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Smart Cities
Foundations and Perspectives

Edited by Pier Luigi Mazzeo and Paolo Spagnolo



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and Paolo Spagnolo*

Published in London, United Kingdom

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<http://dx.doi.org/10.5772/intechopen.114510>
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First published in London, United Kingdom, 2024 by IntechOpen
IntechOpen is the global imprint of INTECHOPEN LIMITED, registered in England and Wales,
registration number: 11086078, 167-169 Great Portland Street, London, W1W 5PF, United Kingdom

British Library Cataloguing-in-Publication Data

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

Additional hard and PDF copies can be obtained from orders@intechopen.com

Smart Cities - Foundations and Perspectives
Edited by Pier Luigi Mazzeo and Paolo Spagnolo
p. cm.
Print ISBN 978-0-85014-393-5
Online ISBN 978-0-85014-394-2
eBook (PDF) ISBN 978-0-85014-395-9

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Meet the editors



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Preface

In an era where cities are evolving faster than ever, the concept of “smart cities” has emerged as a visionary model for urban development. These cities leverage advanced technologies to enhance quality of life, promote sustainability, and improve the efficiency of urban operations. However, the path to achieving these ideals is fraught with challenges ranging from technological integration to data security concerns.

This book, *Smart Cities – Foundations and Perspectives*, is a comprehensive exploration of the multifaceted journey towards building smart cities. It is divided into two key sections, each addressing crucial aspects of this journey.

In the first section, “Smart Cities: Opportunities and Challenges”, we delve into the initial stages of smart city development, focusing on the existing challenges and opportunities. Through detailed case studies, such as the ambitious efforts in Saudi Arabia, we examine the diverse approaches to smart city implementation. This section also covers the evolution of smart cities with a particular emphasis on energy, mobility, and waste management, highlighting how these essential elements are being reimaged in the context of modern urban living.

The second section, “Smart Cities Technologies”, provides an in-depth analysis of the technological innovations driving smart city initiatives. From the Internet of Things (IoT), which serves as the backbone of smart city infrastructure, to renewable energy solutions like geothermal power and advanced vehicle charging stations, this section explores the cutting-edge technologies that are shaping the future of urban environments. Additionally, we address the critical issue of cybersecurity, offering insights into the threats and mitigations associated with the digitalization of city operations.

This book is a collaborative effort by experts across various disciplines, each contributing their specialized knowledge to provide a holistic view of smart cities. Our goal is to present a resource that not only informs but also inspires the readers—be they policymakers, urban planners, or technologists—who are at the forefront of this transformative movement. By understanding both the foundations and perspectives of smart cities, we can work together to create urban spaces that are not just intelligent but also secure, sustainable, and inclusive.

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Section 1

Smart Cities: Opportunities and Challenges

Chapter 1

The Establishment of Smart Cities: Existing Challenges and Opportunities – The Case of Saudi Arabia

Saeed Q. Al-Khalidi Al-Maliki, Ahmed Abdulmutallab Ahmed and Osman Ali Nasr

Abstract

Information and communication technologies (ICTs) have improved the quality of people's lives during the past few decades by performing urban services to build "super cities," sometimes referred to as smart cities. The expansion of smart city programs across the globe is a strategic response by governments to deal with current issues. The goal of the smart city is to use ICTs and knowledge to enhance infrastructure management and city administration. Smart cities have been the subject of several studies, but Saudi Arabia has seen very few of these studies. Due to the region's religious background and pilgrimage activities, this researcher has examined the requirement for ICT framework and made a proposal. In order to meet all requirements for smart cities in the near future, this research suggests a workable ICT model framework and aims to examine smart cities in terms of potential advantages and obstacles to their development in the Kingdom. It also offers a model for creating smart cities in the Kingdom. The study on Saudi Arabia's smart city projects is intended to boost the advantages of beginning to develop smart cities throughout the Kingdom.

Keywords: information, communication technologies, smart, ICTs, Kingdom, Saudi Arabia

1. Introduction

The fundamental concept of the smart city has shared features in terms of key indicators, including a smart economy (sustainable economic growth), easy mobility, clean environment (including wise resource management), smart people, a high standard of living, and smart government [1]. A smart city can increase comfort, ease mobility, save energy, enhance the quality of fundamental services like clean air and drinkable water pipelines, as well as identify current issues and take quick action to

resolve them. It also entails making judgments quickly in the wake of natural disasters or other catastrophic events, gathering data to do so, and sharing that data with others to foster collaboration across many sectors. However, a smart city should be treated as an organic whole, as both a network and linked system, in order to systematically permeate intelligence into each subsystem of a city such as transportation, energy, education, healthcare, housing, and physical infrastructure (e.g., food, water, and public safety) [2].

Existing cities and megacities produce new kinds of technical, physical, and material issues like (1) challenges with waste management; (2) resource scarcity; (3) air pollution; (4) concerns about human health; (5) traffic congestion; and (6) inadequate, deteriorating, and ageing infrastructures [3, 4]. In contrast to technical, physical, or material issues, there is a different set of issues that are social and organizational in character. These kinds are frequently connected to a wide range of diverse stakeholders, high levels of interconnection, conflicting goals and values, and social and political complexity [3]. Therefore, in the near future, it will be necessary to discover suitable solutions for sustainable city development for cities that contribute significantly to growing greenhouse gas emissions caused by inhabitants.

For a better understanding of the smart structure, the main elements of each sector are noted below in **Figure 1** representation of the crucial sectors of smart city development.

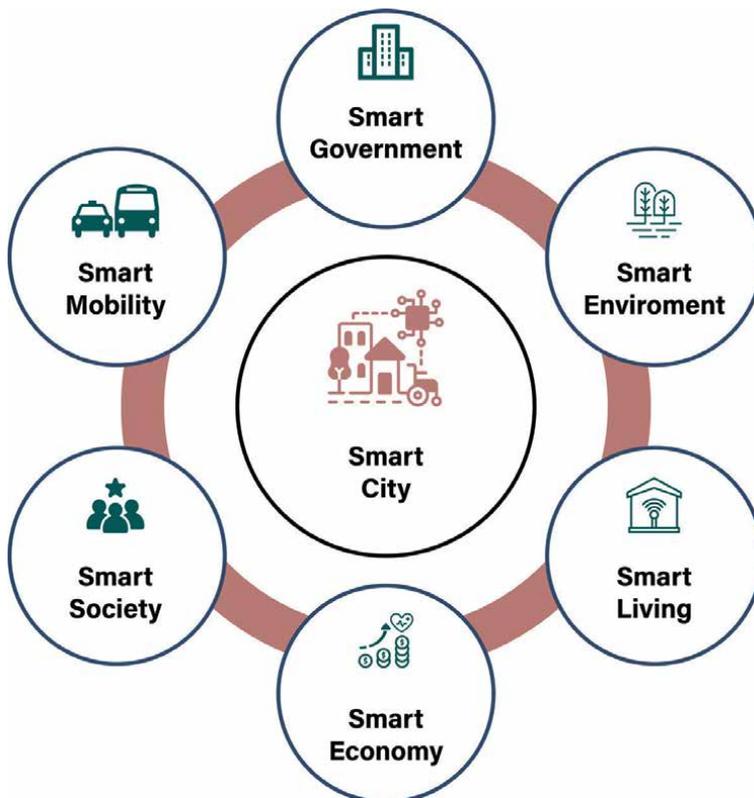


Figure 1.
Core elements of smart city development.

1.1 Smart living

- Sewerage and sanitation
- Water supply
- Electricity
- Stormwater drainage
- Housing
- Citizen safety

1.2 Smart people

- Education
- Participation in public life
- Participation of communities
- Health
- Inclusive development

1.3 Smart mobility

- Transport
- Communication infrastructure
- Information accessed by all digital media

1.4 Smart economy

- Income levels
- Labor market
- Poverty level

1.5 Smart environment

- Pollution
- Sustainable resources
- Management

1.6 Smart governance

- Revenue management
- Administration
- Grievance management
- Policy

The application of ICT is one of the primary components of a “smart city.” Future cities will strive to achieve a balance between technological, human, and physical and software features [5]. The development of smart ICT applications is essential for enabling smart cities to support decision-making and implementation processes, as well as citizen participation in smart city initiatives. ICT is a tool that is fundamentally centered on the citizen and, as such, adopts a citizen-driven approach. The architecture of a smart city must take into account a variety of relevant stakeholders, including end users, groups of end users, IT experts, policy/service domain experts, and public administration. Collaboration between the business, education, government, and private sectors can lead to successful initiatives. ICT provides the fundamental platforms for the development of a smart city, and also it can offer a wide range of advanced services in many crucial fields, including intelligent transportation systems (ITS), environmental and energy monitoring, building management, health-care, public safety and security, remote working, and e-commerce [6, 7]. In other words, ICT is crucial to the provision of seamless and omnipresent services since it connects all the actors and sectors that make up a smart city [6, 8, 9].

