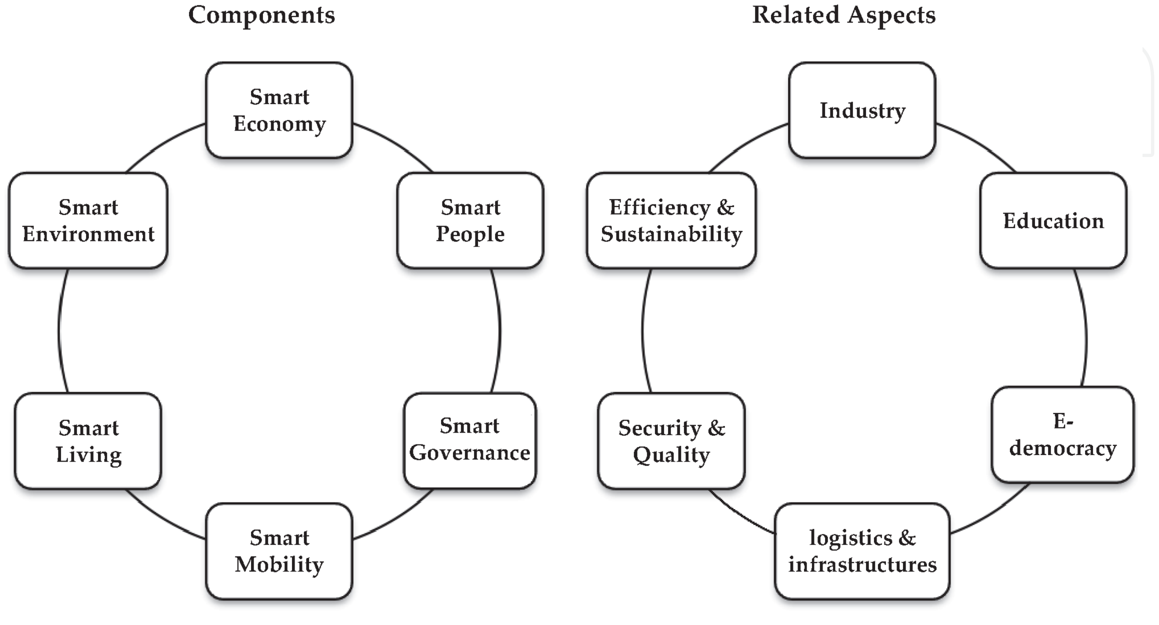

Figure 4.
Key components of a smart city and related aspects.

indicated 6 possible components can be defined as presented in **Figure 4** with a short description of such components as presented in **Table 1**.

2.4 Smart cities characteristics

According to literature and **Figure 4**, six smart components were identified, i.e., economy, people, governance, mobility, environment, and living as the relevant group characterizing a smart city. They can be broken down into 31 relevant factors reflecting the most important aspects of smart components, as shown in **Table 2**.

Smart economics is divided into micro-components, each demonstrating dynamism and productivity, such as creativity, entrepreneurship, and flexibility. Smart people also include components that, like smart economics, imply creativity, and flexibility. Furthermoer, smart people generate and benefit from the social capital

Components	Description
Smart Economy	Eeconomy which is associated with the presence of industries in ICT or employing ICT in production processes.
Smart People	Refered to people possessing creativity, diversity, and education [13]
Smart Governance	Various stakeholders are engaged in decision making and public services.
Smart Mobility	Refers to the use of ICT in modern transport technologies to improve urban traffic.
Smart Living	The smart people factor comprises various aspects, such as affinity to lifelong learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism, open-mindedness, and participation in public life.
Smart Environment	Refers to efficiency and sustainability of environment, while smart technologies are in use.

Table 1.
A brief description of SCs components [12].

Smart Economy	Smart People
• Innovative spirit • Entrepreneurship • Economic image and trademarks • Productivity • Flexibility of labor market • International embeddedness • Ability to transform	• Level of qualification • Affinity to lifelong learning • Social and ethnic plurality • Flexibility • Creativity • Cosmopolitanism/Open-mindedness • Participation in public life
Smart Governance	**Smart Mobility**
• Participation in decision-making • Public and social services • Transparent governance • Political strategies & perspectives	• Local accessibility • (Inter-)national accessibility • Availability of ICT-infrastructure • Sustainable, innovative and safe transport systems
Smart Environment	**Smart Living**
• Lack of pollution of natural conditions • Pollution • Environmental protection • Sustainable resource management	• Cultural facilities • Health conditions • Individual safety • Housing quality • Education facilities • Touristic • Social cohesion

Table 2.
List of characteristics of Smart Cities [14].

of a city, hence, the concept of smart city indicates a combination of education-training, culture-arts, and business-commerce with hybrid social, cultural, and economic enterprises [15]. Smart governance means various stakeholders are engaged in decision making, political strategies and public services, therfore forms Transparent governance. Smart mobility refers to the use of ICT in modern transport technologies to improve urban traffic. Smart environment, reflecting efficiency and sustainability of urban life, includes micro-components such as ambitiousness towards CO_2 emission reduction strategy, efficient use of electricity and water, area in green space, greenhouse gas emission intensity of energy consumption, policies to contain urban sprawl, and proportion of recycled waste. Smart living reflects a city whose citizens have a high quality of life. In such a city micro-components of smart living can be cultural facilities, health conditions, individual safety, housing quality, education facilities, touristic, and social cohesion.

3. Smart building

In this section, smart building definitions, history, and evolution, different classification and contributions are encapsulated. **Figure 5** illustrates an overview of smart buildings in cooperation with a smart city and its components, after which smart buildings shall be introduced.

3.1 Smart building definition

"Smart Building" points out to various technologies incorporated into buildings. There may not be a definite explanation of what turns a building into a smart one.

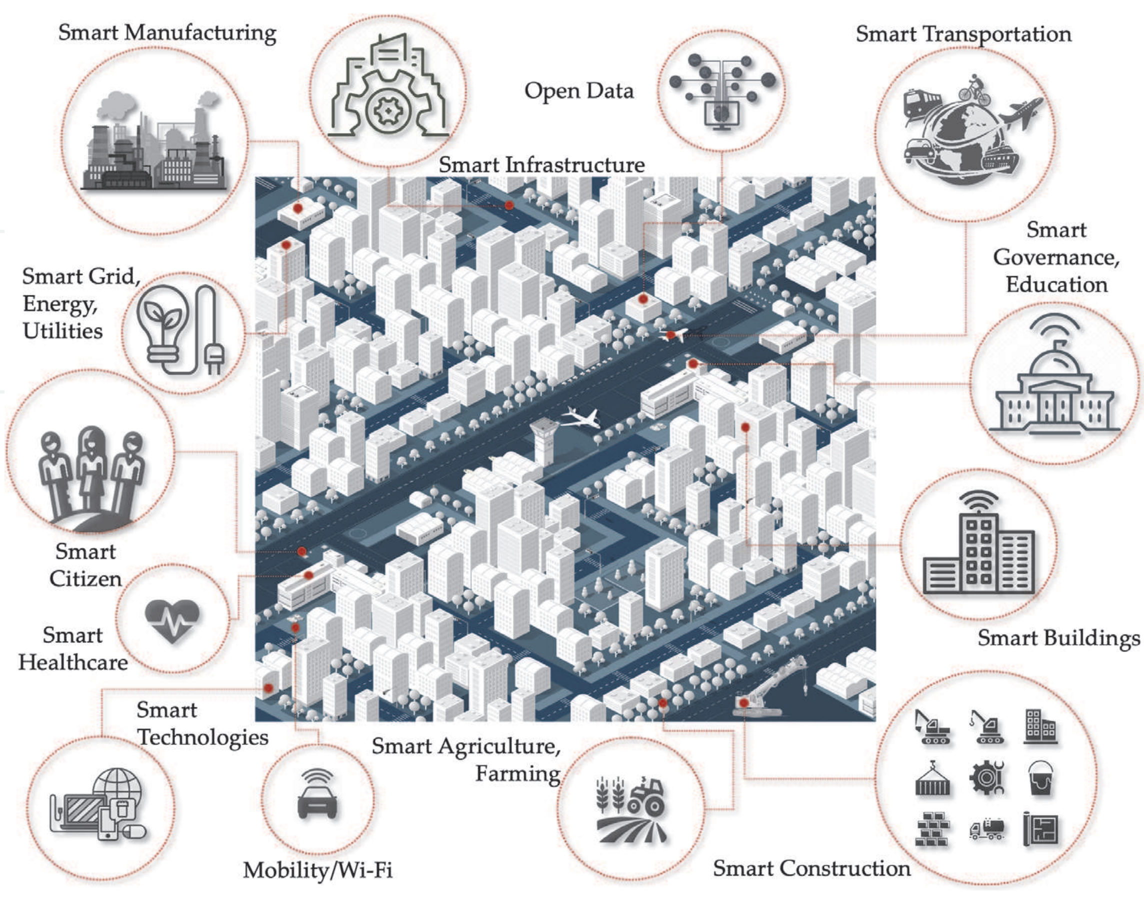

Figure 5.
An overview of smart buildings in addition to other smart components in a smart city.

