

The Influence of Smart Buildings on Smart Cities

The Influence of Smart Buildings on Smart Cities:

Connected Cities

By

Javad Majrouhi Sardroud
and Fateme Vafaei

**Cambridge
Scholars
Publishing**



The Influence of Smart Buildings on Smart Cities: Connected Cities

By Javad Majrouhi Sardroud and Fateme Vafaei

This book first published 2025

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

Copyright © 2025 by Javad Majrouhi Sardroud and Fateme Vafaei

All rights for this book reserved. No part of this book may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the copyright owner.

ISBN: 978-1-0364-5383-1

ISBN (Ebook): 978-1-0364-5384-8

TABLE OF CONTENTS

Tables.....	viii
Figures	ix
Preface	x
Chapter One.....	1
Smart Buildings: A Path Towards a Sustainable Urban Future	
Introduction.....	1
1.1 Definition of Smart Buildings.....	2
1.2 Challenges and Barriers to Smart Building Implementation.....	5
1.3 Opportunities and Benefits of Smart Building Technology	7
1.4 Importance and Objectives of Understanding Smart Buildings and Cities	9
References.....	11
Chapter Two	12
Features and Importance of Smart Buildings	
Introduction.....	12
2.1 Importance of Smart Buildings in Cities.....	12
2.2 Integration of Smart Buildings within the Framework of Smart Cities.....	14
2.3 Performance of Cities in Relation to Intelligence	16
2.4 Smart City and Smart Infrastructures: A Novel Link for Improving Urban Life.....	19
2.5 Smart Cities and Smart Homes: Differences and Integration Challenges	21
2.6 Challenges in Adopting Smart City Technologies.....	23
2.7 The Role of Technology in Enhancing the Efficiency of Smart Buildings	27
2.8 How Smart Buildings Operate Within Smart Cities.....	31
2.9 Impact of Smart Buildings on Health and Well-Being.....	35
References.....	38

Chapter Three:	42
Disruptive Technologies in the Formation of Smart Cities	
Introduction.....	42
3.1 Key Technologies in the Creation of Smart Cities	42
3.2 Mobile Phones as Gateways to the Internet of Things (IoT).....	45
3.3 Incorporating Smartness into Buildings.....	47
3.4 The Role of IoT in Smart Homes	54
3.4.1 Architecture of the Internet of Things in Smart Buildings ...	62
3.5 Blockchain Technology in Smart Buildings.....	66
3.6 Machine Learning in Smart Buildings	70
3.7 Renewable Energy in Smart Building Development	72
References.....	75
Chapter Four:.....	79
The Importance of Standards in Optimizing the	
Performance of Smart Cities	
Introduction.....	79
4.1 International Standard Indicators	80
4.2 Understanding the Standardization Activities of Smart Cities.....	81
4.3 The Main International Organizations in Standardization Are.....	84
4.4 Key Activities of Global Standards Within the BSI Framework... 84	
4.5 A Guide to Standards in the Smartification of Buildings	
and Cities.....	86
4.5.1 International Standards.....	87
4.5.1.1 ISO 37120 Standard - Indicators for Urban Services	
and Quality of Life.....	87
4.5.1.2 ISO 37122 Standard - Indicators for Smart City	
Management.....	88
4.5.1.3 ISO 50001 Standard - Energy Management Systems ..	88
4.5.1.4 ISO 22301 Standard - Security and Business	
Continuity Management Systems	88
4.5.2 Standards Related to Smart Technologies	89
4.5.2.1 ISO/IEC 14543 Standard - Control of Smart	
Home Systems	89
4.5.2.2 ISO/IEC 27001 Standard - Information Security	
Management.....	89
4.5.2.3 BIM Standards - Building Information Modeling	89
4.5.3 Communication Standards and Internet of Things (IoT).....	90
4.5.3.1 5G and IoT Standards	90
4.5.3.2 LoRaWAN and NB-IoT Standards	90

4.5.4 Local and National Regulatory Standards	90
4.5.4.1 Energy Regulations and Sustainable Buildings	90
4.5.4.2 Smart City Regulations in Various Cities	91
4.5.5 Environmental and Sustainability Regulatory Standards	91
4.5.5.1 LEED (Leadership in Energy and Environmental Design) Standard.....	91
4.5.5.2 BREEAM (Building Research Establishment Environmental Assessment Method).....	92
4.6 Importance of Standards in Smart City Development.....	92
References.....	93
Chapter Five	95
The Impact of Smart Buildings on Smart Cities	
Introduction.....	95
5.1 The Impacts of Smart Buildings on Various Aspects of Smart Cities.....	95
5.2 Trend Analysis of Domain Progress: From Innovation to Integration	104
5.3 Key Final Points.....	108