Smart cities are characterized by a widespread usage of ICTs in many urban domains, in order to help cities make better use of their available resources. ICT systems have a number of important advanced techniques; in particular, hard domains refer to office and residential properties, energy grids, natural resources, the management of energy and water sources, proper waste management, and transportation and logistical support [10]. ICTs are currently regarded as a necessary resource for modern society, such as in the distribution of water and electricity, in the digital era. ICT is an interdisciplinary technology that aids businesses in lowering costs, enhancing procedures, fostering innovation, and boosting production. Additionally, it reduces the size of the public sector and enhances the delivery of healthcare, making it quicker and more user-friendly.

This research advances our knowledge of the technological significance of smart technologies and services that are based on smart ICT frameworks for smart cities. It presents a model proposal for building smart cities (**Figure 2**). The model offers a variety of evaluation points, such as the strategic context of smart cities and recommendations for using ICT and smart applications. In light of the concept, it discusses the significance of ICT infrastructure and how to connect it to smart cities in order to deliver electronic services in Saudi cities.

This research is organized as follows: section two reviews the history of the concept of the smart city, smartness, and ICT sectors, with reference to existing literature; section three provides information on investment in IT technology in Saudi Arabia; section four presents the motivation and problem addressed by the research; section five proposes an ICT model suitable for smart cities alongside other

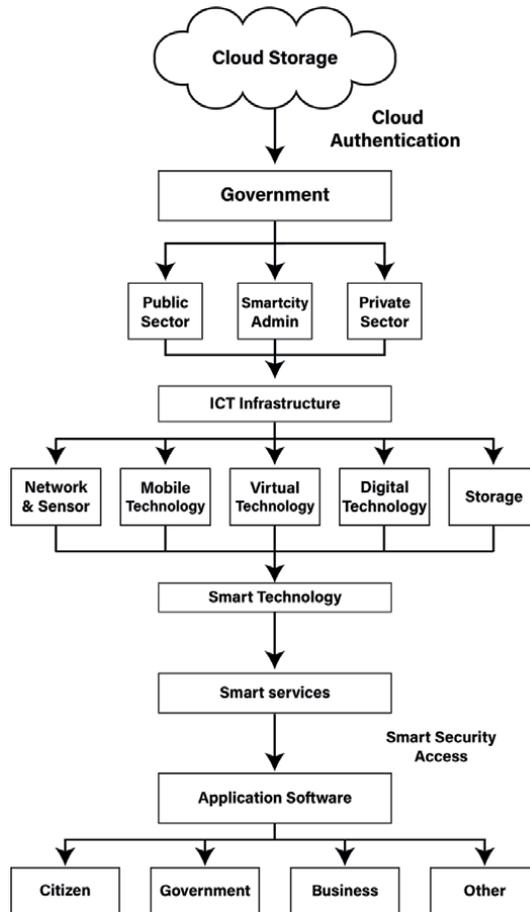


Figure 2.
 ICT structure model for the smart city.

infrastructure. Implementation suggestions are discussed in section six, and the advantages and emerging opportunities of smart cities are presented in section seven. Finally, conclusions are presented in section eight.

2. Literature review

The Ministry of Municipal and Rural Affairs in Saudi Arabia is becoming more reliant on modern technology as a result of how heavily our communities rely on knowledge and ICTs in the real world.

The researcher will start this study by outlining the current situation of Saudi Arabia's use of IT and investment in the country. Al-Maliki [11] claims that the use of ICT is increasing, particularly in the Kingdom of Saudi Arabia. This research study's goal is to determine the effects of ICT investment in Saudi Arabia and the role that the government plays in this context. According to another study by Al-Maliki [12] the adoption of e-governance in Saudi Arabia is influenced by a number of factors, Lack of training and human resources, together with limited computer literacy, were

identified to be the main obstacles to adoption. Al-Maliki [11] also indicates that difficulties with literacy, technical issues, and a lack of knowledge and trust may be the main obstacles to the growth of this kind of business in Saudi Arabia.

Al-Maliki [13] found that Saudi Arabia invests a significant amount of money in its ICT sector, including projects such as an e-government portal, e-government network, e-government interoperability framework, e-payment gateway (Sadad), e-tax system, and electronic information exchange. In this regard, Al-Maliki and Al-Ghobiri [14] did study on smart applications utilized in Saudi Arabian tourism, in particular in the city of Abha. The results support the conclusion that growth in ICT will significantly enhance communications with tourists and provide them with crucial tourist information and convenient tools for managing their travel plans. According to the study, it is now important to take care of Saudi Arabia's smart cities, including Abha and others. Al-Maliki [15] also outlines the elements affecting Saudi Arabian residents' understanding of e-government services. The results demonstrate that Saudi residents' awareness is poor in some areas and that they have a poor comprehension of how to use e-services. Many people believed that the help and support provided to residents was hindered by an obvious lack of managerial support, and there was also a distinct lack of understanding regarding e-government services.

Other research in the literature about smart cities included that of Lee et al. [16]. The study by Lee et al. [16] was another study on smart cities that was found in the literature. This study's goal was to present an integrated road mapping procedure for services, tools, and technology that may be used in a Korean R&D project for developing smart cities. The method for establishing links between devices and technologies, as well as between services and devices, is applied in this work. A thorough case study that demonstrates how several types of road mapping may be linked to generate a clear depiction of the technological changes and uncertainties connected with the strategic planning of complex innovations serves as an illustration of the method.

The "smart city" is defined by Piro, Cianci, Grieco, Boggia, and Camarda [6] as an urban setting supported by pervasive ICT systems that can provide advanced and innovative services to inhabitants in order to improve the general quality of their lives. This study suggests a potential solution to the issue, by emphasizing the issue's applicability in actual situations drawn from the following areas—government and public administration, intelligent transportation systems, public safety, social, healthcare, and education.

In their discussion of city logistics, Perboli, De Marco, Perfetti, and Marone [17] present an integrated picture of freight transportation systems within metropolitan regions with the goal of optimizing them all in terms of effectiveness, security, safety, viability, and environmental sustainability. The idea of "smart cities" has broadened this viewpoint to incorporate many facets of city administration, including building, energy, environment, government, living, mobility, education, and health, among others. They introduce this categorization in their study, which also examines emerging trends in smart cities and highlights key success elements.

Neirotti, De Marco, Cagliano, Mangano, and Scorrano [10] elaborate taxonomy of pertinent application areas, namely, natural resources and energy, transit and mobility, buildings, living, government, economy, and people, to provide a thorough grasp of the concept of the smart city. Additionally, it examines the spread of smart initiatives through an empirical study that aims to understand the impact of various economic, urban, demographic, and geographic factors as well as the proportion of prospective smart initiative domains that are covered by a city's best practices. This book offers policymakers and city managers practical suggestions for developing and

advancing smart city strategies, as well as for organizing actions targeted at the most suitable implementation domains.

The abstract idea of what it means to be a smart city is starting to be replaced by Angelidou's [18] discussion of the factors influencing the smart city notion. Urban futures and the information and innovation economy make up the two main components of this research article's analysis of the recent history of smart cities. The report then explains the push-and-pull forces in modern technology that are driving the demand for smart city solutions. On the one hand, technology is developing quickly, fueling a huge market for products and solutions related to smart cities. On the other hand, there is a demand from cities that aims to address issues with sustainability and efficiency, providing a favorable environment for the economy of smart city products.

We all live in different cities, some of which are advanced technologically while others are still in the early stages of development. One effective example of a smart city in the world is Sungdo in South Korea, located in the south of Seoul. It uses computers, sensors, and alternative energy to monitor and manage energy consumption throughout buildings and roads. Masdar City in the UAE's Abu Dhabi Desert is one of the world's most intelligent, sustainable, and ecologically friendly communities, with a solar power plant right in the midst of the city. Wind farms generate electricity, leaving no environmental pollutants behind. Also, more than 100 million sensors have been installed at Planet City in Portugal to protect people from accidents and fires. There are systems that assist in informing drivers of the available parking spaces. These systems also modify the duration of traffic signal systems in accordance with the volume of traffic. Fujisawa City in Japan was built by Panasonic with a complete reliance on electric power, decreasing the pollution caused by burning fossil fuels. The city is equipped with power stations. As the "Green Capital," Copenhagen, Denmark strives to lessen environmental pollution and promote sustainable buildings. It also serves as a role model for the ongoing modernization of future initiatives.