The term has been defined by various research and it is sometimes interchangeably used as intelligent building or automated building, which are not necessarily the same. That is due to the evolution of the buildings from "conventional", to "automated", to "intelligent", and to "smart" [9, 16].

In 1990, the intelligent building was defined by Powell [17] as a building which controls the environment of itself. Such mode of control did not introduce any interactions made by the user(s). In 1995, Capacity and Institution Building (CIB) proposed the definition of a responsive and dynamic architecture for intelligent buildings which offers the users a cost-efficient, productive and competent environment by 4 fundamental components; i.e., place, process, people and management with interrelations involved [18]. Continental Automated Buildings Association (CABA), in 2002, defined it as a building and the infrastructure which offers occupants an efficient, flexible, safe and comfortable condition by utilizing technological systems, controls and communications, all integrated together [19]. Frank [20] summarized the previously defined explanation of the intelligent building and explained it as an automated building centrally managed to provide users with a safe, comfortable, productive and energy-efficient environment through technological devices which allow sustainability and cost-efficiency. In 2005, Wong et al. [21] discussed that the previously-used definitions centered on minimizing the interaction of users with the building.

It was around 2011 that the term "smart building" started to gain popularity over the previously-used term "intelligent building" [22]. Buckman et al. [23] believe smart buildings are intelligent buildings with additive and combined elements of adjustable control, enterprise, materials and construction. CABA concentrates on the capability of the smart building to adjust itself to different surrounding parameters and conditions using outward context-led data on the behavior of the users [24]. The highlights within the current definition of smart buildings are the concentration on the users and the interaction with the user of a building in high levels [25, 26]. Sinopoli [27] looks at smart buildings holistically and the integration of design, construction and execution where applicable information is acquired within a smart building to facilitate the management of the environment by the users/occupants. In the most recent researches, smart buildings are defined as those which benefit from the efficient and cutting-edge sensors and electronic devices as per connected together and communicate with each other to generate a large amount of data, (refered to as Big Data), to control and manage the building smartly to boost reliability and performance of the building and reduce energy consumption and cost; more importantly to provide a desirable, flexible and safe environment for occupants [28–32]. Smart buildings depict the evolvement of the most up-to-date infrastructure and integration of automated control systems, data computing, and artificial intelligence. The smart building adapts itself to the surroundings according to both inner and outer parameters and can learn [22], interact and self-adapt to the needs of the occupants.

3.2 A brief history of smart buildings

Although smart buildings seem to be a new concept, the origins actually dates back to 1980s, when a new generation of intelligent buildings was constructed in the United States [33]. The first intelligent building was built in Hartfort, the United States in 1984 [20]. It is however believed [34] the concept of intelligent buildings refers to automation rather than intelligence which is rooted back to an earlier time of 1960s, when a building was resourced with an automation system which served as a device for 'work saving time'. In 1973, energy crisis occured which raised awareness on energy consumption style, and subsequently led to the formation of smart features of energy consumption and crime prevention. In the early 1980s, the emergence of two main technologies assisted with the development of the trend; i.e., telecommunications and personal computers. Establishment of networks of technology and real estate enterprises offered a shared telecommunications system to building owners [27]. Integrated single-functional systems for building automation such as access control, security control, lighting control, lift control, electrical systems, fire system, electronic processing and communication of data, text communication and telefax, image communication and TV were generated at single level function as the integration of different subsystems was not possible [34]. In 1990s, technological developments i.e., direct digital control (DDC), video surveillance, access control systems, audio visual systems and cabling systems [27] and integrated multi-functional systems were feasible at building automation system (BAS) and integrated communication system (ICS) level. In 2000s, developments were progressed in the implementation of systems integrated with computers, utilizing Internet protocol (IP) network technologies which boosted network capacity, and remote monitoring and control through the Internet [34]. **Table 3** illustrates the evolution of the smart building, along with time and technology development.

Time	Evolution	The type of building Management
1950s	• Using pneumatic control with compressed air in automated buildings • Execution of fire alarm system [34]	Building Control [36]
1960s	• Emergence of analog and then digital microprocessors • 'work saving time' device implementation	
1970s	• Systems for crime prevention and energy preservation	
1980s	• Construction of the 1st intelligent building • Implementation of single-functional systems • Emergence of telecommunications and personal computers [27]	
1990s	• Implementation of multi-functional systems • Supporting communication among controlled facilities by open protocols	Building Automation
2000s	• Implementation of systems integrated with computers [37] • utilizing Internet protocol (IP) network technologies and boosted network capacity. • Emergence of Wi-Fi • Achieving remote monitoring and control through the Internet	Building Performance
2010s	• Implementation of enterprise network-integrated systems • Delivering multiple services by combining BAS and IT through • Internet Protocol network • Integration and management because of modern IT technologies e.g., Web Services, XML, distance portfolio management and helpdesk management, multimedia communication via cellular phone • Emergence of BIM and embedded intelligence	Smart Building [36]
2020s	• Integration of building and industrial PLC system, cloud computing and IoT, data mining and data-centric energy management, cyber security and protection, hardware and software analytics, the progress of Smart City, and utility meter monitoring and reporting [35]	

Table 3.
The evolution of smart buildings, adapted by the authors from [27, 34–37].

3.3 Smart buildings in the 21st century

Building automation technology and smart buildings have been ever developing since the early 21st century. Smart buildings are now capable of making connections between people, and surrounding environments such that buildings are more responsive to the demands of users and city in a more sustainable fashion which consequently boost human's wellbeing [37, 38]. Currently, the "concept of Industry 4.0" has been put into research with a focus on building sectors. Industry 4.0 is fundamentally the integration of Internet of Things (IoT) and digital data acquired from various sources of sensors and actuators. The Industry 4.0 can potentially enhance safety and substantially lower energy consumption while maintaining comfort in smart buildings [39]. Networking communication technology and inserted micro-electromechanical technologies have recently received much attention. Different devices can be embedded by IoT, which ultimately can enhance sensing capability, identification and communication within the smart systems [40]. Blockchain technology can also be utilized as a measure to control the platform, including the IoT and Building Information Modeling (BIM) [41] in smart buildings [42]. Artificial intelligence (AI)-based systems play an important role for the realization of the five main energy optimization perspectives – users, comfort, safety, design and maintenance in smart buildings [22]. A survey conducted on 45 experts on the future of smart buildings [43] revealed the following technology trends in future smart buildings: (i) Accommodating a single cloud-based IoT platform; (ii) Organizing smart building technology via multiple asset-distinct IoT Platforms. Obviously smart buildings will be more adaptable to the fast change of the demands and needs and focus more on sustainability aspects in the future. Future smart buildings will be highly user-centric, thanks to advanced and innovative analytics, system integration and edge computing as incorporated throughout smart buildings, therefore making remote building management services feasible and boost maintenance.

3.4 Smart buildings features, components, classifications

Major elements of smart buildings can be categorized into four groups; (1) structure; (2) systems; (3) services and (4) interrelations [34]. Another classification includes components of smart buildings into hardware, software, and network based on the concept of IoT and Cloud, data analytics, artificial intelligence, and decentralized energy [44]. New technologies are obviously inevitable in smart buildings and include (but not restricted to) sensor utilization, big data analytics and engineering, fog and cloud computing, development of software engineering, and algorithms of human-computer interaction [45]. A selective classification of smart buildings technology can be compromised of the following components: energy-efficient LED light fixture, occupancy sensors, building dashboards, electrochromic windows or smart glass and indoor positioning [16].

Smart buildings can also be categorized based on the following features: (1) Environmental friendliness – energy and water preservation sustainable design; efficient disposal of wastes; minimizing pollution; (2) flexibility and utilization of space; (3) adding value quality to economic life cycle cost; (4) well-being and health of the occupants; (5) efficient working; (6) security and safety actions – structural failures, fire, earthquake, and disaster; (7) culture– addressing the expectations of the client; (8) innovation and effectiveness of technology; (9) management and construction procedures; (10) sanitation and health [37].