TABLES

Table 1-1: Comparison of Traditional and Smart Buildings	3
Table 2-1: Highlighting the Importance of the Social Dimension in Smart Cities	17
Table 2-2: Differences Between Smart Homes and Smart Cities from Various Perspectives.....	22
Table 2-3: Key Challenges in Adopting Smart City Technologies	25
Table 2-4: Requirements for Smart Building Materials, Services, and Construction	28
Table 5-1: Interrelationships Between Key Variables	96

FIGURES

Figure 1-1: Challenges in Smart Buildings at a glance.....	7
Figure 1-2: Benefits of Smart Building Technology at a glance.....	9
Figure 2-1: Comprehensive Diagram of Smart City Infrastructure	20
Figure 2-2: Smart Urban Paradigm: Paving the Way for Sustainability ...	32
Figure 3-1: Levels of Progression of Building Intelligence.....	49
Figure 3-2: Smart Building Devices	51
Figure 3-3: Integrated IoT and Cloud Architecture for Smart Building Management.....	56
Figure 3-4: Key Components of a Smart Energy Building.....	58
Figure 4-1: Levels of Standardization	82
Figure 4-2: Layered Framework for Smart City Standards	85
Figure 4-3: Comprehensive Standards Overview	92

PREFACE

Humanity's desire for a life of security and safety has always been at the forefront of attention throughout history. This need is significant not only for early humans, who were constantly at risk of losing life's essentials, but also for today's modern society. In the current era, we are witnessing the gradual realization of our ancestors' long-standing aspirations. We now seek conditions that provide not only security and safety but also comfort and well-being.

Technology, especially artificial intelligence, plays a key role in this journey. These technologies can automate many daily tasks, allowing individuals to spend more time improving their quality of life. This book aims to explain the impact of smart buildings on smart cities in a simple and understandable manner. Smart buildings not only constitute a major component of a smart city, but without them, the realization of a smart city would practically be impossible.

The goal of this book is to guide stakeholders and assist them in envisioning the future of cities. By examining the various aspects of smart cities and the interconnections among these areas, we can achieve a better understanding of how to create smart cities. Additionally, recognizing standards and the support of national standard organizations in this process provides the community with assurance that this transformation is both reliable and effective.

With the rapid advancement of technology and the emergence of innovative solutions, there is potential to create cities that are smarter than we can imagine. These cities can significantly enhance daily life through new technologies, allowing citizens to live in safe and comfortable environments.

Realizing this vision requires collaboration and interaction among engineers, academics, and ordinary citizens. Awareness and education regarding smart technologies are of paramount importance. This knowledge can help individuals protect their rights and privacy in an increasingly automated world. Therefore, it is essential to provide sufficient information

to the public and encourage their active participation in the digital transformation process.

Ultimately, the creation of a smart and sustainable city requires cooperation and coordination among all stakeholders. Through this collective effort, we can not only help fulfill human aspirations but also pave the way for a bright and secure future for generations to come.

CHAPTER ONE

SMART BUILDINGS: A PATH TOWARDS A SUSTAINABLE URBAN FUTURE

Introduction

Smart cities begin with smart buildings. Today, "smart city" initiatives are expanding globally. To create smart cities, it is essential to recognize and develop their most fundamental element: smart buildings. With increasing populations and urban development, smartening cities has become a necessity. Buildings, as one of the main components of cities, play a vital role in this process, and their transformation into smart structures forms the foundation for the development of smart cities.

The challenges that may affect urbanization can be addressed through the development of smart cities and the use of information and communication technologies. Smart buildings act as the fundamental infrastructure of these cities, enabling the creation of secure, sustainable, and connected environments for urban communities. Without these buildings, achieving a truly smart city is impossible, as they are the core components of cities. Smartening buildings enhances the interaction between the city's elements and provides intelligent management. The primary goal of this process is to improve the quality of life and offer better facilities in cities.

Smart cities are designed with the aim of enhancing the quality of life and creating secure, sustainable, and connected environments, with smart buildings recognized as the most fundamental element of these cities. In today's world, with rapidly increasing populations and fast urban development, the shift towards smart systems has become an inevitable necessity. Buildings, as the key components of a city, not only play a crucial role in establishing the necessary infrastructure for this transformation, but they should also be regarded as hubs of services and efficiency for their residents.

The development of smart cities is built on the utilization of Information and Communication Technologies (ICT), which can help solve issues such as traffic, pollution, and security. This, in turn, requires the construction of buildings that are equipped with the capabilities of modern technologies. Smart buildings, with their diverse functionalities, contribute to increasing energy efficiency, enhancing security, and providing a comfortable and healthy environment for residents.

