

(REVIEW ARTICLE)



A comprehensive review towards smart homes and cities considering sustainability developments, concepts, and future trends

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World Journal of Advanced Research and Reviews, 2023, 19(01), 1482–1489

Publication history: Received on 20 June 2023; revised on 26 July 2023; accepted on 28 July 2023

Article DOI: <https://doi.org/10.30574/wjarr.2023.19.1.1530>

Abstract

The adoption of Smart Homes (SHs) and Smart Cities (SCs) brings numerous benefits to the society and environment by exploiting the Information communication technologies (ICTs). These include increased efficiency, reduced energy waste, lower utility bills, improved safety and security, enhanced mobility options, and a more sustainable and liveable urban environment using Vehicle-to-Grid (V2G) technology. Moreover, the integration of technology such Internet of Things (IoT) and data-driven solutions can lead to better decision-making, more responsive public services, and increased citizen engagement. However, there are challenges that need to be addressed for the full realization of smart homes and smart cities. These include concerns related to privacy, data security, interoperability of devices and systems, infrastructure investment, and ensuring equitable access to these technologies. Overcoming these challenges will require collaboration between policymakers, technology providers, urban planners, and citizens to create a framework that balances innovation, privacy, and sustainability. Despite the challenges, the potential benefits of smart homes and smart cities make them compelling solutions for the future. By leveraging technology to create more efficient, sustainable, and liveable spaces, smart homes and smart cities have the potential to significantly improve our everyday lives and contribute to a more prosperous and environmentally friendly future.

Keywords: SHs; SCs; ICT; V2G; IoT

1. Introduction

Smart Homes (SHs) and Smart Cities (SCs) are emerging concepts that aim to leverage technology to enhance the quality of life, improve efficiency, and promote sustainability in our living spaces [1]. The SHs and SCs have been extensively discussed in the literature as potential solutions to overcome limitations in traditional home and urban environments such as enhanced energy efficiency, sustainable urban development, and improved resource management [2]. The literature emphasizes the potential of smart homes and smart cities to overcome limitations in traditional home and urban environments, leading to more sustainable, efficient, and liveable spaces [1]. However, challenges related to data privacy, cybersecurity, scalability, and equitable access to technology remain areas of concern and require further exploration and development.

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The contribution of the article is comprehensively presenting the advantages and disadvantages of smart home and cities systems from sustainable developments perspective. The remaining sections in the article are organized as follows: Section 2 is comprehensively presented the recent state-of-the-art of smart homes and smart cities. The Functional barriers of smart homes towards sustainable smart cities along with the further explanation are presented in Section 3. Summary dissection of smart homes and cities are in Section 4. Section 5 is discussing the future trends and recommendation of smart homes and cities. Eventually, conclusion and list of references are closing the article.

2. Literature of Smart home and smart cities

The state-of-the-art of the utilized technologies in smart homes and smart cities are presented in the literature. Various scholars discussed different types of technologies. Energy management strategy of microgrid system is conducted in the literature based on multi objective approaches for smart homes [3]. The aforementioned study is studying the different strategies to smoothly spreading the power among devices on smart homes in order to achieve sustainable development goals. Similarly on the previous objective of cited reference, a systematic review conducting the smart conservation systems from smart homes to gain a larger system towards smart cities [1]. Another study found in the literature and presented the utilization of Electric Vehicle (EV) in smart homes to in order to meet the aims of smart cities to charge EV [4]. Moreover, various forms of smart homes and cities, the RESs integration is counted as one of them as reported in [5]. Furthermore, smart cities is providing several advantages by overcoming power and environment limitation using nano generation considering different technologies such as bibliometric and machine learning [6]. Due to the wide number of smart home applications such as smart parking, smart bridge, intelligent shopping based on blockchain that secure and trusted public emergency services as presented in [7], Based on the Internet of Things (IoT) technology, smart devices are operating at homes [8].