Smart buildings are also defined as three main management solutions: (1) Information system- acquiring data from different devices, collecting, reporting and visualizing the patterns, and enabling decisions for the related actions; (2) Analysis system - further data analysis to find out particular insights where regular utilization consists of modeling to offer measurements and verification abilities e.g., fault detection and diagnostics (FDD); and (3) Control systems - connecting to the assets and controlling assets in the smart building such as heating, ventilation and air conditioning (HVAC) and lighting systems, changing set-points using schedules and adjusting conditions [46].

3.5 Smart building contribution to the world

Smart buildings offer the most effective way for cost efficiency and the utilization of technology systems of the building. During a building design phase, the whole building technology systems design is coordinated by one designer and combined into the construction documents, which indicates each system and meets the elements of the common system or the integration of bases for the systems. It consists of cabling, cable pathways, equipment rooms, databases of system, and devices communications protocols. The final design is referred to as a contractor. Deficiencies in the design and construction process is therefore minimized with time and costs being saved. Given technology systems of the building is integrated on the horizontal and vertical aspects in building operations, therefore it gives occupants access to building's operation data and information and manage respective section. Beneficiary to building owners and developers, it contributes to property value improvement. To facility and property managers, it offers further efficient subsystems and effective management alternatives e.g., system management consolidation. As the design and construction are combined proportionally, it can assist architects, engineers, and construction contractors achieve higher efficiencies and contributes to savings in the project [27].

In addition to management systems, smart buildings can significantly influence other sectors; i.e., retailing (smart shops), health cares (in smart hospitals/homes), and safety and security (intrusion/detection systems) [47].

Smart buildings offer a variety of solutions and benefits e.g., detecting the number and activity of the user, healthcare, energy usage and sustainability-related services i.e., HVAC systems control, heat control, comfort modeling, device control, load predicting, power management, lighting control, longevity and satisfaction [27, 31, 48]. Smart technologies can also offer opportunities for plug loads, HVAC systems, lighting, window shading, human operation, automated system optimization, and connected distributed generation and power [29]. Smart buildings' passive design strategies smartly engineered in smart buildings makes building systems tailor both environmental situations and user needs [32]. Safety, productivity and comfort are provided to the users in smart buildings. Users' comfort is ensured through smart HVAC systems, smart water, gas, electricity metering, occupancy detection and monitoring systems and even hybrid charging technology of vehicles [31]. Contributions of smart building can be summarized as follows: (1) occupants comfort: smart buildings learn the occupants' behavior and make efforts to enhance occupants' comfort level; (2) saving energy: smart buildings can significantly reduce energy usage, and costs associated; (3) saving time: the automation of daily routines can significantly save time; (4) safety: detection of fire, gas leakage, using self-diagnosis systems, capable of alerting, enhance safety level; (5) expert systems: embedded in smart buildings can hold the knowledge of the areas; (6) healthcare: in smart buildings, health-related decisions are of the highest priority in which services e.g., suitable temperature, air condition factors, and light intensity are supplied; (7) assistance: as smart buildings can improve life quality of elderly and disabled people by providing comfortable, safe and supportive environments; For instance, providing assistance in daily routines, alerting the family and/or social services in case of emergency, mitigating loneliness by connecting to other individuals via Internet [44].

4. Smart homes

In this section, smart home definitions, history, and evolution, different classification and contributions are discussed.

4.1 Smart home definition

Smart homes are recognized as an important focal point in smart buildings [45] and described in section one. The term "Smart Home" is defined [49] as a home benefiting from a "Controller" to combine the different automation systems. The most well-known controllers in homes are connected to computers within the programming period only, after which home control tasks are performed independently. Home systems integration leads to better communication among systems via home controller. Consequently, it triggers a single button and voice control of the different systems in the smart home at the same time, in scheduled scenarios or operating modes. In other words [50], smart homes are recognized as automated buildings benefiting from installed detection and control systems, i.e., air conditioning and heating, ventilation, lighting, hardware, and security systems [51]. As new systems with switches and sensors can communicate with a central axis (typically referred to as gateways). The gateways are systems which control user's interfaces and connection to a tablet, cell phone, or computer. Such systems network connection is managed by IoT. A smart home is also defined as a residential extension of building automation which includes the control and automation of the whole utilized technology [52]. As such, a smart home comprises appliances, lighting, heating, air conditioning, televisions, computers, entertainment systems, big home appliances e.g., washing machines, fridges, and security systems (e.g., camera systems with the function to interact with each other), and controlled remotely by means of a schedule, cell phone or internet. Such systems include switches and sensors connected to a central hub, and controlled by a user, a wall-mounted terminal or mobile unit via internet cloud services.

4.2 Smart home history

The idea of smart home was initially formed in the 1990s [53] and a brief timeline of smart home evolution is illustrated in **Figure 6**.

4.3 Smart home features, technology classifications, and components

Smart homes include five basic features; i.e., (1) Automation: the capability of accommodating automatic devices or carrying out automatic functions; (2) Multi-functionality: capability of conducting different tasks or creating various outcomes; (3) Adaptability: capability of learning, predicting and meeting the wants of users; (4) Interactivity: capacity to provide and allow communications among users; (5) Efficiency: capability to perform functions conveniently and save time and costs [53].

The smart home technologies benefit from four classification criteria, including (1) collecting the data: required data is collected after which being accessible; (2) processing the data: the collected data is processed and analyzed and can be

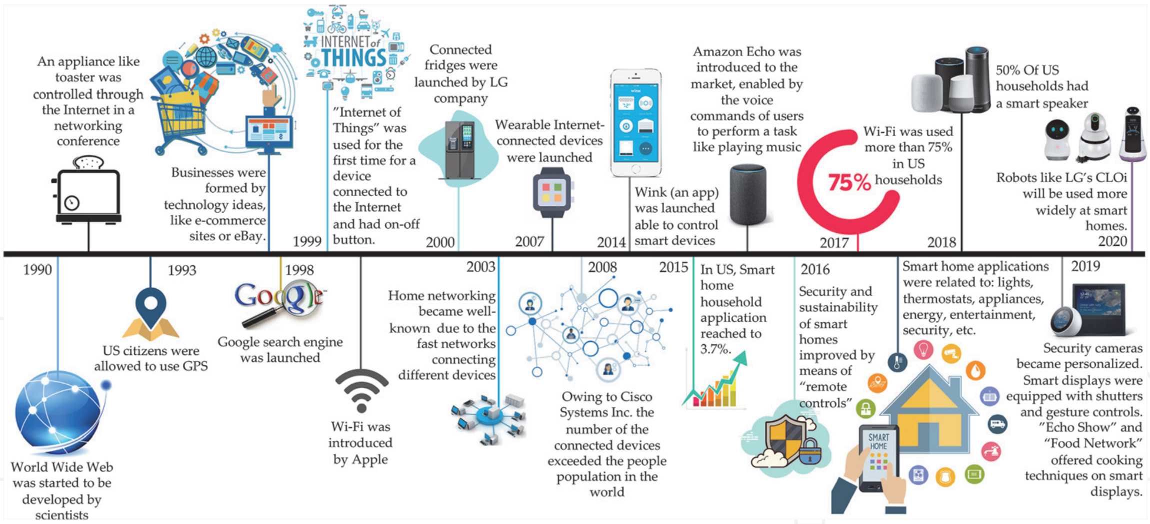

Figure 6.
Smart home evolution timeline.

combined; (3) representing the data: the data is accessible to the users; (4) controlling and interacting abilities: the status is accessible to the users and the functions of related technologies are monitored.

Smart home components can also be categorized [52] as follows: (1) Sensors which collect indoor and outdoor data of home and measure the conditions of the home. Sensors are therefore connected to the home and to the embedded home devices. Data is collected and sent through local networks to smart home servers constantly; (2) Processors which carry out local and combined activities. Processors are also connected to the cloud for extended source-based applications. The data collected by the sensors is consequently processed by processes via local servers; (3) A set of softwares are wrapped as APIs which allows external apps performance and follow the pre-defined parameter format. APIs can process data and manage essential tasks; (4) Actuators which provide and perform commands within the server or other control devices. Actuators can translate activities which are required to the command syntax. The system can launch commands to the suitable device processor; (5) Databases which store processed data as collected from sensors and cloud. Databases can also be used for analyzing, presenting, and visualizing data. The processed data is stored in the database for future usage.