3. Research motivation

The smart city is expanding quickly as urban areas' population ranks rise at an ever-increasing rate. Residents worldwide are dealing with a wide range of hazards, worries, and issues as a result of urban populations, particularly in cities. Due to the extraordinary rate of urban growth, it is more important than ever to discover creative approaches to resolve current problems amicably. The main goal of these methods was to look into the availability and use of ICT services for creating smart cities and to support the connection between ICTs and various services provided by the cities.

The Saudi Ministry of Municipal and Rural Affairs implemented five smart initiatives, including smart attitudes, smart lighting, solid waste, smart cameras, and environmental pollution measuring devices. The following are some other important ICT service-specific goals:

- Determine which ICT services are appropriate for the smartness approach
- Learn about the smart city's Internet and network connectivity
- Assess ICT strategy and put smart city policies into place

- Elements that influence ICT use in smart cities
- How is cloud data storage system connected to smart city connectivity?
- Data security and authentication are components of smartness
- Integration between smart sectors
- Data application accessibility and availability
- The cost and maintenance of ICT tools in the smart city concept
- Ensuring data privacy, individuals, companies, and local municipal administration

According to Ref. [19], the National Transition Program 2020 and the Kingdom's Vision 2030 inspired the Saudi Arabian Ministry of Municipal and Rural Affairs to develop the "Smart City Concepts" initiative, a municipal transformation initiative. In collaboration with the commercial sector, this initiative intends to implement the ideas and components of smart cities in five Saudi cities by 2020. This project, which examines the elements of smart cities and the diffusion and activation of their application, is one of several significant projects being undertaken by the ministry, and it should be highlighted. The program argues that the readiness of the cities in the Kingdom of Saudi Arabia to become smart cities varies. According to research on the components of smart cities, Makkah is the most prepared city, followed by Riyadh, Jeddah, Madinah, and Al-Ahsa [19]. The ministry notes that it has started to develop national policies and local strategies to transform the five cities over a number of years, making two of them smart cities in 2018, three by the end of 2019, and all five by the end of 2020. According to the program, research is being conducted to ascertain whether Saudi cities are prepared to transition into smart cities based on best practices from across the world and science (vision, culture of innovation and participation, procedures, technology, data, urban planning).

The creation of jobs, attracting investment, and improving the quality of life in cities are all significant goals of smart cities. Cities in Saudi Arabia have a lot of the characteristics necessary to qualify as smart cities. They have excellent natural resources, infrastructure, and robust economies.

According to Makkah [19] the Ministry of Municipal and Rural Affairs in Saudi Arabia notes that the field survey targeted 17 cities, including the major ones in the country, which together account for roughly 72% of the country's population. These cities are: Makkah, Riyadh, Jeddah, AlMadina AlMonawara, Alahsa, Dammam AlKhubar, Qatif, Taif, Buraidah and Onaiza, Abha.

4. Existing challenges

ICT platforms are key enabling factors of a smart city due to their capacity to provide a significant number of fundamental services for citizens. Many different types of devices will coexist in a smart city and interact with one another in order to carry out, join, and take part in a variety of services that support human life. As a result, the following challenges may arise:

- Equipment costs
- Replacing the existing ICT structure
- Requiring changeover technology
- Establishing public and private smartness
- Limited technical capacity
- Horizontal and vertical coordination between sectors
- Coordination between central government, state government, and local government
- Ability to handle different software applications for smart city solutions
- Reliability of utility services
- Universal software access at any time, 24/7
- Local language support
- Authorized personnel entry for using utility services
- Access to new ICTs is dominated by a small number of educated individuals
- Accessible space and insecurities based on social category or age
- Climate change is expected to have significant impacts on smart cities
- ICT structure should be fast, reliable, and provide effective access
- ICT structure should have the capability to identify user location
- Seamless support for mobile users to access different networks
- Adequate and alternative facilities in case of ICT system failures

The Ministry of Municipal and Rural Affairs applies the concepts of smart cities in accordance with best international practices in this regard, which will assist cities in implementing change and contribute to the implementation of ICTs.

Numerous electronic applications for municipal services were developed by the Ministry of Municipal and Rural Affairs. The concepts and standards for smart cities aim to deliver the maximum advantage for assisting in the transformation of smart cities by allowing them to operate efficiently and effectively in accordance with the performance of urban and community activities while consuming fewer resources.

In order to achieve the goals of intelligent transformation, the ministry addresses a number of challenges that are inherent in making Saudi cities smart, such as the integration of information and data, access to suitable participation models with

the private sector, and smart community partnerships. A project titled “Study of the Application of Smart City Components in Urban Planning” was started by the ministry in 2015. The study focused on 17 main cities in the Kingdom, including the capitals of the relevant regions, which together account for 75% of the country’s population. The study covered the creation of a strategic vision for the city’s intelligent transformation, preparation for technical infrastructure, accessibility to a culture of innovation and engagement, data accessibility, and procedural clarity. To incorporate smart concepts and get the cities of the Kingdom ready to accept instructions for establishing smart cities, the ministry added these standards to the “urban planning and management” standard. More than 3300 population samples were field-surveyed for the study, along with 60 executive officers working in the secretariats of these cities [20].

5. An effective ICT structure model for a smart city

ICT is the cornerstone on which the idea of smart cities is based since it serves as the foundation for cross-domain networking. The requirement for smart city building tools concentrates on ICTs, policies, and legal frameworks, and emphasizes the importance of information availability.

Haidine et al. [21] emphasize the significance of the primary applications connected to smart city infrastructure in their study of smart city infrastructure and the role of ICT.

They offer a blueprint for smart cities that focuses on the economy, governance, ecology, and society—four crucial facets of embracing the city. They exhibit the essential elements of sustainable smart cities as well as the crucial ICT support for these elements during the construction of smart city infrastructure. Their model highlights crucial facets of digital architecture (IT and communications infrastructure). Additionally, there is a service infrastructure that offers services like e-government, healthcare, and education.

The model of Haidine et al. [21] also provides a road map for the application of ICT in smart cities. They emphasized that by connecting and organizing all of the various interactions within the infrastructure of the smart city parts, ICT plays a significant role as a core network for the smart city. According to a different study [22], ICT infrastructure in smart cities is essential to the growth of traditional cities and the process of making a city smart. According to Hernández-Muñoz et al. [7], the growth of urbanization is now heavily reliant on smart technology and intensive ICT solutions.

ICT and its subfields, including cloud computing, Internet access, big data, and remote sensing systems, have accelerated innovation in solutions and services and the unification of applications in recent years, which has helped to lower the cost of efficient cities [23]. Additionally, the International Telecommunication Union (ITUFocus)’s Group on Sustainable Smart Cities [24] researched the traits and tenets of the smart city. Four factors—the environment, sustainability, city-level services, and quality of life—reflect a city’s economics, government, environment, and society [24]. A smart city’s core industry, infrastructure, can be broken down into some categories: physical infrastructure, smart buildings, smart transit, smart water, smart waste, smart healthcare, and smart education. In their study, ITU [24] noted that every nation has a distinct character and culture. Depending on the nature of its projects, each nation also has the potential to meet the problems it will encounter and

its own idea of what smart cities should be like. The objectives of smart cities are to provide all residents with a comfortable and high-quality living environment through ICT and other technologies.

After evaluating the earlier studies, the researcher chose an infrastructure and ICT model for this study that could make smart city initiatives in Saudi Arabia easier to implement in the near future. The researcher's proposed ICT structure model is clearly shown in **Figure 2**. The proposed model addresses the need to comprehend smart cities and the challenges that limit their development it also demonstrates how the management of municipal services in Saudi cities might profit from this fast-expanding technology. The cloud storage technology is connected to a government platform, providing public and private sectors with authentications. Eventually, residents, the government, corporations, and other parties will be able to access a wide range of smart services via smart security access from the ICTs. The model will assist in identifying opportunities and challenges and how to address them in the process of creating smart cities or transforming traditional cities into smart cities. It can reduce time and costs for Saudi Arabian residents, the government, and corporate organizations while increasing access to some applications and electronic services. E-government applications will become more efficient in this model and its electronic services, and the provision of information, services, and transactions will be improved. The proposed structure will assist in overcoming obstacles during the initial phases of the development of smart cities.

5.1 Cloud storage

The preferred method for local administrations to increase productivity has become cloud storage, which gives outside city governments the ability to deliver a technological platform for data collection and mining as well as for producing city applications over a virtual private network or the public Internet. Input from sensors, smartphones, digital electric meters, or other smart input devices that are relevant to the operations of cities or towns cannot yet be used by the majority of city networks. Data collection requires specialized technology, software, and apps that can show the data in an understandable way.