3. Functional barriers of smart homes towards sustainable smart cities

3.1. Functional barriers of smart homes towards sustainable smart cities

While smart homes and smart cities offer the potential for greater sustainability, there are several functional barriers that can hinder their progress as listed below and further exploited in Table 1 while the advantages and disadvantages are tabulated in Table 2 [1].

- Interoperability
- Flexibility
- Decentralization
- Scalability and infrastructure
- Energy consumption and efficiency
- Regulatory and Policy Frameworks

Table 1 Barrier functions of smart homes and smart cities

| Functions | Remarks |
|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Lack of interoperability | Smart homes often consist of a variety of devices and systems from different manufacturers. |
| Cost and accessibility | Can be a significant barrier Particularly for low-income households. |
| Privacy and security concerns | Smart devices gather vast amounts of personal data Potential for breaches or misuse of this data is a significant concern for individuals. |
| Infrastructure limitations | Implementing smart city initiatives often requires significant investments in infrastructure. |
| Regulatory and policy challenges | The rapid advancement of smart technologies has outpaced the development of regulations and policies governing their use. Regulatory frameworks that incentivize and support the adoption of smart homes and smart city solutions are essential for their successful implementation. |

| | |
|----------------|-----------------------------------------------------------------------------------------------|
| Digital divide | Refers to the gap between those who have access to digital technologies and those who do not. |
|----------------|-----------------------------------------------------------------------------------------------|

Table 2 Merits and demerits of key factors of

| Functions | Merits | Demirtas |
|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Lack of interoperability | Flexible Ease of use Scalability in smart environments | May not be compatible with each other. Can limit the effectiveness of smart home systems Hinder their integration into larger smart city initiatives |
| Cost and accessibility | The initial investment required for purchasing and installing devices, as well as ongoing maintenance costs, can make smart home solutions inaccessible to a large portion of the population. | Ensuring affordability and accessibility is crucial for the widespread adoption of smart homes and smart city initiatives. |
| Privacy and security concerns | The increased connectivity and data collection inherent in smart homes raise concerns about privacy and data security | Addressing privacy and security issues is crucial to building trust and encouraging the adoption of smart home technologies |
| Infrastructure limitations | Upgrading or installing sensors, communication networks, and data management systems. Availability and capacity of infrastructure can be a limiting factor. Particularly in older cities or areas with limited resources. | Connectivity issues reduced scalability |
| Regulatory and policy challenges | Clear guidelines and standards that address issues such as data privacy, security, interoperability, and environmental sustainability. | Slow adoption and implementation |
| Digital divide | benefits of smart homes and smart city initiatives | Unequal access to the internet and digital literacy can create disparities in the adoption. Bridging the digital divide is crucial to ensure that everyone can benefit from the potential of these technologies. |

Addressing these functional barriers requires collaboration between various stakeholders, including governments, technology providers, urban planners, and community organizations. Efforts should focus on developing interoperable and affordable solutions, safeguarding privacy and security, investing in infrastructure, establishing supportive policies, and bridging the digital divide. By overcoming these barriers, smart homes can contribute to the larger goal of creating sustainable and inclusive smart cities. A review of the key aspects and potential benefits of smart homes and smart cities are figure out in Figure 1.