4.4 Smart home aims and contributions

Smart homes were initially aimed at enhancing users' comfort level and making daily life easier, and provide occupants with ambient intelligence, remote home control or home automation systems [53]. The advantages of smart homes integrated with IoT can be summarized [50] as follows; (1) "Energy conservation" in which energy waste is lowered using improved IoT technology, higher quality and reliability of devices, improvements in system security and applications, and sensible use of devices; (2) "Decreased cost of fundamental needs of smart homes" contributing to advancement in smart home technologies that are based on IoT, application of medical technology services, using wireless technology and a security system, using energy conservation devices, and suitable users' behavior; (3) "Healthcare" contributing to medical services, appropriate living for the elderly, easier communication with health centers, treatment alarms, controlling, and monitoring elderly patients; (4) "Entertainment and comfort" with more comfortable, convenient to use and control, and easy to pay bills.

This section comprises Tables of the existing research on smart buildings and smart homes, respectively. **Table 4** summarizes 5 papers related to smart buildings. **Table 5** shows the number of databases, and papers extracted per each database. **Tables 6** and 7 present the summary of reviewing 46 papers related to smart home technologies.

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
• Modeling, Analyzing and Predicting Security Cascading Attacks in Smart Buildings Systems-of-Systems (SoS) [54] • To predict attacks at architecture stage using software engineering approaches	• A Model-Driven Engineering method, Systems-of-Systems Security to benefit from: (1) a modeling language (SoSSecML) for secure SoS modeling (2) Multi-Agent Systems (MAS) for security analysis of SoS architectures. • A case study conducted on a real smart building SoS.	• Cascading attacks i.e., individual attacks, Service Denial were detected. • SoSSec to be extended to address various strange behaviors and non-functional properties i.e., safety and trust.
• Prediction Model for Personal Thermal Comfort in Naturally Ventilated Smart Buildings [55] • To enhance non-air-conditioned or naturally ventilated buildings to increase users' satisfaction	• Different datasets were used from various climates and seasons to identify an optimum feature set. Variables were selected and processed by supervised machine learning techniques i.e., Support Vector Machines (SVM) and Naïve Bayes Classifier.	• Indoor and outdoor temperature and humidity, under any given climate or season, were identified.
• An IoT-Based Thermal Model Learning Framework [48] • To propose a learning platform of plug and play to recognize the thermal model of each smart building zone based on low-resolution data from intelligent thermostats without human intervention	• To automatically train the thermal properties of the building directly from historical data of building operation. Inputs included: temperatures, relative humidity, time of the day, day of the week, and seasons. • Thermal model learning pipeline includes: (1) data acquisition from thermostats; (2) thermal model learning on cloud infrastructure or an edge device; (3) ultimate learnt model provision to other applications of smart control. • Five common supervised models for learning tested include: polynomial regression (PR), support vector regression (SVR), random forest (RF), extreme gradient boost (XGB), and neural network (NN). The model with the best function is applied to train the prediction model of the temperature gradient. • An office building on a real-based data collection was conducted for the developed thermal model learning platform.	• A trustworthy thermal comfort assessment was delivered when operating intelligent control. • To be incorporated with an IoT-led BEM and to deliver a precise thermal model to other intelligent air conditioning control algorithms with no extra hardware cost. – the process of learning could provide learnt model on cloud infrastructure and edge device, for a single thermal zone, in minutes. • Does not need configuration for each building, thus enhances the speed to adopting this technology in the market. • Future study: (1) platform assessment on other types of buildings with more changeable occupancy and operation behavior; (2) to adopt in multi-phase cooling/heating systems.

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
• Application of Integrated Building Information Modeling, IoT and Blockchain Technologies in System Design of a Smart Building [42] • To utilize blockchain technology as a securing and controlling framework incorporated with IoT and BIM.	• Effective energy usage and environmental trace control. Blockchain provides an extra layer of data security. The suggested system design allows amending and updating data in cases of reconstruction or renovations; it prohibits unauthorized users from acquiring data on the operation of a building, i.e., the position of sensors and cameras. Data can be acquired from the IoT systems and recorded in Blockchain prior to storage.	• Secure maintenance and management of data concerning. • Can be used in many types of public and private buildings. • Integrated BIM, IoT and blockchain technologies make a novel framework assisting digital transformation in the AEC.
• An Intelligent and Smart Environment Monitoring System for Healthcare [56] • To propose a straightforward android-based wound healing response to monitor external environmental factors for wound recovery purposes.	• Temperature, humidity, smoke, and dust are monitored by microcontroller with multi-sensors. • It consists of (1) Arduino Sensors-based data collection, (2) data recording, (3) data assessment by NN, (4) use of Android App to indicate wound healing level. • It was tested in a house, a park and an industrial building.	• Prediction accuracy rate ranged 96–99%. • Future studies include: (1) applying other machine learning methods i.e., Fuzzy system, Decision Trees, and KNN; (2) using more sensors for wound microenvironment monitoring;

Table 4.
Reviewed papers related to smart buildings.

Data bases	Papers reviewed
Elsevier	16
Springer	16
IEEE	14
Total	**46**

Table 5.
Detailed numbers of databases, and papers extracted per each database (reference: Authors).

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
• Activity-Aware Sensor Cycling for Human Activity Monitoring [57] • To predict the residents' behavior accurately to make a balance in "energy consumption".	• An activity-aware sensor cycling (ASC) to manage uncommon and unpredicted activities and makes a balance between sensors' energy usage by a scheduling algorithm.	• ASC sensor detects 99% of activities and warranties the network lifetime for 2000 h.
• Enabling IoT for In-Home Rehabilitation: Accelerometer Signals Classification Methods for Activity and Movement Recognition [58]	• The system is using an accelerometer sensor on patient's smartphone platform. Patient's movement is recognized upon physical	• SVM-based accuracy is >90% in activity recognition and > 99% in movement recognition. • Future works: A combination of

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
• A "healthcare system" aimed at home treatment and therapy using an "activity/movement recognition system".	activities using support vector machines (SVMs), decision trees, and dynamic time warping (DTW).	SVM and DTW as SVM alone was unable to recognize movement recognition in few cases.
• An Intelligent Human Behavior-Based Reasoning Model for Service Prediction [59] • "Energy management system" aimed to decrease energy waste using a service prediction model and a smart home platform.	• A human behavior-based reasoning (HBR) based on auto regressive prophecy and case-based reasoning (CBR) was used.	• Better performance and higher prediction accuracy than other existing models, particularly in the peak of activities. • A combination of linear prediction and human behavior reasoning contributed to saving energy. Also a combination of embedded systems, ZigBee wireless communications, and appliance control protocols offered less problems when controlling smart homes.

Table 6.
Reviewed papers related to smart homes.

Title & Journal Category & Objective	Details of the proposed survey	Finding or Contribution Limitation & Suggestions
• Patients' Adoption of WSN-Based Healthcare Systems: An Integrated Model of Facilitators and Barriers [60] • This "healthcare system" aimed to find factors which may influence individual's intention to use wireless-sensor-network in smart home healthcare system. Based on which the developers can be more aware of key factors in designing such systems to encourage people to use it.	• A combination of qualitative and quantitative methods is used. • Factors which affect system adoption were identified, (2) A model, by which a number of hypotheses on adoption factors can be proved was proposed. • A semi structured interview of 6 home healthcare patients and 9 medical experts, plus a survey questionnaire from 140 respondents.	• The encouraging factors include ability to enhance the life quality and supporting emotionally. While discouraging factors are their negative feeling of privacy, attachment, and costs. • Future work: to enlarge sample size, broaden culture, age and gender range.
• Benefits and Risks of Smart Home Technologies [61] • The paper focused on the "attitude" towards smart home and investigated the understanding of 3 groups of users.	• A comparative analysis on the ideas and understanding of 3 groups of current users (n = 42), future users (n = 1025) and industry (n = 62) was conducted on the pros and cons of SHS and the policymaker's roles. -The paper benefits from field studies (survey), content analysis, and statistical analysis	• (1) Future users have positive perception on different usage of SHTs i.e., energy management, indoor controlling and promoting safety. (2) Available users and future users both expressed concerns on transferring self-reliance, independence and data security; (3) Policymakers positively influence in SHT market by formulating standards/guidelines.
• The Impact of Social Connectedness and Interaction Types on Perceived Social Support and Companionship [62] • Focused on "human-device interaction and social adoption" to investigate the notion of	• A human–device social connectedness survey where human–device interaction was classified into two categories (1) internal relation (Inner Social Connectedness-ISC) defined as relation between user - devices in user's own smart home; (2) external relation. 2 types of engagements:	• (1) both type of human-device relations boost user's social experience; (2) Direct engagement with internal relation is more efficient; • Future studies: building up more objective factors rather than subjective ones.