As essential infrastructures in smart cities, these buildings offer facilities that enable greater connectivity and interaction between various city components. Without smart buildings, achieving a truly smart city is impossible. These buildings not only assist in the intelligent management of resources but also improve the quality of life and provide better services to citizens.

However, the smartening of buildings also comes with challenges. Technical issues, initial costs, and the need for technical skills are among the obstacles in this path. Additionally, a proper understanding of the benefits of these buildings for residents and officials is also a significant challenge. Therefore, efforts to raise public awareness and provide necessary training in this area can facilitate the implementation of smart buildings.

1.1 Definition of Smart Buildings

Smart buildings refer to a collection of structures that utilize advanced technologies to optimize their performance in various areas. These buildings typically include advanced automation systems, smart sensors, and integrated communications that allow different components and systems within the building to operate simultaneously and efficiently. The primary goal of smart buildings is to provide a safe, comfortable, and efficient environment for residents while reducing operational costs and energy consumption.

The first definition of a smart building was published in 1989 by the Intelligent Buildings Institute of the United States. A smart building was described as providing an efficient environment through optimized structures, systems, services, and management, along with the interrelations among them. Later, the emphasis was placed on its impact on operational efficiency, the effectiveness of urban residents, and the use of information and communication technologies (Apanaviciene, Vanagas, and Fokaides 2020). The concept of smart buildings is believed to have originated in the United States in the 1970s, stemming from the needs of the industry. The

first application of smart buildings was in large production halls, which was later extended to office, residential, and public buildings.

The concept of smart buildings continues to evolve with the development of technology, information technology, building technology, and the implementation of socio-economic concepts such as sustainable development and the circular economy. The advancement of automation and its use in controlling the performance of mechanical devices in buildings has led to the development of structures known as "smart buildings," which respond "intelligently" to all external and internal conditions. The primary tasks of smart solutions include recognizing the habits of family members and controlling their environment without direct intervention. Users' needs change, work methods evolve, innovations are introduced, and new technologies emerge, necessitating transformations in buildings. There is an increasing awareness of the need to care for the environment, which continues to contribute to the development of smart buildings (Radziejowska and Sobotka 2021).

These types of buildings utilize the Internet of Things (IoT) to collect and analyze various data in real time. For instance, the sensors installed in these buildings can continuously measure temperature, humidity, and air quality, allowing heating, ventilation, and air conditioning systems to be adjusted in ways that enhance residents' comfort while simultaneously reducing energy consumption. At the same time, smart buildings can also improve the safety and security of residents. By installing surveillance systems and motion sensors, residents can be alerted to any suspicious activity, and they can simultaneously use alarm systems to notify emergency services.

Smart buildings utilize advanced technologies and differ significantly from traditional buildings in various aspects. Table 1-1 highlights the key differences between conventional and smart buildings:

Table 1-1: Comparison of Traditional and Smart Buildings

Features	Traditional Building	Smart Building
Energy Management	High energy consumption without optimization	Optimized energy use with sensors and IoT
Security	Basic manual security	Advanced security with cameras and sensors
Comfort	Basic facilities	Remote control of temperature, lighting, etc.

Interaction with Urban Environment	Limited interaction	Integration with urban systems like traffic
Operational Costs	Fixed and unpredictable costs	Reduced costs through smart resource management
Eco-friendliness	Reliance on non-renewable energy sources	Use of renewable energy like solar power

This comparison illustrates how smart buildings surpass conventional ones in terms of technology, sustainability, and user-centric features, making them indispensable for the development of smart cities.

Furthermore, smart buildings have the capability to integrate with other urban infrastructures. This means they can effectively collaborate with traffic management systems, renewable energy resources, and public services. This integration allows for the rapid exchange of information and better decision-making in real time. In fact, these buildings not only contribute to enhancing the quality of life for residents but can also lead to a reduction in the environmental impacts resulting from urban activities. Specifically, by utilizing renewable energy systems such as solar panels and wind turbines, smart buildings can aid in the production of clean energy and reduce dependence on non-renewable resources.

Another feature of smart buildings is the ability to control them remotely through smart devices such as smartphones or tablets. This capability allows residents to easily manage various systems within the building, both in terms of security and comfort. For example, they can remotely lock and unlock entry doors, adjust lighting, and control temperature settings.

As the world moves towards sustainable and smart cities, smart buildings are recognized as a key element in this process. In fact, these buildings not only help improve the quality of life for residents but can also contribute to reducing the environmental impacts resulting from urban activities. Ultimately, smart buildings are considered a successful model for achieving urban sustainable development goals and contribute to the creation of efficient and sustainable urban communities.

These buildings not only optimize resources and reduce costs, but they also enhance the quality of life and facilitate social interactions.