5.2 Smart city administration

Greater mobility requirements, rising security concerns, and rising population concentration in consumption levels have all had a transversely significant impact on various city areas. In order to overcome these challenges cities must adopt more effective administration models, which will then help to consolidate city growth and enable flexible and systematic growth. A sustainable administration will be able to provide citizens with higher-quality, more effective services at a lower cost as a result. Better interaction and effective savings will result from achieving an integrated vision of the entire city. ICT contributes to a city's efficient infrastructure and services, making them more intelligent, interconnected, and effective. These services and infrastructure include city administration, education, healthcare, public safety, business, transportation, and utilities. Networks are connected in a smart city in a way that allows them to support and benefit one another. Therefore, to maximize efficiency in the pursuit of competitiveness and sustainability, the technology used and the data collected should be able to continuously analyse and distribute data about the city to give the best solutions to a variety of problems from the perspective of the entire city.

5.3 Smart technologies

Smart devices allow users to be interconnected no matter where they are. These devices can be used to share data or access information. Embedded systems, smart devices, sensors, and actuators can improve a city's space and infrastructure by facilitating real-time data management and information processing for the city's administration. Smart technologies enable innovative methods for city transport administration, traffic regulation, and environmental pollution monitoring systems, among other facilities for urban growth, such as restoring a city's key infrastructure. Furthermore, the development of crucial services is made possible by the extensive and pervasive use of smart technology.

5.4 Mobile technologies

In a setting where the Internet and web applications are used, mobile technologies play a vital role in the development and distribution of smart services, which can be attributed to the creation and spread of sensors of various types. Innovation in the field of embedded systems is also essential because it offers a platform for effective ICT structures, allowing user data to be transformed into information that can be used to optimize business developments through continuous, secure integration with cloud services such as creation, monitoring, provisioning, tracking, managing, controlling, and forecasting.

5.5 Virtual technologies

The development of a suitable multi-dimensional information structure will be aided by virtual technology and network connections. ICT makes it possible for multiple networks to operate simultaneously on an ICT structure, each with unique features and purposes. ICT includes two essential components: (1) The best possible virtual network capacity allocation based on communication traffic; and (2) The best possible virtual network route optimization based on smart people's usage. This technology will improve network utilization efficiency and allow telecom providers to offer high-speed communications to more customers and smart devices.

5.6 Digital networks

Digital service is a critical component of any smart city design. Critical urban areas, including educational institutions, business and industrial hubs, government offices, and emergency response units, have seen a surge in wireless device and fiber-optic cable connectivity. These wireless and fiber-optic networks are essential because they assure high-speed Internet access. The long-term objective of building such an infrastructure is to enable an open broadband network that all city residents can use. The widespread use of high-speed Internet encourages the establishment of smart city models and innovative approaches to particular social problems. In addition, transportation will include a significant traffic management unit that will use sophisticated mobile applications.

5.7 Network and sensor technologies

The ability of modern ICTs to instantly connect huge networks of people and organizations over greater geographic distances at a low cost is what gives them their

revolutionary potential. Within the framework of the current smart city models, they have significantly increased economic growth, transformed businesses, markets, and organizations, modernized learning techniques and knowledge exchange, and empowered individuals and communities. Additionally, they make it easier to install the sensors needed to create intelligent city solutions. With the help of an appropriate ICT that monitors parking space availability, handles traffic congestion, predicts the arrival times of trains, busses, and other modes of public transit, etc. Sensors can be utilized to manage the mobility needs of citizens.

5.8 Safety and security

Protection of the general people and the security of the infrastructure, which are integral to the idea of smart cities, are considered to be safe and secure in the context of smart cities. Public safety includes issues like hazard management, crisis response, and civil security. Rescue services, disaster preventive services, police services, and others have new opportunities and challenges attributable to the smart city. Urban areas that are highly networked offer completely new information sources that can be used to protect the public. It is imperative that ICT security requirements be carefully reviewed when designing any new system related to smart cities.

6. Implementation phase of the proposed ICTs

It has been demonstrated that the usage of ICTs is a key indicator of a smart city. Significance of ICT technologies for enhancing a city's effectiveness and ensuring a more secure future across networks of people, business centers, research and technology, infrastructure development, water consumption, energy consumption, and spaces. These ICT elements work together in a smart city, supporting and enhancing one another. In order to maximize efficiency in the quest for affordability and sustainability, the technology and data collection utilized in smart cities should be able to continuously analyse and distribute data about the city. To enable vital communications within the same region and country, data and information sharing and communication throughout the city should be used as a standard and reusable method. Our proposed ICT structure will empower a smart city to create intelligent data, information, people, and organizations. It will make it possible to redesign the interactions between government, the private sector, non-profit organizations, communities, and citizens. Smart cities cannot be developed by only deploying sensors, networks, and analytics in an effort to improve efficiency; implementation of our suggested ICT model is a crucial component.

Three crucial entities will be involved in our implementation phase. The first of these is government, or the senior decision-makers who are crucial for developing a vision, launching, sanctioning, and promoting ICT activities, as well as for legislation and adopting "enabling" policy frameworks. In the second place, are the administrators of smart cities, who frequently carry out ICT projects. Mid-level administration can also play a significant role in identifying and promoting new ideas, especially if they have a strong grasp of ICT potential. Lastly, if an enabling climate is there, the private sector will have the greatest capacity to develop and modernize. The private sector may play a crucial role in advancing ICT and be essential to its expansion and sustainability.

The planned smart city will meet user needs for content retrieval in a quick, dependable, and efficient way. The location of certain data will be identifiable when

more smart technologies are connected. The smart cities in Saudi Arabia are placing a greater focus on the security aspect of the above structure. The main challenge for the smart city is mobility; our plan offers smooth mobility assistance, free from service interruptions while switching between different access networks. Storage, bandwidth, and computing capabilities are additional crucial features of the proposed structure. Furthermore, any form of system failure can be managed using our implementation ICT model. Any strategy, including top-down, bottom-up, and hybrid approaches, can be implemented using the ICT structure we have given.

6.1 Top-down approach

One of the most significant issues in the contemporary digital environment is the smart city. New business opportunities may arise if a city is able to utilize its data to better serve its workers, residents, visitors, and the community at large. Implementing smart cities is a crucial area of fresh thinking for giving people and society access to the newest digital technology. In terms of managing and formulating policy, our ICT structure may collaborate with top management. It is designed to connect advanced technological capabilities in an attempt to build resilient, sustainable, and equitable cities that can give us a better quality of life.

6.2 Bottom-up approach

The bottom-up strategy helps city dwellers and workers to live secure lives with their families. Therefore, the fundamental elements that give rise to urban life include; individual human activity in their personal and family lives, as well as their official participation in society. As a result, the bottom-up approach is heavily emphasized in smart cities and smart urbanization. It makes it possible for private businesses, community reformers, and citizen-led creativity to be successful while generating long-term profit and social value. Cities will be more productive as a collective and more resilient and stronger when economic or climatic events change their circumstances if the chance to do so is broadly available. People use whatever resources available to them to get by in life, support their families, and create profitable business environments. This is known as a bottom-up approach. Cities benefit from bottom-up creativity for all of their residents, thus we must modify and enhance them to better foster this creativity.

6.3 Hybrid approach

The hybrid approach is a worldwide technique event aimed at exploring the emerging nature of the city and the potential transformation of the urban condition as a result of ongoing ICT innovations and their integration into the physical context of the city. The concept of a hybrid structure for non-motorized road users combines the usage of smartphones and currently commercially accessible net-based mobility services. A number of research initiatives have been launched to develop door-to-door multimodal mobility support for travelers to increase the flexible use of public transportation. These programs will guide the traveler as needed, similar to a car navigation system, but independent of the mode of transportation. Because we are integrating new technology from the bottom-up rather than from a top-level restructuring or implementing structure, the integration approach will result in a program that is both cost-effective and requires a minimum amount of time to build.

7. Advantages and emerging opportunities

Better services for citizens and society will be made possible by smart city mechanisms that manage operations without requiring human interaction. Achieving socioeconomic and environmental benefits is made possible by smart cities. Though it can be challenging to choose the ideal platform for this, only the proper platform, collecting the appropriate data, can lead to broad market adoption among millions of consumers each year.