Title & Journal Category & Objective	Details of the proposed survey	Finding or Contribution Limitation & Suggestions
relation and engagement between user and smart devices.	direct/unmediated (user is engaged with the device directly) and indirect/ mediated (user is engaged with the device via an agent). • Controlled experimental study in a smart home prototype using questionnaire with 96 participants, Wizard-of-Oz" technique, AXURE RP 8.0 prototype tool, and statistical analysis.	
• Comprehensive Approaches to User Acceptance of IoT in a Smart Home Environment [63] • To identify main criteria of user's approval towards IoT technologies in smart homes and explore a thorough model containing five possible factors and technology acceptance model (TAM).	• A survey (interviews and questionnaire) on user's acceptance of IoT. Citeria included: enjoyment, compatibility, connectedness, ease of use, usefulness, attitude, intention to use, control, cost collected from 1057 participants. • Confirmatory Factor Analysis (CFA) Structural Equation Modeling (SEM) and Statistical analysis were used.	• Compatibility, connectedness, control, and cost are key factors of technology approval from user's perspectives. • Future research: promoting IoT technologies in a smart home by paying attention to the user experience.
• Convenience and Energy Consumption in the Smart Home of the Future: Industry Visions from Australia and Beyond [64] • The paper focused on the "industry vision" towards energy management security systems" to investigate the vision on the convenient life notion of smart homes and energy savings implications.	• Survey of industry visions on the convenience and energy consumption. Analysis of online articles, magazines and in-depth interviews with 10 industry experts in smart homes were carried out.	• The conflict of simplicity and complications among the vision of smart home industry. • Future research: how to evade and interrupt the notion of convenience in Smart home.

Table 7.
Reviewed tables related to people acceptance of smart home technologies.

5. Systematic analysis of smart buildings

The smart building literature summarized in **Table 4** included research of the latest studies. Selection of papers were made based on a varying spectrum of smart buildings deemed to be of prime importance so that a holistic overview of technologies embedded in smart buildings are provided. Examples included security systems, [54, 55] users' thermal comfort [48], blockchain technology [42] and external environment monitoring system in smart buildings [56].

6. Systematic analysis of smart homes

The papers reviewed in this section were found using a combination of the following keywords: "smart home" and "automated home" as per published on Elsevier, Springer and IEEE databases. Databases as stated above are well-recognized as the most highly-cited ones than other databases in the field. All papers were published between 2010 - 2019 reporting various technologies utilized in smart homes, as well as surveys and questionaries which reported public viewpoints on technologies as such.

From the above 46 articles in smart homes, 2 review Tables are formed and presented. **Table 6** focuses on the technological systems according to different functions and performances in smart homes; **Table 7** presents a review of surveys investigating the people's acceptance or adoption of newly proposed smart homes-based technologies. Three articles as examples are shown in **Table 6** as following and the rest are included in the appendix.

Articles reviewed in the **Tables 6** and **8** (appendix) are categorized in different clusters according to function and objectives. Articles [57, 80, 87, 100] were focused on the "activity/movement recognition systems"; articles [60, 65, 68–72, 92, 97] were focused on the "healthcare systems"; articles [59, 67, 74, 75, 79, 81, 82, 84–86, 89, 93, 95, 98] were focused on the "energy management systems"; articles [66, 78, 88, 90, 91, 94] were focused on the "security systems"; article [73, 96] focusing on the "home management systems"; article [99] was focused on the "automation systems; Also articles from a combination of systems in a frameworks such as [58] focused on the "activity/movement recognition systems and healthcare systems"; articles [101, 102] were focused on the "home management systems and automation systems"; article [83] was focused on the "energy management systems and security systems"; and article [75] was focused on the "energy management and home management systems".

Table 7 presents the papers that focused on the survey from user or market to evaluate their attitude and vision, acceptance or adoption of the smart home technologies.

7. Conclusion

Ambitious projects using modern technologies to develop the city are increasingly expanding worldwide. With such ever increasing interest, authorities, officials and managers are therefore strongly pursuing the idea of incorporating varied technologies in different buildings. Given rapid growth of technology embedded in the different aspects of buildings and the increasing trends in smart cities, smart buildings, and smart homes, the present chapter reviewed and summarized existing technologies/systems currently adopted in buildings/homes. A general overview of smart city components, smart building functions and clusters, . A holistic view on smart cities/buildings/homes, history and evolution, advances made over the past decade, components, classifications, current gaps, limitations, and future trends were provided. Papers in smart buildings and smart homes were searched from reliable datasets i.e., Elsevier, Springer, and IEEE, reviewed and summarized in Tables. Papers were categorized according to the proposed systems and frameworks in the following clusters: security systems, healthcare systems, energy management systems, building/home management systems, automation systems, and activity/movement recognition systems.

Overall, the positive features, or the expectations of the smart buildings, homes and cities can be summarized as follows: higher energy efficiency, connectedness, compatibility, energy management and controlling, promoting safety, enhancing life quality and provide emotional support to users' and cost efficiency.

Despite all such positive features, there exist undesirable aspects that should be taken into account to achieve the smartness, e.g., pitfals oriented around transferring self-reliance, independence, data security, privacy, and costs need to be appropriately addressed.

Attempts, however, have been constantly made to eliminate such negative perspectives. Examples include efforts made to reduce negative perceptions of the public via mechanisms i.e., guaranteeing the reliability and simple use of smart technologies where policymakers and expert panels can facilitate the expansion of smart technology market by enforcing/developing standards and guidelines. Suggesed papers for future works are listed as follows:

- To increase mobile battery capacity to support wearable sensors [68].
- To improve the reasoning process, evaluate ethical, clinical and economical aspects further to the functionality and usability aspects. [71].
- To expand the number of behavior situations [92].
- To include further tasks based on different scenarios and develop application platforms such as MicroApp [101].
- To promote IoT technologies in a smart home using users' experiences [63].
- To extend platform application on other types of buildings and adopt in multi-phase cooling/heating systems [48].

Appendix

43 articles are summarized in **Table 8** as an addition to the **Table 6**.

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
• Fog Assisted-IoT Enabled Patient Health Monitoring [65] • A "healthcare system" to monitor the patients remotely, classify events based on fog computing, mine the patients' health data at cloud layer, and make real-time decisions, based on fog computing at smart gateway.	• Devices implemented in the data acquisition layer included: bio sensors, smart wearables, smartphone, smart devices, RFIDs, and smart monitors. Recognition of patients' events and choosing between normal and abnormal events was based on the Bayesian belief network (BBN) by embedded data mining, distributed storage, and notification services at the edge of the network, and triggering-based data transmission.	• Model validity was assessed using 67 patients health data living in smart homes for a month. • Significantly accurate and responsive model in recognition of the event state compared to other algorithms.
• Smart Secure Homes: A Survey of Smart Home Technologies that Sense, Assess, and Respond to Security Threats [66] • Eisting technologies in "security system" were reviewed.	• (1) Identified a varying spectrum of security problems (2) Summarized existing independent sensors and methods to detect threats.	• Future work: new security risks to be investigated. Unusual circumstances to be automated using a combination of sensors to sense incongruity more accurately and faster.
• A Generic User Interface for Energy Management in Smart Homes [67] • Aimed to introduce a generic user interface for operation systems, which can be easily adapted to different types of buildings to aid "energy management systems".	• (1) Various roles and permissions were introduced. (2) A number of data models were designed. (3) Few functional components are being known to support different kinds of issues of smart homes. • Design, function, and use of the	• The system can fullfill remote reachability, responsiveness, role management, flexibility and generality. It does not meet the system configuration. It proved to be >90% functional, and informative on the amount of energy used in homes and contributed to save costs.