1.2 Challenges and Barriers to Smart Building Implementation

The smart building process, despite its significant advantages, faces numerous challenges and barriers that can impact the development and implementation of these technologies. Given the rapid advancements in technology and the need for designing smart buildings, various challenges and obstacles can affect the implementation and acceptance of these technologies. These challenges pertain not only to technical and economic aspects but also encompass social, cultural, and policy dimensions.

In recent years, with the increase in urban populations and pressures from sustainable development, the need for smart buildings as a solution for optimal resource management and enhanced quality of life for residents has become increasingly apparent. However, various obstacles can slow progress in this field. On one hand, the high initial costs associated with designing and implementing smart technologies deter many developers and building owners from investing in this area. On the other hand, technical and socio-technical challenges related to the integration of various systems can lead to difficulties in the optimal utilization of these technologies.

Moreover, social concerns such as privacy and data security significantly impact the acceptance of these technologies. Residents may be sensitive to the use of smart systems and data collection, which can hinder the widespread adoption of these technologies. Additionally, cultural and social changes in residents' habits and behaviors require time and educational efforts to enable individuals to adapt to new technologies.

Ultimately, despite these challenges, a systematic approach and interdisciplinary collaborations can help identify and overcome existing barriers. Given the importance of smart buildings in achieving sustainable development goals and smart cities, examining and addressing these challenges is considered a fundamental priority in urban development. These challenges include financial, technical, social, and cultural aspects, which are discussed below:

1. Financial Challenges:

One of the biggest obstacles to implementing smart buildings is the high initial investment costs associated with new technologies. The expense of installing automation systems, sensors, and related equipment can be burdensome for many developers and building owners. This issue is

particularly pronounced in countries with limited financial resources. Furthermore, the absence of clear business models for generating revenue from smart buildings can deter potential investors.

2. Technical Challenges:

The implementation and integration of smart systems require technical knowledge and expertise. The lack of defined standards and communication protocols can lead to problems in the interoperability of various systems. Additionally, the ongoing maintenance and updates required for these systems present another challenge, as many owners may not possess the necessary skills to manage these technologies.

3. Social Challenges:

Social issues also represent a significant barrier to the smart building process. Concerns related to privacy and data security, especially with the expansion of the Internet of Things (IoT) and user data collection, arise prominently. Residents may be sensitive to constant monitoring and data collection. Moreover, there may be inequalities in access to these technologies, exacerbating the digital divide among different community groups. Familiarity with standards can address security challenges, which will be discussed further.

4. Cultural Challenges:

Cultural challenges also play a role in the acceptance of smart technologies. Changing residents' attitudes and habits toward using new technologies and adopting new cultures requires time and education. In many cases, residents may resist using smart technologies, especially if they feel that these technologies do not align with their daily lives.

5. Policy Challenges:

Support for appropriate policies and regulations to facilitate the development and operation of smart buildings is essential. The absence of comprehensive and coordinated policies can hinder progress in this field. For example, the lack of financial incentives for investors or regulations for privacy and data security can reduce the willingness to invest in these types of buildings.

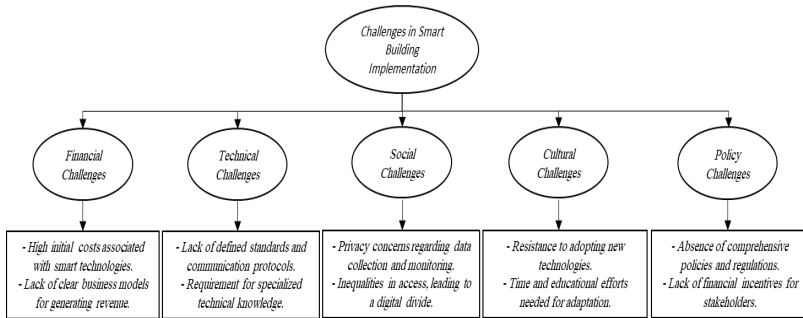


Figure 1-1: Challenges in Smart Buildings at a glance

● Given these challenges, there is a need for collaboration between government, industry, academia, and civil society to advance the smart building process. Educating and raising awareness among residents, along with improving technical and financial infrastructures, can help overcome these barriers. Ultimately, addressing these challenges can pave the way for the creation of smart and sustainable buildings that contribute to the realization of smart city objectives.

1.3 Opportunities and Benefits of Smart Building Technology

In addition to the existing challenges and obstacles, the smart building process offers significant opportunities and advantages that can positively impact quality of life, cost savings, and environmental sustainability. Given the challenges faced in the smart building process, exploring the opportunities and benefits of these technologies is of particular importance. Smart buildings provide an innovative solution to meet the increasing urban needs and enhance the quality of life for residents, presenting an exceptional opportunity. These opportunities not only contribute to improving individuals' quality of life but also lead to sustainability and resource conservation.