The main goal of creating a smart city is to benefit society with effective services. **Figure 3**, clearly demonstrates that the residents of the city are the primary beneficiaries of the smart city. A unique ICT infrastructure is needed for planning and management in order to offer services around-the-clock. The initiatives from the Saudi Arabian Ministry of Municipal and Rural Affairs will benefit the chosen Saudi cities by improving living standards and population satisfaction, boosting urban sustainability and competitiveness, enhancing city management effectiveness and prosperity indicators, lessening negative environmental effects, drawing in both domestic and foreign investment, and promoting job growth.

Our proposed ICT structure will provide many benefits to the government, environment, economy, society, people, and private organizations.

7.1 Benefits to the government

The proposed ICT structure assures that the efficient use of public resources and data can hasten the development of other smart cities within the country, giving

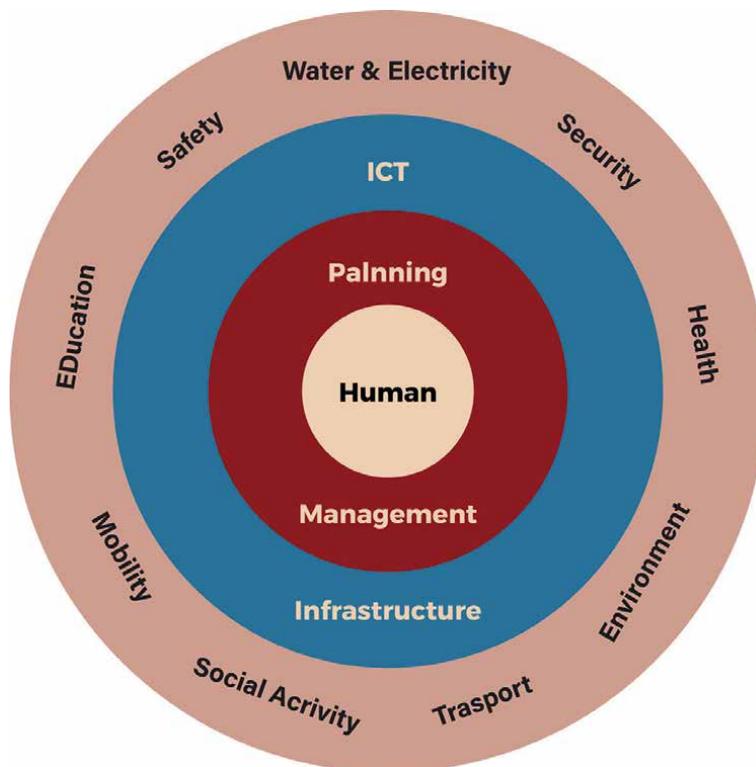


Figure 3.
ICT integration with human and smart services.

the country a national competitive advantage. ICT structure can boost government accountability, transparency, responsiveness, and democratic control, promote citizens' self-empowerment, and their social involvement and commitment, improve the next generation of empowered civil servants, develop innovative technology, ensure efficiency in government services, and create value for the wider economy.

The proposed ICT structure additionally includes the first right-to-information initiative, which enhances the public right to access information from a human rights perspective. The open government data movement is another example of this, which largely promotes the release of government data for socioeconomic justifications. According to the reasoning, making such information available to the general public can benefit society by fostering more democratic participation and more socially inclusive service delivery. The government will be able to connect citizens directly with all available services and resources with the use of distinctive methods for identifying citizens. Smart city apps will concentrate on releasing electronic services through various applications, such as Google smart devices, in terms of security. This will make it easier to identify the most significant distinctions between conventional and smart cities in the future.

7.2 Benefits to the people and society

Municipalities all around the world are under pressure to build strong infrastructures to handle the rising demand for housing, city services, and efficient transportation. Concerns about quality of life are also being addressed by society. ICT can boost human resource technical expertise and educational quality, resulting in higher productivity and quicker development. This perception entails boosting a city's tourism appeal, strengthening the quality of life in terms of services, and fostering social cohesion and safety. The education sector will also be connected to modern technology and its integration into teaching technologies in colleges and schools, with a focus on the importance of modern technologies in terms of enhancing and streamlining the educational process.

7.3 Benefits to the private sector

The local smart city administration cannot provide all services. Therefore, private industry participation in the development of smart city concepts is needed. Private industries are spotting chances to collaborate with city decision-makers on the designs of smart city initiatives as they search for new sources of income and attempt to capitalize on consumer interest in anything digital. Cities, in turn, are aware of the necessity of enhancing their security, economic prosperity, and environmental health. Partnerships between the private sector and city administration to create more livable, sustainable, and resilient communities are becoming more common. Establishing how a networked city connects its citizens and assisting private industries to strengthen the national economy and increase job possibilities for citizens is a vital duty of municipal governments and their administration.

7.4 Environmental benefit

Economic growth and activity in a smart city are sustainable and logically incremental since they are founded on market forces that are oriented toward success.

Citizens, businesses, the government, and the environment all profit from them. Smart cities can enhance the effectiveness of waste management while reducing energy use and greenhouse gas emissions. The installation of self-powered garbage cans that wirelessly inform collection vehicles to collect the waste is made possible by the ICT structure, contributing to the maintenance of a healthy environment. Through Wi-Fi connectivity, the use of smart networks for rainwater drainage, flood control, trash recycling systems, and other features, this system may support parks and pedestrian walkways.

7.5 Economic benefit

ICT is now the foundational technology for the development of smart cities. Broadband networks and mobile telephony are made possible by the Internet's quick spread. Deepening capital through ICT investment is crucial for economic growth because it creates the infrastructure for ICT use and gives businesses useful hardware and software. The existence of a sector generating ICT goods and services is related to the second significant economic consequence of ICT. Since ICT production has been characterized by rapid technological advancement and a very strong demand, having such a sector might be vital for growth. As a result, the industry has expanded very quickly and significantly boosted exports, employment, and economic growth. The first pillar of a smart city is increased public transportation efficiency, a reduction in transaction costs, facilitating the quality of goods and services, quality monitoring, etc. in addition to the economy. As a result, all license-related information and business-related administrative issues will be electronically preserved.

As mentioned in the sections above, the main feature of developing smart cities in Saudi Arabia is the support they will provide to the residents, government, environment, and economy through continuous improvement to the quality of life. For example, smart cities will link residents to the Internet of Things and will provide services that meet their needs, such as effectively managing infrastructure and improving parking management in urban areas, which will improve traffic flow and reduce parking times.

Smart cities in Saudi Arabia will also improve urban planning, reduce the cost of real estate and electricity, and reduce the time taken from the consumer (transportation time, decision-making time, etc.).

In addition, applying smart city technologies in Saudi Arabia will contribute to improving life in cities by providing smart networks and cloud services to residents, and by using artificial intelligence and machine learning to analyse data and provide innovative solutions in areas such as transportation and mobility, security and safety, health and healthcare, housing and infrastructure, energy and water, and society and culture. The most important goals of building smart cities are improving quality of life, efficiency of services, safety and protection, and the sustainability of the city, as well as saving time and effort for residents through the application of modern technologies, automation, and smart control of public services and facilities.

As for the negative aspects of developing smart cities in Saudi Arabia, there are a number of disadvantages related to the technological side; the application of technology in smart cities is usually extremely complex, and it suffers from many implementation challenges at the governance and management levels, and also at the level of cooperation between citizens, private organizations, and city governments.

8. Conclusion

Applications of ICT can be found in almost every field, they enhance both our professional and personal life. The results of this investigation strongly imply that the effective development of smart cities around the world depends on the inclusion of ICT. It also emphasizes the motivational ICT infrastructure that supports numerous successful initiatives of smart applications. Coordination of ideas, projects, people, and society is made possible by the establishment of a smart city administration. Coordination at the local level can be crucial for solutions' adoption as well as for ensuring their integration across a range of initiatives. Several smart cities emphasize that data about public services can be made available as open sources. Our proposed ICT methodology is capable of creating enthusiasm and awareness in society, to deploy, operate, and maintain ICT hardware, software, and systems so that they function effectively across all industries, which produces more knowledgeable and skilled individuals.

The suggested method for ICT infrastructure can be applied in one of three ways: top-down, bottom-up, or in a hybrid mix. Significant advancements in IT infrastructure over the past few years have helped create ICT-based infrastructure that is transforming conventional cities into smart cities. However, additional work needs to be done to advance smart city initiatives, and this work needs to be done by Saudi city municipalities so that the city's infrastructure system may be developed with the proper ICTs. In order to address the challenges associated with the development of smart cities within the Saudi context, this research covered topics linked to smart cities and plans launched by the Saudi Arabian Ministry of Municipal and Rural Affairs to transform a number of cities into smart cities. Finally, this research could pave the way for future research on smart cities and municipal involvement in creating suitable answers to the problems that municipalities may encounter when creating smart cities.