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
	system is firstly evaluated qualitatively by a prototype after which quantitatively assessed by questionnaire as distributed to the system users.	• Future work: (1) The configuration issue to be solved, therefore extra interface is required. To collect and analyze various buildings configuration requirement. (2) Integrating other features e.g., security or music.
• A Health Gateway for Mobile Monitoring in Nursing Home [68] • The "healthcare system aimed to monitor people, particularly in nursing homes, remotely.	• The proposed remote health monitoring system (RHMS) operates with wearable devices in nursing homes, public healthcare centers, and smart homes in which elderly or patients live. The gateway consists of six components: MCU, camera with Wi-Fi, RFID reader, infrared temperature module, Wi-Fi module to convey health data, and Bluetooth to receive data from wearable sensors. Identity, vital signs, temperature, location, and falling action detection was automatically collected from each individual.	• The gateway conveys gathered data through Wi-Fi to the server. In case data were not normal, the gateway sends an alarm to the serve. The server sends out patient's location to physicians' mobiles to find patient. • Future work: (1) Investigating the quality of communication network which transfers the data (2) Increasing mobile battery capacity, which supports wearable sensors.
• A Hybrid Key Item Locating Method to Assist Elderly Daily Life Using IoT [69] • A "healthcare system" aimed to support the elderly living in their homes by storing elderly movements data and provide assistance to easily find necessary items	• (1) Data is collected by sensors and transmitted by Bluetooth, (2) Data is processed by Kernel program, (3) after which findings are visualized by mobile apps. • Sensors are placed in two different positions: in elderly's important items they may miss or fixed in a location in the home. Each item position is shown on mobile phone. • The algorithms combine xBeacon sensing equipment, received signal strength indication positioning, event analysis method, and intelligent cutting algorithm.	• The system can contribute to finding the location of elderly important items and tracking routine behavioral patterns; opportunity for elderly to live without others help.
• A proposal based on BCI system to aid patients with amyotrophic lateral sclerosis [70] • A "healthcare system" to assisst patients with amyotrophic lateral sclerosis (ALS).	• The proposed system (BCI) works with a digital assistant BrainWave sensor called EEG using an android-based operated software to enable ALS patients perform activities such as: controlling TV by Infrared, controlling lighting by SSR28 module, and using an air conditioner. • The BrainWave sensor in the shape of a headset can capture patients' brain frequency and	• 80% of participants' approval in which patients accompolished daily tasks. • Patients' independence and self-esteem was improved. • Future work: developing a prototype in real homes with real patients.

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
	can recognize patients' eye blink strength	
• A Tailored Smart Home for Dementia Care [71] • A "healthcare system" to recognize special needs of patients suffering from dementia and to design a smart home to suit dementia patients.	• Dementia care requirements were identified and collected data were analyzed, after which a prototype was developed. • The prototype consists of a combination of sensors, an android tablet for a digital frame, and a digital wireless radio for evaluating the sound capacity of the smart home, Raspberry Pi (model B) for the gateway, communication interfaces, middleware, managing and monitoring interfaces, reasoning engine, and rule management interface.	Suitable according to stakeholders' opinion with potential application in real smart homes which assisted caregivers. Future work: to (1) evaluate the prototype by more participants, (2) evaluate the prototype in real smart homes, (3) improve the performance of the reasoning process, (4) evaluate ethical, clinical and economic aspects further to suit functionality and usability.
• Aging in Place – How Smart Home Technologies, the Built Environment and Caregiving Intersect [72] • The "healthcare model" aimed to give the elderly the ability to be independent, safe, and maintain well-being in homes.	• (1) Functionality of an automatic light sensor for a potential remote control purposes was evaluated using a 90-year-old widowed woman case study who was living alone (2) Functionality of a video doorbell lock was evaluated using a 79-year-old woman case study who was living alone and had difficulty to open a front door (3) Functionality of the robotic lawn mower was examined using an 82-year-old man living with his wife who was not able to do household tasks any longer.	• Case studies' feedbacks: The light sensor gave Julie the confidence of moving from place to place, and her daughter believes Julie's home is safer. Mixed feelings with the video doorbell lock. Her nephew has a remote-control app on his cellphone to screen the front door happenings. Husband is worried about the maintenance costs and possibility for the lawn mower to be stolen. • Future work: Further studies to be conducted to find ways to entice the elderly to use new technologies.
• An Assistive VLC Technology Using EOG [73] • The proposed system is based upon the "controlling (management) system and healthcare system" to control the devices employed in smart homes and to help the seniors or disabled citizens.	• Eyeglasses equipped with electrooculogram signal based assistive visible light communication is the innovative proposed system. • Surface electrodes made of silver chloride are located around the person's eyes to capture the vertical and horizontal eye movement signals. Signals are processed and conveyed by white light LED and a photodetector. The more eye patterns (e.g., up-down-up pattern or Eye blink) included, the more devices can be controlled. • A digital door lock is employed to test the validation of the proposed scheme.	• A reliable and accurate system contributing to green and safe smart homes assisting seniors or the disabled. • Various eye patterns can be utilized, thus more devices can potentially be controlled: potential contribution to other research areas.

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
• An Open Source Smart Home Management System Based on IoT [74] • The proposed “energy management system” is aimed to solve energy conservation problems.	• A combination of sensors, microcontrollers, devices (i.e., fans and lights), web server and database, software to aid HTTP communication, a PC framework, and mobile app. • The user chooses app model after which, the sensors may turn a device on/off based on evaluations made on room status. Collected data is sent to the server by microcontroller. Upon filtering, data is stored and visualized.	• One-month data collection of room energy usage decreased ~45. • Compared to other systems, the proposed system is reliable, scalable, open source and effective in terms of costs and energy.
• Deep Learning Model for Home Automation and Energy Reduction in Environment Platform [75] • The “energy management and Home management systems” is aimed to propose (1) a novel platform for a smart home environment, which is powerful, interoperable secure and low cost, and (2) a novel algorithm for energy efficiency based on Deep Neural Networks (DNNs).	• A modular platform called SHE and consists of: on-premises deployed agent that works with Z-Wave and ZigBee, a remote control that is mobile, and a cloud service for data processing. • Includes 14 various sensors and actuators i.e., multi-sensor (for detecting temperature, movements, luminance, and humidity); Smart plug (turning the connected devices on/off and recording energy consumption); Window or door sensor; Z-Wave (controlling sensors and actuators); Meters (measuring energy consumption and rain); Dimmer (controlling light); Switch (controlling the garden watering); infrared controller.	• A platform to enhance the interoperability between sensors and actuators was proposed with focus on reducing energy consumption., Two various DNN models (NILM and ELF) were proposed to identify rare energy usage patterns, and suggest users how to reduce energy consumption. • Future work: (1) improving ELF algorithm to reduce false-positive results (2) proposing a model to cover further home appliances.
• Empowering the selection of demand response methods [76] • The “energy management system” framework assists users to identify the best demand response methods and reduce the costs.	• Firstly, the researches gathered user-specific set of Requirements (REQs) by literature analysis and expert interviews. Secondly, SOCs for responding to each REQ is presented by research and expert interviews. Thirdly, Deming’s benchmarking is used and matched with each (Sate Of Charge) SOC. All information flow of the framework was analyzed and events were also added to the scenarios. Fourthly, a prototype was implemented to test the appropriateness and practicability of the proposed framework. • A simulation study based on seven types of households was performed to test the framework.	• When the best demand response methods is selected, the users will pay less money, flatten the load profile, and reduce the peak load. • Limitation: evaluation is based upon simulation; in-reality implementation is missing. • Future work: developing other contexts beyond residential buildings.

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
• Fall Detection Using ultra-wide band (UWB) Sensors and Unsupervised Change Detection [77] • The proposed "healthcare system" aimed to detect fall using an unsupervised algorithm.	• The system includes non-wearable ultra-wideband and radar sensors that consist of transmitter and receiver. • The transmitter used in the device spreads the pulses to the environment and the receiver receives and records them. The received pulses are analyzed (by SEParation (SEP) algorithm) to diagnose the problem in case a fall has happened. • The sensor is located over the door frame to detect the movements. Raw data from sensor is sent to the computer.	• 97% accuratcy rate with SEP algorithm • Best choice to detect unsupervised falls and non-falls activities using SEP algorithm. • Supervised algorithm can detect all falls, however, number of labeled samples should reach a threshold to perform as good as unsupervised one.
• Home Automation- An IoT-Based System to Open Security Gates Using Number Plate Recognition and Artificial Neural Networks [78] • The "security system" is proposed an automatic system that opens security gates.	• An ambient light sensor and control circuit are employed to control the environment light. • Vehicles with license plate recognition can work with the system. Image processing is utilized to recognize the license plate and the characters. For optical character recognition, an artificial neural network is utilized.	• 88% and 93% accuracy in training data and license plate character, respectively. • Can be controlled by a mobile app or web interface and generate security gate notifications on mobile.
• Intelligent Energy Efficiency Model Using Artificial TensorFlow Engine [79] • The "energy management system" by this article proposes a framework to help the IoT devices work efficiently with together.	• Three proposed models are: (1) Intelligence awareness target (IAT) that works based on IAT sensor, IAT smart phone, and IAT smart appliance, (2) Intelligence energy efficiency (IE^{2}S), (3) Intelligence service TAS (IST). • IAT can recognize the data value based on the situation with responsibility to gather the environmental data by a combination of sensors. Data processing and analyzing roles are played by IE^{2}S as a server and recognizes the users' consumption patterns to enhance the service for working automatically. And the role of predicting, managing, and controlling the service is played by IST.	• Model can can minimize activities of the network deemed to be unnecessary. • Future work: (1) Developing intelligent algorithms with enhanced prediction accuracy, where network can be directly analyzed.
• Latent Feature Learning for Activity Recognition Using Simple Sensors [80] • The "activity recognition system" aimed to recognize activities using deep learning methods.	• A deep and hierarchical autoencoder, which works with different environmental sensors: motion detector sensors, contact switch sensors, pressure mats, mercury contacts, float sensors, and etc. The stacked autoencoders that	• Deep learning outperformed other methods. • Future work: (1) developing convolutional neural networks and recurrent neural networks for activity recognition (2) developing multi-resident activity recognition.