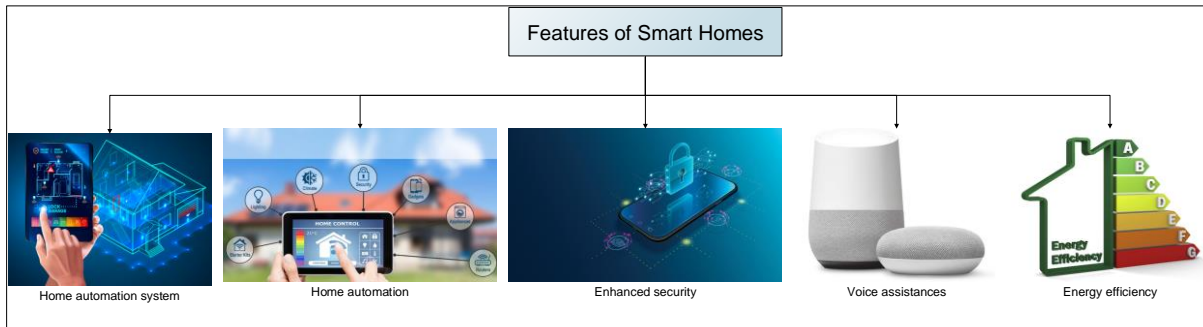


Figure 1 Features of smart homes [1]

Smart Homes are residences that are equipped with various devices and systems that can be controlled and automated to enhance comfort, convenience, and security. Some notable features of smart homes include:

- **Home automation:** Smart homes utilize technologies like Internet of Things (IoT) to connect and control various devices such as lighting, heating, cooling, appliances, and security systems. This allows homeowners to remotely monitor and control these devices, leading to energy savings and improved convenience.
- **Voice assistants:** Integration of voice-controlled virtual assistants like Amazon Alexa or Google Assistant enables hands-free control of devices and systems within the home. Users can give voice commands to control lighting, play music, set timers, and even control other connected smart devices.
- **Energy efficiency:** Smart homes often include energy management systems that monitor and optimize energy consumption. This can involve automated adjustments to lighting, heating, and cooling based on occupancy, weather conditions, and user preferences, leading to reduced energy waste and lower utility bills.
- **Enhanced security:** Smart home security systems can include features such as video surveillance, motion sensors, door/window sensors, and smart locks. These systems can be accessed remotely, providing homeowners with real-time alerts and the ability to monitor and control their home's security.

Smart Cities: Smart cities are urban environments that leverage technology and data-driven solutions to improve various aspects of urban life, including transportation, energy, waste management, and public services. Key features of smart cities include in Figure 2.



Figure 2 Key features of smart cities [8], [9].

- **Intelligent transportation:** Smart cities utilize technologies like traffic sensors, GPS, and data analytics to optimize traffic flow, reduce congestion, and improve public transportation systems. This can lead to reduced commute times, improved air quality, and enhanced mobility options [10], [11].
- **Sustainable infrastructure:** Smart cities emphasize the use of sustainable and energy-efficient infrastructure. This includes smart grids that optimize energy distribution, renewable energy sources, efficient waste management systems, and the integration of green spaces for improved quality of life [12].
- **Data-driven decision-making:** Smart cities rely on the collection and analysis of data from various sources to gain insights and make informed decisions. This data can help city officials identify patterns, predict demand, and optimize resource allocation in areas such as transportation, healthcare, and emergency services [13].
- **Citizen engagement:** Smart cities aim to foster citizen participation and engagement through the use of digital platforms and mobile apps. These platforms enable residents to report issues, access public services, and provide feedback, fostering a more inclusive and responsive urban environment [14].

Overall, the adoption of smart homes and smart cities has the potential to bring numerous benefits, including improved efficiency, increased sustainability, enhanced safety and security, and a higher quality of life for residents. However, challenges related to privacy, cybersecurity, and infrastructure investment need to be addressed to fully realize the potential of these concepts.

4. Discussion

The different between smart home and smart cities from various perspective are listed in Table 3.

Table 3 Smart home and smart cities from various perspective [1].

| classification | smart home domain | smart city domain |
|-----------------------|-------------------------|--------------------|
| End-users | Homeowners (individual) | Citizens |
| IoT devices | 50 or more | 10 million or more |
| Connectivity | Separated | Integrated |
| Scale | Small | large |
| Feature | Functionality | Compatibility |
| Property | Private property | Public property |
| Energy-saving benefit | Direct | Indirect |
| Data storage | On-premise | Cloud computing |

4.1. Future trends for Smart home and cities

Due to the significant of energy saving globally, further studies are needed to overcome energy challenges to meet smart homes and cities aims based on climate changes. In the future, smart homes and cities are expected to continue evolving and incorporating advanced technologies to enhance efficiency, convenience, and sustainability. Below listed some potential trends that scholars may exploited them for their future studies.