By utilizing advanced technologies, these buildings offer residents enhanced comfort, security, and health benefits. The implementation of smart systems for controlling temperature, lighting, and other environmental features enables residents to live in a more comfortable and secure environment. Additionally, intelligent monitoring systems can

enhance security within living spaces, assuring residents that they are in a safe and controlled environment.

Another advantage of smart building technology is energy conservation and reduced operational costs. By employing intelligent energy management systems, energy consumption is optimized, contributing to lower costs and environmental protection. Especially in situations where cities face environmental challenges, the use of smart buildings can provide an efficient solution for improving environmental conditions.

Ultimately, smart buildings are recognized as key components in creating smart cities. These buildings not only enhance the quality of life and security of residents but also contribute to improving urban infrastructure and achieving sustainable development. Given these advantages, smart building technology can be seen as an effective strategy for addressing urban challenges and improving the quality of life in modern communities. This section examines these opportunities and benefits:

1. Enhancing Quality of Life:

Smart buildings elevate the quality of life for residents by providing optimized facilities and services. From intelligent temperature and lighting control systems to high security through surveillance cameras and motion sensors, these buildings create a safe and comfortable environment for residents. Moreover, smart systems can respond to the specific needs of residents, including those of individuals with disabilities or the elderly, thereby facilitating access to services and amenities.

2. Energy Savings:

One of the notable benefits of smart buildings is their ability to reduce energy consumption. By employing advanced technologies, these buildings can intelligently control heating, ventilation, and air conditioning (HVAC) systems. For instance, installing temperature and humidity sensors allows for automatic adjustments of the climate control settings, which reduces energy usage. This not only helps save on costs but also minimizes the environmental impact associated with energy production.

3. Reduced Operational Costs:

Through optimized energy consumption and smart building management, operational costs can be significantly decreased. Smart systems can identify

and prevent technical issues before they occur, thereby reducing the need for costly repairs. This reduction in expenses helps owners and developers experience a greater return on investment.

4. Increased Productivity:

Smart buildings can enhance the productivity of employees and residents. By providing optimal working and living conditions, individuals can focus better and continue with their activities more effectively. For example, lighting and air conditioning systems that adjust based on user needs can create a more efficient and calming environment.

5. Supporting Smart Cities:

Smart buildings play a fundamental role in the development of smart cities by improving urban infrastructure. By connecting buildings to urban management systems, essential information can be gathered to make better decisions and be utilized effectively. This contributes to creating a sustainable and efficient urban environment, ultimately enhancing the quality of life for residents.

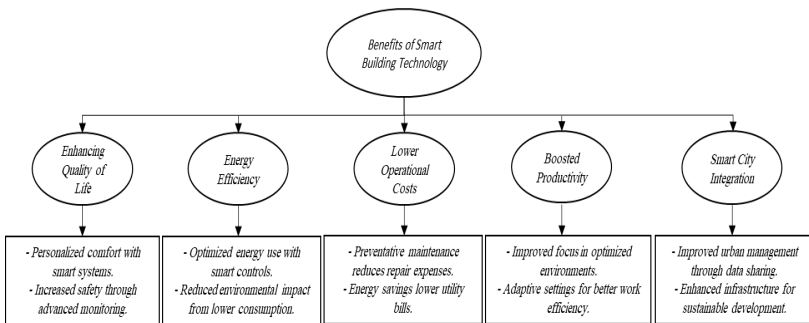


Figure 1-2: Benefits of Smart Building Technology at a glance

1.4 Importance and Objectives of Understanding Smart Buildings and Cities

This book examines the importance and impact of smart building technologies on the formation and development of smart cities. In today's world, with the rapid expansion of urbanization and the increase in urban populations, the need for resource optimization and the creation of sustainable environments is increasingly felt. In this context, smart

buildings are recognized as the primary agents of transformation in urban life. These buildings, using modern technologies and smart management systems, contribute to improving efficiency, reducing energy consumption, and enhancing the quality of life for residents.

One of the main objectives of this book is to comprehensively assess the characteristics and requirements necessary for the formation of smart cities through the smart building process. This book explores various domains of smart buildings that can help achieve the objectives of smart cities. For instance, examining the diverse impacts of smart buildings on sustainability, safety, and the comfort of residents can lead to a better understanding of the benefits of these technologies.

Additionally, the book provides scientific strategies and recommendations for improving the development and operation of smart buildings in urban environments. These strategies may include resource management techniques, energy consumption optimization, and the enhancement of social interactions in urban spaces. The significance of this book is noteworthy in several areas:

1. Comprehensive Scientific Reference: This book serves as a valuable scientific resource for researchers and students by collecting and accurately analyzing information and various studies on the smart building and city sectors. Providing deep and up-to-date knowledge about concepts and technologies related to smart cities and buildings highlights the importance of this book for those conducting research in this field.