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
	are used in this study are: one-layer denoising autoencoder called DAE and two-layer stacked denoising autoencoder called SDAE. • 3 datasets (3 smart homes) were used for model evaluation purposes.	
• Multi-Objective Power Scheduling Problem in Smart Homes Using Gray Wolf Optimizer [81] • The "energy management algorithm" tends to solve power scheduling problems to reduce energy bills and peak to average ratio and raise users' comfort level.	• A multi-objective gray wolf optimizer, which is an algorithm called GWO.	• The algorithm outperformed genetic as well as other algorithms.
• An Innovative Heuristic Algorithm for IoT-enabled Smart Homes for Developing Countries [82] • The proposed system is for "energy management system" aimed to investigate an improved algorithm for DRSREOD- demand response (DR) combined with renewable energy sources (RESs) and energy storage system optimal dispatch in home energy system managements (HEMs)	• The proposed system uses heuristic algorithm and joins demand response (DR) with optimal dispatch dependent on overabundance existing PV energy, maximum charge/discharge rates and vector of states of charge (SOC).	• Variety and programming pliability for customers was achieved once MS and multi-objective genetic algorithm/pareto optimization (MOGA/PO) was applied to. • Future study includes changes in the behavior of CE, TBD and Pgsize parameters and HEMS estimation time.
• A Novel Smart Energy Theft System (SETS) for IoT-based Smart Home [83] • The proposed "energy management and security systems" aims to introduce a smart system to discover energy stealing activities by aggressors of households' energy systems and warn the customers.	• The proposed smart energy theft system (SETS) uses energy usage data, machine learning models (i.e., MLP, RNN, LSTM, and GRU) and statistical models. • SETS can meter the energy usage of household's devices in real-time manner and compare the real data to find any abnormality.	• This system can boost the safety of IoT-based smart home energy systems to 99.96%.
• A Secured Smart Home Switching System Based on Wireless Communications and Self-energy Harvesting [84] • The proposed "energy management system" aims to employ a safe smart home switching system based on wireless communications and inner energy repository.	• The proposed secured smart home switching system is composed of (1) photovoltaic for storing energy purposes, (2) access control system, (3) smart hub design system. The system unifies electricity access control of a building' energy storing system, and wireless communication for smart switches and sockets.	• A promoted system for safety and energy efficiency in buildings is achieved with: (1) certain users' authority to make the electricity on/off using code; (2) storing energy for active devices using PV systems and wireless communication for smart switches and sockets.
• Load Profile-based Coordination of Appliances in Smart Home [85]	• A profile-matched time-shift (PMS) optimization algorithm approach which diagnoses a	• (1) Lower cost and more energy saving compared to other methods. (2) flexible and

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
• The proposed system is for "energy management system" aimed to study the load pattern of different devices at home and their optimal simultaneous operations to reduce energy consumption and the overall energy price.	series of begin times of various home devices based on the energy usage costs, delay tolerances, and energy sources limits.	can work in various scenarios. • This method can be further applied and examined for various energy sources in a home.
• Online Energy Management for a Sustainable Smart Home with an HVAC Load and Random Occupancy [86] • The proposed system is for "energy management system" aimed to reduce total energy cost of home devices and thermal discomfort cost related to users (with HVAC load and occupancy).	• The algorithm is to make queues related to indoor temperature, electric vehicle charging, and energy storage; and to reduce cost of average time energy use of HVAC. The system works without predicting any system parameters and knowing the HVAC power demand.	• Substantial simulations that pursue real-life trends show the efficacy of the proposed framework. • Future studies: developing online HVAC control in other types of buildings such as commercial buildings.
• A Knowledge-driven Approach for Activity Recognition in Smart Homes Based on Activity Profiling [87] • The proposed "activity recognition and movement system" aims to present an activity recognition platform in smart homes which is able to recognize targeted activities from off the subject data with higher success rate.	• The proposed activity recognition platform consists of: (1) pre-processing data, (2) automatic segmentation, (3) Activity profiling, (4) removing irrelevant information, (5) creating vectors. • It benefits from classification algorithms (Naïve Bayes, SVM and J48) and ANOVA statistical testing.	• Significant improvements made with training data sets in terms of a number of attributes, activities, and the way the sensors are distributed in homes. • The technique recognized the targeted activity from the irrelevant ones with 42% lower inaccuracy.
• A Matrix-based Cross-layer Key Establishment Protocol for Smart Homes [88] • The proposed "security system" aims to generate secret session keys for security between appliances made by different manufacturers in smart homes.	• A matrix-based cross-layer key establishment protocol, with four stages: (1) Home gateway makes system parameters; (2) Home appliances draw out master keys (shared with the home gateway) at physical layer; (3) The home gateway deals out secret key seeds for home appliances; (4) Any two appliances can straightly make a secret session key at higher layers.	• (1) Any two appliances can directly establish a secret session key without using any pre-shared secrets; (2) The protocol is a cross-layer design; (3) Any two appliances in the protocol can establish a secret session key when they do not pre-share any secrets, and it is achieved without much energy usage; (4) The protocol supports key updating and network scalability.
• A Novel Minimum Cost Maximum Power Algorithm for Future Smart Home Energy Management [89] • The proposed "energy management system" aims to decrease the price of consumer's electricity usage by optimizing energy scheduling plan without making any discomfort	• A novel Minimum Cost Maximum Power (MCMP) algorithm to solve the formulated problem of Mixed Integer Linear Programming (MILP). • Price of electricity usage, peak demand reduction, task completion and time of response were analyzed and compared in four different load scenarios.	• Compared to other models: (1) decreases electricity usage and peak demand more efficiently; (2) includes 100% task completion of all home appliances; (3) is less complicated and better performed in real-time situations; (4) is novel and not used before. • Future researches includes energy management in industrial sector.

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
• A Privacy Preserving Communication Protocol for IoT Applications in Smart Homes [90] • The proposed system is for "security system" aimed to present a communication protocol for smart home systems that ensures safety and energy efficiency	• A a Smart Home Systems (SHSs) Protocol for security. It comprises an appliance group, a monitor group, a central controller, and user interfaces. It goes through the following four main phases: (1) key Generation, (2) encryption, (3) Message Authentication Codes (MAC) generation and verification, and (4) decryption. • Safety and privacy-keeping communication protocol applies chaos-based encryption (logistic map) and MACs.	• The first generic architecture design layout for future SHSs. • The system promoted the protocol to achieve better safety and privacy-keeping features with less computations suitable scalability.
• A Security Authorization Scheme for Smart Home IoT Devices [91] • The proposed system is for "security system" to introduce a permission platform for smart home appliances that are connected to unsafe cloud. The instructions are transferred to the user's smart phone for approval.	• The architecture of the proposed security permission platform consists of (1) smart home appliances, (2) cloud platform, (3) smart-phone application. • For the security system and permission platform, the FIDO UAF (Fast Identity Online-Universal Authentication Framework) protocol was selected. The system benefits from open-source IoT cloud, a platform like IoT Kaa, and Several programming languages.	• (1) introducing a platform to create digital ID for both smart appliances and the users, (2) implementing the scheme in an available software and hardware system, (3) designing a cloud federated permission for smart home based on the FIDO permission messages, (4) introducing a security platform in which a user can ask for FIDO permission via cloud platform each time, (5) carrying out tests using Kaa IoT Cloud and assessing delay times.
• Adaptive Monitoring System for E-health Smart Homes [92] • The proposed "healthcare system" aims to introduce a novel adjustable e-health monitoring system for old people.	• An Adaptive Monitoring E-health System, which gathers pertinent data to appraise the user's health condition based on the situations of his daily life activities and is able to learn the activity profile of the user. • Gray Model (GM) is used to predict model (to learn and predict the behavior and level of dependency trends). Markovian model is employed to evaluate the system for generating long term realistic scenarios. • Functional Autonomy Measurement System (SMAF) is pursued to outline the user's activities. Functional abilities adopted were: Activities of Daily Living (ADL), Mobility, Communication, Mental Function and Instrumental Activities of Daily Living (IADL).	• 100% accuracy in high monitoring, 95.8% in medium monitoring, and 91.9% in minimum monitoring. The system diminished energy usage by 48.3%, network traffic by 49.3% and daily activities processing by 54.3%. • Future research include: (1) expanding the number of behavior situations, (2) considering timing logic and break between activities, (3) Including more factors e.g. age, season, location, etc., (4) Incorporating multiple prediction models and assessing effects on the risk and resources, (5) expanding monitoring with vital signs