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Exploring the Evolution of Smart Cities: A Review on Energy, Mobility, and Waste Management Aspects

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Abstract

Smart cities leverage data, technology, and networked systems to enhance sustainability, liveability, and efficiency for residents. They integrate various digital technologies to manage infrastructure and resources effectively, utilizing data from sensors and Internet of Things devices to optimize processes and improve decision-making. This urban development paradigm aims to enhance the quality of life through technology. A study employing the SPAR-4-SLR protocol assesses the current state of smart city initiatives by reviewing academic literature, journals, and reports. Focusing on energy, mobility, and waste management, the research evaluates the integration of smart grids to optimize energy distribution and support renewable sources. Additionally, it examines how autonomous vehicles and micro-mobility solutions could revolutionize urban transportation, reducing pollution and improving accessibility. Furthermore, the study investigates advancements in waste management, including tech-enabled approaches to minimize waste, streamline collection, and promote recycling. Targeting policymakers, academics, urban planners, and stakeholders, this research aims to inform strategies for building sustainable and efficient urban environments.

Keywords: smart cities, SPAR-4-SLR, smart grid, mobility, waste management

1. Introduction

The concept of the smart city entails the imperative for structures to possess the capability to autonomously react to external stimuli, thereby obviating the necessity for human decisions or interventions in the process [1].

In fact, following other definitions [2], the common factors in the construction of this idea is the integration of Information and Communication Technologies (ICT) on advanced data processing, for improving living standards in a context of limited resources and to enhance performance efficiency of regular city operations. In almost all the definitions, it is possible to identify an interest in environmental sustainability

and awareness of new challenges that the current urban paradigm of development must face. The recent urban development paradigm centered around “smartness” has evolved since the late 1970s, driven by factors such as globalization and the neoliberal urbanism paradigm, giving rise to a new city concept. In the 1990s, a shift occurred from a purely competitive city model to the idea of a sustainable city, with competitiveness remaining significant as sustainability became integral. Subsequently, the “smart city” model has emerged as one among several frameworks for urban development within the context of the new economy [3]. Since the adoption of the Kyoto Protocol in 1997, global recognition of climate challenges faced by cities has led to the proposal of the smart city paradigm as a strategy to address this challenge. However, it is crucial to acknowledge that climate change is not the sole urban challenge; cities also grapple with resource scarcity, identity crises, economic downturns, population migrations, and poverty [1].

The practice of adding various adjectives to describe cities is relatively recent, starting around the late 1990s. This trend arises from the need to attribute new characteristics and descriptions to cities as evolving entities. The evolution of these definitions has shifted from considerations about digital implementation and technology presence in cities to identifying secondary roles attributed to people or addressing climate change [1].

The term “smart” began to be associated with innovative, multi-tasking products like the “Smart car” from 1996 or the first mobile phone introduced by IBM in 1992. The concept of the smart city is also traced back to the idea of the smart earth proposed by IBM in 2008. This development model, integrating urban and digital technology, emphasizes the use of artificial intelligence (AI), Internet of Things (IoT), big data, and other digital technologies for urban governance. The goal is to disconnect urban development from environmental pollution and promote sustainable economic development in cities [4].

The term “smart” can mean both “intelligent” and “attractive”. Given the diverse meanings of “smart”, it is challenging to find a unique definition. Still, the term generally conveys notions of flexibility, self-adjustment, autonomy, resourcefulness, and ecological friendliness [5].

Smart cities aim to adapt to changes and involve citizens in decision-making. However, there are concerns about neglecting key urban challenges like pollution, infrastructure, and social disparities [6].

The implementation of the smart city concept globally takes various forms, seen as either a singular project or a network project encompassing thermal, electrical, and mobility components. It is also viewed as a comprehensive design strategy for the entire urban environment. Smart projects differ in terms of the specific object being implemented, whether technology, process, strategy, or approach, with objectives ranging from sustainability to addressing social or economic challenges. Collaboration among stakeholders is crucial in smart city projects, linking success to involving private and public sectors, small and medium enterprises, associations, professionals, universities, and citizens. Despite this, smart city projects often follow a top-down approach, initiated by the public sector and involving digital and energetic engineers, as well as digital industries [1].

A smart city can be seen as an ongoing process focused on attaining goals related to sustainability, inclusion, safety, and resilience. In this context, technology functions as a facilitator, working in conjunction with other tools such as participation, cultural heritage, and innovation. It is logical to assert that the primary objective of a smart city is to tackle societal challenges, primarily aimed at enhancing sustainability.

This involves optimizing the overall performance of the urban environment and enhancing the quality of urban life to promote citizens' well-being and foster economic growth [1].

The European Commission (EC) gives this definition of smart city: "A smart city integrates physical, digital, and human systems into traditional networks and services to optimize energy resources and reduce emissions, benefiting both citizens and businesses". The concept of a "smart city" goes beyond the use of digital technologies, including energy-efficient buildings, integrated renewable energy sources, sustainable heating and cooling systems, smarter urban transport networks, enhanced water supply, and improved waste disposal facilities to address the economic, social, and environmental challenges of the city. Smart cities depend on political commitment and broad, inclusive citizen engagement to provide sustainable and inclusive solutions, with the aim of making cities more resilient [7].

European Union (EU) emphasizes six key themes, encompassing Smart Governance, Mobility, Environment, Economy, Living, and People. Addressing the shift toward low-carbon and smart cities, the EU's annual report stresses the pivotal role of partnerships like the Covenant of Mayors and the 100 Climate-neutral and Smart Cities Mission. These initiatives emphasize the necessity of raising awareness and providing guidance on best practices related to renewable energy and energy efficiency. Joining a renewable energy community, exemplified by initiatives like the Cities Energy Saving Sprint, is a significant stride for citizens. Given that cities are accountable for almost 75% of global energy consumption and 70% of global CO₂ emissions, they play a vital role in managing energy-intensive public buildings, social housing, infrastructure, and vehicle fleets. Local and regional authorities (LRAs) must lead by example, considering their interaction with citizens and local businesses. Digital technologies are integral to achieving energy reduction goals, although their widespread use demands careful management to prevent an unintended increase in energy consumption [8].

The European Commission's report outlines a mission to make 100 European cities climate-neutral by 2030, emphasizing customized Climate City Contracts, citizen participation, funding access, a just transition, and identifying policy gaps. This mission advocates for systemic transformations in city governance, promoting a holistic, citizen-driven approach and integrated urban planning for effective climate action [9].

The European Roadmap for 2050 details a strategy for carbon neutrality, focusing on key action blocks like energy efficiency in buildings, renewable energy sources, cleaner mobility solutions, and digital solutions in urban areas and smart cities. Strategic priorities include fostering a competitive industry, circular economy practices, smart network infrastructure, bioeconomy, carbon sinks, and carbon capture and storage.

In this work, the smart city SC concept was addressed, and a literature review was conducted to explore SC in the scientific literature and provide academics and policymakers a general overview on the topic in order to facilitate future steps toward the implementation of it.

2. Methodology

A systematic literature review may be viewed as a scientific research process that advances our understanding of both new and current material in the review topic [10]. Three stages are involved: Assembling, Arranging, and Assessing.

Assembling is the process of locating and obtaining material; arranging is the process of organizing and cleaning; and assessing is the process of reporting and evaluating literature.

This study’s methodology is based on these steps as outlined in the Scientific Procedures and Rationales for Systematic Literature Reviews (SPAR-4-SLR) protocol. Previous studies, mainly on sustainability research in general, have used this protocol [11–14].

The SPAR-4-SLR method consists of three phases as shown in **Table 1**. Specifically, in the first Assembling phase, the domain identified as smart cities in the scientific literature is defined. After that, the research questions in this case are two:

1. How much is Smart City explored as a topic in the literature?
2. What are the main results on the domain of the topic in terms of energy, mobility, and waste management?