2. Increasing Awareness in the Professional Community: This book contributes to raising awareness among the professional community regarding the concepts and challenges associated with smart building technologies. By studying this book, engineers, architects, and policymakers can gain a better understanding of the current state and advancements in the field of smart building technologies.

3. Establishing a Foundation for Future Research: With its extensive information and analyses, this book acts as a starting point for further research. Researchers can use the content of this book as a foundation for their studies and gain a better understanding of key topics and challenges.

4. Contributing to the Growth of Smart Technology Knowledge: By gathering information on smart cities, modern technologies, standards, and existing challenges, this book aids in the growth and evolution of knowledge

in the field of smart buildings and cities. Readers can enhance their knowledge by studying these materials.

5. Better Understanding of Standards and Challenges: This book thoroughly examines the standards and challenges of smart building technologies, allowing readers to familiarize themselves with the requirements and obstacles in this field. This understanding can contribute to improving the design and implementation of smart building projects. Additionally, familiarity with standards can help build public trust.

References

- Apanaviciene, Rasa, Andrius Vanagas, and Paris A. Fokaides. **2020**. “Smart Building Integration into a Smart City (SBISC): Development of a New Evaluation Framework.” *Energies* 13 (9): 2190. <https://doi.org/10.3390/en13092190>.
- Radziejowska, Aleksandra, and Bartosz Sobotka. **2021**. “Analysis of the Social Aspect of Smart Cities Development for the Example of Smart Sustainable Buildings.” <https://doi.org/10.3390/en14144330>.

CHAPTER TWO

FEATURES AND IMPORTANCE OF SMART BUILDINGS

Introduction

Smart buildings are recognized as an integral part of smart cities. These buildings utilize advanced technologies to reduce energy consumption, improve security, and enhance the comfort of residents. In these buildings, connected devices and automation systems are employed to ensure the optimization of resources and the comfort of individuals simultaneously.

Smart buildings not only need to have adequate internal functionality, but they also need to be integrated with larger urban infrastructures. This integration allows them to communicate with urban systems and other buildings, ultimately achieving urban cohesion. Data sharing and better coordination among different sectors contribute to more effective decision-making at higher managerial levels. These features make smart buildings beneficial not only for individual lives but also for a more sustainable and efficient urban future.

2.1 Importance of Smart Buildings in Cities

According to projections, by 2050, the urban population is expected to reach 68.4% of the total world population. Actions are necessary not only to address the increased consumption of fossil fuels in cities but also to mitigate the excessive energy consumption of homes. Specifically, buildings and infrastructure account for approximately 40% of global energy consumption (H. Kim et al. 2021). Cities occupy only 2% of the Earth's surface but produce more than 70% of greenhouse gas emissions, with 70-80% of these emissions originating from buildings (Morvaj, Lugaric, and Krajcar 2011). According to a study by the United Nations Environment Programme, buildings globally consume about 40% of energy, 25% of water, 40% of resources, and approximately 33% of greenhouse gas emissions. Residential and commercial buildings account for around 60%

of the world's electricity consumption, which can be reduced by implementing smart buildings by up to 30% in water use and 40% in energy consumption, leading to savings of 10% to 30% in maintenance costs (Apanaviciene, Vanagas, and Fokaides 2020). Siemens (2011) demonstrated that “the use of smart and sustainable building technologies can reduce energy consumption in buildings by up to 30%. Reduced energy consumption, and consequently increased energy efficiency, significantly lowers operational costs and contributes to climate and environmental protection” (“Energy Efficiency in Building Automation and Control Proven Applications for Heating and Cooling Supply,” n.d.).

In recent years, various studies have proposed technical infrastructures where energy-saving systems for smart homes in smart cities can be implemented. Most articles have analyzed the technical features of smart homes, focusing on existing technologies in smart homes and suggesting future energy-saving systems based on current technological advancements. Despite rapid technological changes, there is still little connection between smart homes and smart cities concerning physical, digital, and theoretical aspects. Usable technologies within smart homes are limited to low-communication technologies. Smart homes are expected to play a key role as the fundamental component of smart cities in their development and expansion (H. Kim et al. 2021).

Policymakers state that the core of advanced technologies is not urban policy and development but rather the care for citizens. The smart city strategy brings innovative changes at the city level to help improve conditions and status, promote industrial development, identify quality talents, and create a smart urban model. Over the years, Western cities have experienced five types of transformations: urban reconstruction in the 1950s, urban revitalization in the 1960s, urban modernization in the 1970s, urban development in the 1980s, and urban regeneration in the 1990s. Urban reform, considering the real challenges and opportunities for city development, improves policies for the systematic implementation and management of urban systems and enhances the quality of urban life (Liu et al. 2021).