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
• An Information Provision System to Promote Energy Conservation and Maintain Indoor Comfort in Smart Homes Using Sensed Data by IoT Sensors [93] • The proposed "energy management system" aims to conduct a platform to collect sensing data of environmental parameters (to assess PMV Index) and user's response (comfort desire) to diminish electricity usage while keeping indoor thermal comfort.	• Combines both environmental data and user's response to (1) gather different data from sensors to assess PMV (Predicted Mean Vote) and user's comfort desire, and (2) to choose relevant information from the dataset • PMV Index was assessed by K-means clustering.	Decreased electricity usage by 5.15% and promoted the comfort satisfaction by 42.3%. Qualitative evaluations of indoor comfort enhanced by 16.4%. • Networked sensors gathered data for the system. Future studies: collecting data in a central database operated by a company or the smart city.
• Anonymous Secure Framework in Connected Smart Home Environments [94] • The proposed "security system" aims to provide a secret and safe platform in connected smart homes with less computations and cost.	• An Anonymous Secure Framework (ASF), which creates effective permission and key approval. It provides an unknown and unconnected environment for identity and data of smart devices. Automated Verification of Internet Security Protocol and Application (AVISPA) tool, the BAN-logic and informal analysis are employed.	• (1) less computations and less communication cost; (2) Enhanced safety compared.
• Categories and Functionality of Smart Home Technology for Energy Management [95] • The proposed "energy management system" aims to investigate and recognize various home products on the market and finds out their functions, quality, and their potential for energy savings.	• A coding guide was devised underlying previous work and improved in a repetitive procedure. Qualitative data analysis based on 50 items of the codes.	• Findings indicated choices for saving energy (operational and behavioral) and shifting loads among most product groups. • Future research is to determine the interaction between users and smart home products.
• Context-aware Decision Making under Uncertainty for Voice-based Control of Smart Home [96] • The "home management" framework aims to analyze the environment in terms of comfort and independence including voice alarms for immediate actions.	• The decision making and the action is taken with the voice command of a user or when an abnormal situation is discovered by the system. The system is based on a knowledge model and the decision making is processed in uncertainty.	• (1) overall model accuracy level was 85% (min. 71%, max. 100%); (2) Markov Logic Network presented an integrated base involves with logical requirements, uncertainty, and missing data; (3) The system can learn from the data;
• Delivering Home Healthcare through a Cloud-based Smart Home Environment (CoSHE) [97] • The proposed "healthcare system" aims to propose a cloud-centric platform in smart homes to prepare thorough information for health supervisors by monitoring user	• Collecting data via wearable sensors that are not intrusive and also through environmental sensors. A home gateway processes data and sends to a private cloud. This cloud prepares health supervisors with access to real-time information of the user health state. CoSHE consists of four main parts of smart home	• Possible to reach thorough and useful information by unifying context and health-related data and deliver the information to supervisors to monitor the health state of the user. • Limitations: raise energy consumption • Future researches include warning systems to predict the

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
location, activities, mental and emotional state.	environment, wearable devices, private cloud system, and home service robot.	disease and warns health supervisors in risky situations.
• Demand Response Implementation in Smart Households [98] • The proposed "energy management system" aims to propose an optimized-based scheme for energy-saving and cost reduction in smart homes to control the operation of home appliances which their loads can be controlled and are able to store energy (e.g. EV and EWH) considering demand response and the load pricing time.	• Designed for smart houses with photovoltaic (PV) systems combined with Energy Storage System (ESS). Electric vehicle (EV) and electric water heater (EWH) are controllable appliances with storage capability. Effective timing of appliance's energy usage and the demand scheme are scheduled.	• When applying this intelligent optimization-based algorithm, the daily energy price reduced 29.5% - 31.5% comparing to an ordinary rule-based algorithm
• Emulating Home Automation Installations through Component-based Web Technology [99] • The proposed "automation system" of homes aims to introduce a platform based on KNX protocol to imitate, test and validate the home automation environment in a virtual web-based platform before the hardware is installed.	• The proposed component-based web technology platform represents the operation of real devices in a virtual web-based environment based on KNX Network. The virtual devices perform and interact via web environment which permits to make components that create various kinds of data (text, audio, image, video, animation, etc.). COScore structure manages these components. Web services can manipulate the platform and web users' interface can test the behavior regarding this data. • COScore based on CBSE, MDE, web services, HTML5, CSS3 and JavaScript technologies are employed.	• The platform allows testing, validating and analyzing the behavior of home automation devices virtually prior to real installation to minimize risky situations. • Future studies: (1) creating graphical version of the models, (2) applying an MDA approach for the installation, (3) applying security solutions, (4) using another network or protocol apart from KNX.
• Identifying Multiuser Activity with Overlapping Acoustic Data for Mobile Decision Making in Smart Home Environment [100] • The proposed system is for "activity Recognition and movement system" aimed to propose a system to detect activities of users by automatically identifying the various and overlapping sounds in a real-time context in smart homes using acoustic-based LED lighting.	• Sounds of user's activities are collected and detected by audio sensors in a real-time manner. The sounds are classified for activity recognition.	• Higher accuracy rate than existing classification algorithms. Future studies: Improvement of smart recognition systems with further experiments in real-time manner.
• ImAtHome-making Trigger-action Programming Easy and Fun [101]	• For every home, the application makes a database on the cloud with different	• Majority of the respondents particularly young people found ImAtHome user-

Title, Category & Objective	The proposed system function and details	Finding or Contribution Limitation & Suggestions
• The proposed "automation and home management systems" aims to propose a framework for smart home users to control smart appliances by setting certain commands for operations without having any expertise.	groups and sub-groups of various rooms and devices. It can find, add or remove rooms and devices, access their data, and control or command (even vocally) different functions.	friendly. • Future work includes: applying more users and tasks with different scenarios based on different application platforms e.g. MicroApp.
• IoTtalk-RC: Sensors as Universal Remote Control for Aftermarket Home Appliances [102] • The proposed "automation and home management systems" aims to introduce a software-based platform for distance-control of smart home devices	• The proposed system is IoTtalk Remote Control (IoTtalk-RC), which uses sensors (e.g. temperature & humidity Sensors) to control one or more tasks of smart home devices (e.g. electric fans). An infrared device for receiving (IrR-D) and one for transmitting (IrT-D) are connected to IoTtalk server which can be installed in a cloud or Wi-Fi AP. The Smart device is connected to the IoTtalk server via wireless system. Computations and analytic analysis are employed.	• (1) Short delay time even when IoTtalk server is far at a virtual machine of a cloud; (2) The disorganized series of sending due to the delay time is insignificant; (3) efficient platform; (4) IoTtalk is a solution to replace the usual infrared remote controller of smart devices needs new programming from the developers.

Table 8.
Reviewed papers related to smart homes.

Author details

Reyhaneh Karimi[1]*, Leila Farahzadi[2], Samad M.E. Sepasgozar[3], Sharifeh Sargolzaei[4], Sanee M. Ebrahimzadeh Sepasgozar[5], Mohsen Zareian[6] and Akram Nasrolahi[2]

1 The University of Science and Culture, Tehran, Iran

2 Islamic Azad University, Tehran, Iran

3 The University of New South Wales, Sydney, NSW, 2052, Australia

4 University of Zabol, Zabol, Iran

5 The Knowledge Enterprise Payesh Tajhiz Arad, Gorgan, 1734533998, Iran

6 Chalmers University of Technology, Göteborg, 412 96, Sweden

*Address all correspondence to: reyhanehkarimi@rocketmail.com

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