Assembling	<i>Identification</i>
	Domain: Smart Cities in the scientific literature Research questions: 1. How much is Smart City explored as a topic in the literature? 2. What are the main results on the domain of the topic in terms of energy, mobility, and waste management? Source quality: Scopus
	<i>Acquisition</i>
	Search mechanism and material acquisition: Scopus Search period: 2019–2024 Search keywords: in Abstract, Keywords, and Title “Smart cities” OR “Smart city” Total number of articles returned from the search: 12160
Arranging	<i>Organization</i>
	Organizing codes: Language, Document Type, Source Type, Subject area, Journals titles, Exact keywords.
	<i>Purification</i>
	Language: English Source type: Journals Document type: Article Subject areas included: “Environmental Science”, “Energy”, “Business, Management and Accounting” Journals included: Sustainable Cities And Society; Cities; Urban Studies; Environment And Planning B Urban Analytics And City Science; Frontiers In Sustainable Cities; Smart And Sustainable Built Environment; Urban Science; Computational Urban Science Keywords for subtopics: for Smart Grid in SC: AND EXACT KEYWORD “Smart Grid” OR “Smart Power Grid” for Mobility in SC: AND EXACT KEYWORD “Mobility” OR “Electric Vehicle” OR “Autonomous Vehicles” for Waste Management in SC: AND EXACT KEYWORD “Waste Management” Total documents retained from arranging stage: 528
Assessing	<i>Evaluation</i>
	Analysis method: Content analysis of representative results.
	<i>Reporting</i>
	Reporting convention: words (smart cities-related aspects) Limitation: Data types, subject areas, number of documents included. Source of support: No fundings requested. Documents reported in detail as representative: 18

Table 1.
SPAR-4-SLR methodology application.

In terms of the quality of resources, we chose to conduct the research on Scopus in line with what was suggested by [10] also regarding search and acquisition mechanisms.

In terms of the search period, the analysis was limited to the last 5 years in order to have a current overview of the topic. The keywords used in the generic analysis of smart cities were “Smart City” or “Smart Cities” in the title, abstract, or author keywords.

At the end of this phase, 12,160 results were obtained.

The second Arranging phase consists of identifying and applying so-called organizing codes or filters to the search. In this case, the filters applied particularly concerned the language type of the source document, the subject area, and the precise keywords for the analysis of the three subtopics under discussion.

In terms of document type and source type, it was decided to analyze only journal articles, which tend to be more comprehensive than, for example, conference proceedings or less theoretical than books.

Furthermore, the subject areas “Environmental Science”, “Energy”, and “Business, Management and Accounting” were selected and limited to the journals listed in **Table 1**.

Regarding the three sub-themes, we focused on the concept of smart grid, sustainable and autonomous mobility, and waste management by selecting a few keywords from the author’s keywords after the assembly phase.

At this point, 528 results were obtained.

Finally, for the Assessing phase, the content of several articles considered representative of the topic of Smart Cities in general, as well as the three subtopics, was analyzed in order to carry out an analysis to discuss the main themes that have emerged in the recent literature.

3. Results

The findings from the literature review following the second stage of the methodology application exhibit a notable concentration of results, particularly evident between 2021 and 2022, as visually depicted in **Figure 1**.

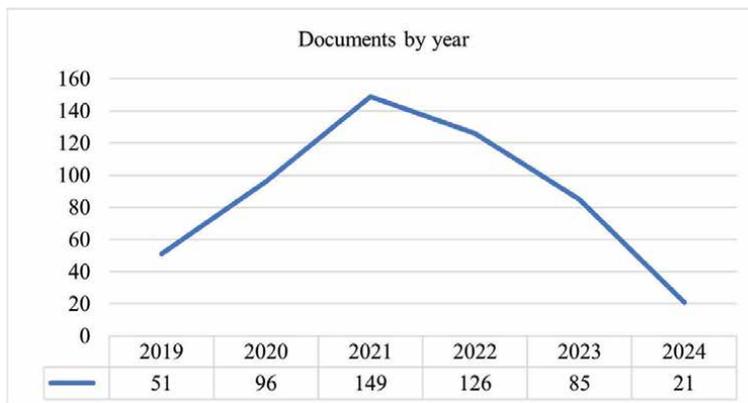


Figure 1.
Documents by year. Own elaboration based on Scopus results.

Notably, the distribution of results per country showcases significant contributions from various regions. Leading the tally, the United Kingdom emerges with 85 results, closely trailed by China and the United States, each yielding 80 results, with India and Australia following suit with 54 and 42 results, respectively (**Figure 2**).

Despite the absence of European Union (EU) countries in the top five, a discernible trend emerges in the funding landscape. The EU emerges as the primary funding sponsor, contributing to 47 results collectively, with China, South Korea, and the United States following suit with 31, 12, and 11 results, respectively (**Figure 3**).

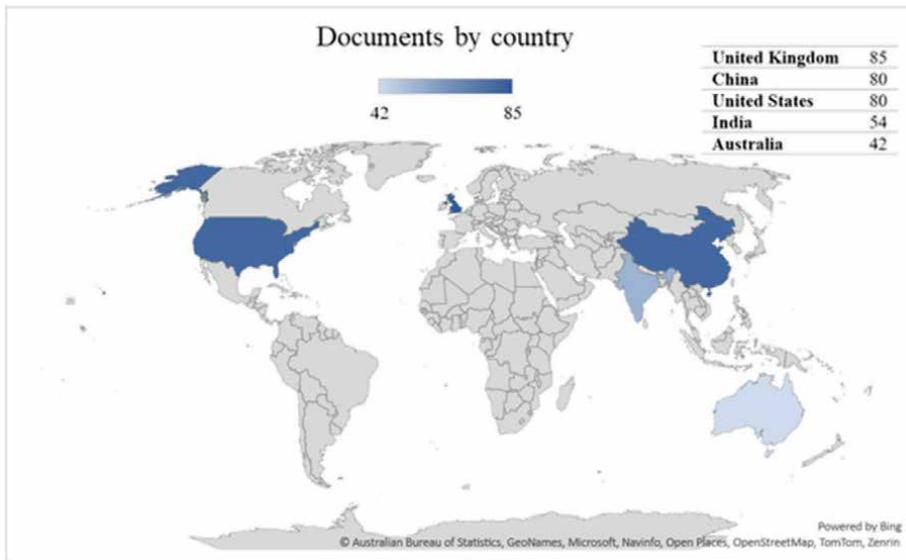


Figure 2. Documents by country. Own elaboration based on Scopus results.

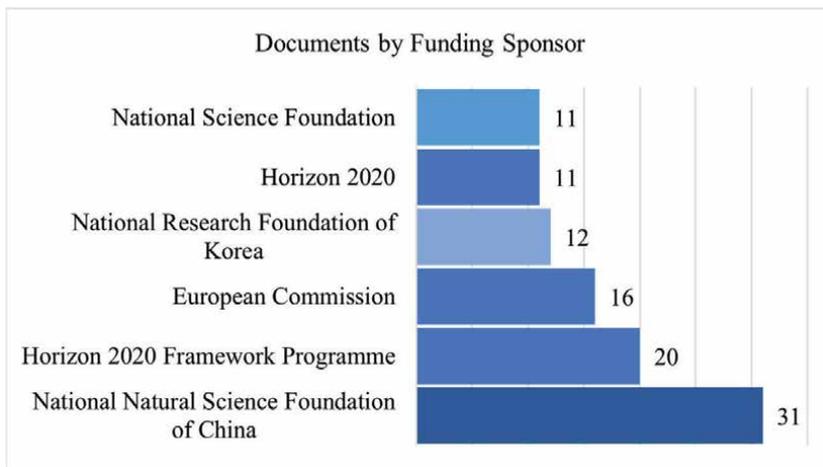


Figure 3. Documents by funding sponsor. Own elaboration based on Scopus results.

Following a thorough examination of the resultant papers, a focused debate proceeded, centered on a sample of findings from 18 studies. It aims to explore into the larger domain of smart cities while also going further into subtopics such as smart grids, mobility, and waste management within smart cities. Notably, each subtopic was assigned four separate articles for investigation, enabling a thorough examination of these essential aspects of urban growth.

4. Discussion

The smart urban infrastructures developed by European and American governmental entities prioritize the establishment of intelligent transportation systems and digital manufacturing facilities. Exemplifying this paradigm, the city of Dubuque in the United States collaborated with IBM to undertake the conversion into intelligent manufacturing facilities. However, the development of such urban landscapes remains in the nascent phase and the approaches adopted are various among nations in their endeavors. China's active engagement in smart city development is evidenced by the fact that 76% of cities within the nation have already incorporated smart city projects [4].

The Chinese government has actively promoted smart city development. One instance is the "National New Urbanization Plan (2014–2020)", which places emphasis on smart city construction integrating technological applications, and infrastructural domains. The deployment of sensor platforms has contributed to the monitoring of daily life activities. The objective of smart city initiatives resides in advancing perceptions, interconnectivity, applications, and innovations across sectors [15]. The 14th Five-Year Plan of China endorses the imperative developmental objective of promoting the advancement of a sustainable economy [16]. The implementation of the Smart City Pilot Policy (SCPP) in 2012 signifies China's actualization of these objectives.