For over two decades, the term "smart buildings" has been used to introduce the concept of equipment, networks, and energy efficiency in buildings. In the latter half of the 1970s, a building was constructed using the concept of energy efficiency, and in the 1980s, a building that could be controlled via a home personal computer was built. Today, smart buildings utilize the concepts of the 1970s and 1980s, incorporating additional subsystems for

managing and controlling renewable energy resources, appliances, and energy consumption through wireless communication technologies. This enables smart buildings to control devices and appliances within the buildings and communicate with their surrounding environment. They can also adapt to network conditions and connect with other buildings, thus creating active microgrids or virtual power plants (Morvaj, Lugaric, and Krajcar 2011).

2.2 Integration of Smart Buildings within the Framework of Smart Cities

To establish a genuinely intelligent urban ecosystem, various domains—including smart homes, buildings, grids, and meters—must collaborate within the smart environment. These interconnected elements are crucial to the development of an authentic smart city (Al Dakheel et al. 2020). In smart cities, buildings are digitally linked and interact with one another, enabling efficient resource management, lower energy usage, and reduced carbon emissions. This interconnectedness also encompasses other urban systems, including transport and energy infrastructures, fostering an integrated approach to sustainability.

By leveraging modern technology for optimizing energy and resource usage, smart buildings can contribute to achieving more environmentally friendly and economically viable conditions and situations. In addition to energy efficiency and sustainability, smart buildings enhance the livability of cities. Comfort, productivity, and safety for residents all benefit from advanced building automation technologies. Smart building systems can ensure that indoor air quality is optimal, temperatures are suitable, and lighting is sufficient for residents. They can also provide real-time monitoring for building security, contributing to the safety of cities (Walters 2011).

More Effective Smart City Services Enabled by Smart Building Platforms. Smart buildings utilize digital infrastructures and communications, as well as collected data, to create insights and new services that will be valuable to the city. For example, a smart building can host various sensors that monitor weather conditions, traffic patterns of vehicles and pedestrians, and the status of the building itself. There are many innovative services that can be developed using the data collected from both inside and outside the smart building (Kumar, Vasilakos, and Rodrigues 2017).

Several proposed titles related to assessment frameworks for smart buildings and cities have been published by researchers in recent years (Apanaviciene, Vanagas, and Fokaides 2020).

1. Smart Building Coefficient
2. Honeywell Smart Building Score
3. Assessment for Smart Buildings provided by Omar
4. European Union Smart Readiness Indicator Scheme
5. Smart City Assessment Framework provided by Sharifi

In 2005, an online tool called the "Smart Building Coefficient," with over 300 questions, was introduced by the Continental Automated Buildings Association to assess the intelligence level of buildings. The Smart Building Coefficient guide focuses on the design of issues such as building structure and systems, building automation and security systems, building communication systems, building management applications, and facilities that are relevant when selecting appropriate smart building components to connect to the building's automation network. The evaluation of the smart city concept encompasses far more areas compared to smart buildings.

A smart city envisions the more efficient use of its resources in an innovative, creative, or intelligent manner. The idea of a smart city, simply put, means the participation of city residents in its creation—residents are not only stakeholders in the actions but also initiators and creators. Most definitions of smart cities emphasize the use of technologies and their multifaceted functionality. A smart city represents a new dimension of urban life, combining more effective digital communication networks (comparable to nerves), pervasive intelligence (comparable to brains), sensors and indicators (comparable to sensory organs), and software (comparable to knowledge and cognitive competence). One of the important features of a smart city is that it cannot exist independently of other efficient urban systems (Radziejowska and Sobotka 2021).

An urban exchange process for evaluating the performance of various smart technology programs, in terms of carbon emissions, shows that smart energy grids, smart water infrastructure, and sensor-based waste collection successfully reduce the potential for global warming and improve environmental performance. At the same time, technologies such as smart windows and greywater recycling in smart homes reduce environmental performance. In other words, a smart window on a hot summer day can lower its light absorption or dim itself to limit the amount of light passing

through, thereby reducing the need for cooling and saving electricity (Obringer and Nateghi 2021).

Greywater recycling refers to the process of collecting, treating, and reusing domestic wastewater. This wastewater primarily comes from household sources like sinks, baths, and washing machines and contains substances such as soap, shampoo, dishwashing liquid, and similar materials.