1. **Increased Connectivity:** Smart homes and cities will become more interconnected, enabling seamless communication between devices, systems, and infrastructure. This will lead to enhanced automation, data sharing, and personalized experiences.
2. **Internet of Things (IoT) Expansion:** The number of IoT devices within homes and cities will increase significantly, allowing for greater integration and control over various aspects of daily life. Everything from appliances and lighting to transportation and waste management systems will be interconnected [15], [16].
3. **Energy Management:** Smart homes and cities will prioritize energy efficiency and sustainability. Energy management systems will optimize energy consumption by monitoring and adjusting lighting, heating, cooling, and appliances based on real-time data and user preferences. Renewable energy sources such as solar panels and wind turbines will be integrated more extensively [17].

4. **Advanced Security:** Future smart homes and cities will feature enhanced security measures. Biometric authentication, facial recognition, and AI-powered surveillance systems will provide robust protection against intrusions. Automated emergency response systems will also be in place to detect and respond to potential threats [18], [19].
5. **Artificial Intelligence (AI) Integration:** AI will play a crucial role in smart homes and cities. Machine learning algorithms will learn and adapt to user behavior and preferences to automate tasks and provide personalized experiences. AI-powered virtual assistants will become more intelligent, understanding and responding to natural language commands [20].
6. **Sustainable Infrastructure:** Cities will focus on sustainable infrastructure development, incorporating green spaces, eco-friendly buildings, and optimized transportation systems. Smart grids will be implemented to manage energy distribution and reduce waste. Water management systems will promote conservation and efficient usage [12].
7. **Mobility and Transportation:** Smart cities will prioritize sustainable and efficient transportation options. Electric vehicles, autonomous cars, and shared mobility services will become more prevalent. Smart traffic management systems will optimize traffic flow, reduce congestion, and minimize travel times [21].
8. **Enhanced Healthcare and Wellness:** Smart homes will integrate healthcare technologies to monitor and improve wellness. Wearable devices, remote health monitoring systems, and AI-powered diagnostics will enable personalized healthcare services. Homes will be designed with features that promote physical and mental well-being [22], [23].
9. **Data Privacy and Security:** With increased connectivity and data collection, ensuring privacy and security will be of paramount importance. Strict regulations, encryption protocols, and user-controlled data sharing mechanisms will be implemented to protect personal information [24].
10. **Citizen Engagement:** Smart cities will emphasize citizen engagement and participation. Digital platforms and mobile apps will enable residents to access information, provide feedback, and actively contribute to decision-making processes. Communities will be empowered to shape the development and policies of their cities [14].

It's important to note that these trends are speculative and based on current technological advancements and projections. The actual future of smart homes and cities may vary based on various factors.

5. Conclusion

In conclusion, smart homes and smart cities are transformative concepts that leverage technology and data-driven solutions to enhance the quality of life, improve efficiency, and promote sustainability in our living spaces. Smart homes offer features such as home automation, voice assistants, energy efficiency, and enhanced security. These technologies provide convenience, energy savings, and increased control over various aspects of our homes. By integrating devices and systems, smart homes enable remote monitoring and control, leading to greater comfort and security for homeowners. Smart cities, on the other hand, focus on optimizing urban environments through the use of technology and data. Intelligent transportation systems, sustainable infrastructure, data-driven decision-making, and citizen engagement are key elements of smart cities. By leveraging traffic sensors, data analytics, and smart grids, smart cities aim to reduce congestion, improve public transportation, optimize resource allocation, and enhance the overall quality of life for residents.

Compliance with ethical standards

Disclosure of conflict of interest

All authors declare that they have no conflict of interest.

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