Smart buildings operate within the broader context of a smart city, which itself must be part of wider smart energy and transportation networks. Therefore, it is essential that smart buildings integrate into a larger framework. This requires intelligent approaches to managing and coordinating the diverse processes and technologies involved, moving toward "digital infrastructure" that can alter how smart environments function to make them monitorable. More importantly, this infrastructure can bypass the limitations of physical infrastructure through broader functionality (El-Diraby and Sobhkhiz 2022).

Providing smart services in residential buildings is easier compared to commercial buildings, as residential buildings have fewer technical devices and less complex efficiency requirements. Commercial buildings typically have more public visitors, and their building models present greater challenges compared to residential buildings, which house fewer residents. Additionally, the costs associated with purchasing and installing smart devices and infrastructure are higher in commercial buildings than in residential ones (Qolomany et al. 2019).

2.3 Performance of Cities in Relation to Intelligence

The growing migration from rural areas to cities creates opportunities -such as better educational and job prospects) on one hand, but also presents challenges (for public sectors and residents) on the other. In fact, public sectors around the world face various challenges in many of their areas of responsibility, such as education, healthcare, housing, security, emergency services, electricity, water, traffic flow, parking, waste management, and environmental protection (Dryjanski et al. 2020). Rapid urbanization occurs alongside climate change, both of which increase pressure on the physical cyber infrastructure within cities as well as the services provided by these systems. These unprecedented challenges have compelled researchers, policymakers, and stakeholders to call for new paradigms in urban planning and management, including the concept of smart cities.

While access to information and communication technology for collecting and analyzing data on a large scale is an important aspect of smart cities, it is not a sufficient criterion for enhancing urban performance. In fact, a unique focus on technology while neglecting other key elements such as social, economic, and human capital or sustainability can present an incomplete picture of smart cities. Several definitions of smart cities go beyond sensor networks and large-scale data collection and analysis to describe the economic and social aspects of smart cities (Obringer and Nateghi 2021).

Emphasizing the social dimension of smart cities lays a vital foundation for achieving sustainable urban development. This approach highlights five essential objectives designed to improve residents' quality of life, foster inclusivity, and encourage active community participation. These objectives address key aspects such as empowering individuals, enhancing community engagement, and promoting the equitable application of technology.

Table 2-1: Highlighting the Importance of the Social Dimension in Smart Cities

Key Objective	Description	Examples/Applications
Enhancing Human Capital	Empowering individuals with knowledge, skills, and resources to participate actively in community-building and contribute to innovation.	Offering free digital literacy programs, vocational training, and innovation labs in urban areas.
Behavioral Transformation	Instilling a sense of shared responsibility and purpose among citizens, encouraging them to collaborate and take ownership of their city's development.	Organizing city-wide sustainability campaigns, participatory urban design projects, and collaborative energy-saving initiatives.
Community Development Dimension	Developing inclusive strategies that address diverse user needs, skills, and interests while fostering cultural sensitivity and a sense of belonging.	Promoting neighborhood-based programs like communal gardening, skill-sharing workshops, and localized health initiatives.

User-Centric Technological Focus	Implementing smart technologies tailored to enhance daily life, addressing specific urban challenges while prioritizing user satisfaction and adaptability.	Introducing responsive urban lighting systems, on-demand transport services, and user-friendly interfaces for public utilities.
Strengthening Social Networks	Building robust community bonds by encouraging collaboration, trust, and digital inclusion for a more cohesive and supportive urban ecosystem.	Launching citizen-driven policy platforms, inclusive urban apps, and community networking events to bridge social gaps.

Smart buildings significantly contribute to fulfilling the requirements of smart cities by integrating advanced technologies that optimize energy use, ensure sustainability, and enhance user experiences. The objectives outlined in this framework enable the active participation of residents in transforming urban living through smart solutions, starting with smart buildings. Residents of such homes can benefit immensely from these innovations, which not only streamline household management but also lead to long-term savings in time and expenses. As Angelidou (Angelidou 2014) also highlights, the five primary objectives for promoting resident engagement in smart city transformation begin with smart buildings. These objectives focus on improving quality of life, enhancing inclusivity, and encouraging active community participation. Smart buildings optimize energy use and help save time and costs, while actively involving residents in the transformation of urban living.

Smart cities focus on the integration of information and communication technology (ICT) with social capital. These cities combine social and human capital with ICT to enhance quality of life and encourage economic growth. A city is considered smart when it collaborates with its community in implementing ICT to ultimately improve their quality of life (Obringer and Nateghi 2021). Consequently, sustainable smart cities cannot exist and develop without their greatest asset: their residents. Angelidou (Angelidou 2014) argued that “smart cities are those that adopt human-centered approaches to integrate technology throughout the city with the aim of advancing human and social capital”. Townsend (Townsend 2014) presents two perspectives on smart cities: “one emphasizes that they enable real-time