Disagreement has arisen among scholars expressing concerns about the environmental implications and the potential for crowding-out effects caused by the operation of smart city initiatives [4]. Various sources contribute to pollution in a smart city, giving rise to three types of pollutants. On the other hand, a pollution monitoring system can aid in effectively managing the pollution factor. The Smart City Construction (SCC) policy in China has significantly contributed to environmental benefits which will become fully apparent only in the long run. However, the effectiveness varies among cities. In particular, Smart City Construction policies exert influence on pollution dynamics through optimization of industrial structure, technological innovation, and the rebound effect. This conclusion posits SCC as an effective approach.

Another study examines the influence of the Smart City Pilot Policy on the enhancement of Energy and Environmental Performance (EEP) [16]. SCPP has elevated in pilot cities, indirectly improved, and enhanced EEP due to the SCPP exhibiting a short-term lag effect that gradually diminishes over time. Additionally, the SCPP does not generate substantial spillover effects. In cities characterized by lower administrative levels and limited resource endowments, the SCPP demonstrates a more pronounced effect in enhancing EEP.

But what about cities' resilience? A city's ability to handle and recover from unforeseen disasters and pressures. The collaboration between smart cities and urban resilience aims to improve urban performance and promote a better quality of life. In a smart city, the use of Information and Communication Technologies (ICTs) is pivotal for enhancing resilience. An analysis of resilience in China emphasizes that

intelligent infrastructure and ICT solutions are primarily responsible in the infrastructure, economic, and institutional sectors. The research reveals a dilemma: since limited real-time citizen awareness and evaluation standards impede the practical transformation of ICT [15].

Whereas cities are an important key element for sustainable development [17], the primary emphasis in construction prioritization lies in modern technology and economic development, often disregarding considerations for green spaces, environmental preservation, and the development of efficient urban infrastructure [15]. This includes the challenge in establishing emission baselines. Effectively translating ambitious climate mitigation commitments into action requires comprehensive capacity building across various domains [18].

Focusing on green total factor energy efficiency (GTFEE), [17] reveals a substantial enhancement in Urban Green Total Factor Energy Efficiency (GTFEE) attributable to the implementation of Smart City Projects (SCP), such as its facilitation of clean energy development, optimization of industrial structure, energy conservation, emission reduction, and increased production. Consequently, it is evident that there is a connection between resilience, energy efficiency, and sustainability [15].

In energy generation and consumption, integrating large data centers for cloud computing is crucial. The study [19] investigated Dynamic Energy Management (DEM) strategies in cloud-based data centers (CDCs) to optimize energy use. A specialized framework for CDCs was developed to enhance energy efficiency, representing a proactive approach to addressing energy challenges in these centers.

The challenges in smart city development encompass technical, socio-economic, and environmental domains. Technical concerns involve ensuring security and managing data [20, 21]. Socio-economic challenges include the need for citizen acceptance and government support. Environmental issues range from the adoption of 6G technology to managing natural disasters [21]. The effort involves developing Cyber-Physical Systems (CPS), and initiatives aligned with Sustainable Development Goals (SDGs) [20].

On the other hand, smart city initiatives wield substantial influence in urban planning, promising a transformative impact through the integration of technology and data-driven strategies.

Camero [22] and Javed et al. [21] highlight the potential of integrating computer science and information technology for improving decision-making, resource allocation, and urban service delivery. These initiatives address urban challenges and emphasize Smart City planning's role in ensuring widespread accessibility to technological benefits. They underscore the significance of incorporating technologies for crime prevention and crisis management.

Certain technologies will be important: Internet of Things (IoT) enables connectivity and communication between devices and sensors; Blockchain provides secure and transparent transactions; Sixth generation (6G) networks and WiFi-7 provide high-speed and reliable connectivity; connected and automated vehicles (CAVs) improve transportation efficiency and reduce traffic congestion [21].

Moreover, urban analytics is essential due to the growing accessibility of real-time data and enhanced computing power, leading to an increased capacity to identify patterns of urban systems. This allows for development of applications of those patterns. Among them, intelligent traffic management stands out as one of the most established areas [23].

Growing academic literature examines the rise of smart-sustainable urban development, challenging its characterization as a digital solution. Scholars, as articulated

by Martina et al. [24], argue that this narrative functions as a “greenwashing”. In essence, the critique contends that the proclaimed sustainability is overshadowed by the underlying outsourcing dynamics to powerful global entities. The concept of the Urban Smart-Sustainability Fix highlights the intentional integration of digital and environmental objectives. The first is to improve the manageability, align with the existing ecological modernization agenda. Moreover, concerns about transformative claims linked to smart-sustainable urban development persist in the discourse [24]. The results include investments aimed at attracting the “creative class”, along with advancements in tourism and widespread adoption of global internet platforms [25].

Cities play a pivotal role in achieving the 2030 SDGs, the integration of smart technologies, as emphasized by Blasi et al. [25] can contribute to address social and environmental concerns. However, water management and governance areas are still lacking alignment. They highlight that smart cities involve citizen participation. The focus on smart mobility and living aims at efficient daily movements and enhancing quality of life. Approximately one-third of SDG indicators can be measured at the local level. Research on the relationship between smart cities and SDGs, as noted by Sharifi et al. [26], focuses on the smart cities’ positive contributions to achieve specific SDGs. However, a gap exists in exploring potential adverse effects, especially in examining how financial challenges are associated with implementing smart city concepts. They acknowledge the co-benefits, but caution that challenges must be addressed. COVID-19 pandemic underscored the connections between smart cities and SDGs, particularly in terms of health and climate action. The pandemic has also brought to light unethical practices that demand resolution. To optimize the contribution of smart cities to SDGs, the authors stress the need for multi-scale, transparent governance mechanisms and robust regulatory frameworks. They call for future research to include other SDGs and explore the implications of platformisation, intended as “the penetration of digital platforms in different economic sectors and spheres of life”.

Smart cities explore innovative technologies like the “digital twin city” to enhance decision-making. Deren et al. [27] define a digital twin city as an advanced application that connects the physical world with an interactive virtual space using urban data from sensors and cameras. Its features include mapping, virtual-real interaction, software definition, and intelligent feedback. White et al. [28] emphasize how digital twin smart cities enhance public engagement and transparency. The interactive nature of the digital twin facilitates feedback and issue reporting, creating a virtual loop for efficient problem-solving [23]. They highlight the risks of neglecting broader social considerations and community values, leading to potential biases and discrimination. Laufs et al. [29] draw attention to ethical considerations, raise concerns about compromising individual privacy, and emphasize the need for rethinking the planning process to address privacy and data protection issues. Priya et al. [30] discuss challenges related to the application of digital twins, emphasizing the exchange of enormous amounts of sensitive data. They introduce a technology focusing on privacy preservation, integrating it into digital twins presenting challenges and offering solutions where end-users can train the global model in their local environment, updating only the parameters in the global model after the training process.

Blockchain technology has emerged as a transformative force, offering a decentralized and immutable database for transactions in a peer-to-peer network. Bhushan et al. [31] highlight its potential to address security challenges in smart cities, providing attributes like auditability, transparency, immutability, and decentralization. The traditional central server systems storing smart city device data face challenges

like data breaches and the need for multiple management authorities. Blockchain’s promising applications extend across various smart community domains. Categorized into public, private, and consortium types, blockchain comes with distinct control mechanisms and authentication protocols. Blockchain’s relevance also extends to emerging technologies, facilitating secure vehicle-to-vehicle communication without relying on a central authority.

Table 2 offers an overview of the challenges and solutions recognized.

4.1 Smart grid in SC

Vazquez-Canteli et al. [32] highlight the importance of building energy simulation and machine learning algorithms. This combination develops adaptive energy controllers based on real-time sensor data, promoting energy savings, and responsiveness to demand in smart cities. Techniques like Q-learning and regression algorithms enhance control algorithm adaptability, integrating renewable energy sources and storage devices into buildings.

Turning to the energy sector’s efficiency, Sospiro et al. [33] underscore the opportunity presented by the development of smart grids. However, challenges arise in incorporating renewable energy resources for environmental sustainability and ensuring robust cybersecurity for smart grids. Mohammadpourfard et al. [34]

Theme	Challenges	Literature solutions
Participation	<ul style="list-style-type: none"> • Citizen acceptance and involvement • Government support for Smart City initiatives 	<ul style="list-style-type: none"> • Emphasis on citizen participation in Smart City development • Integration of participatory approaches in decision-making
Data	<ul style="list-style-type: none"> • Security and management of data • Exchange of enormous amounts of sensitive data 	<ul style="list-style-type: none"> • Addressing security concerns in data management • Developing technologies for privacy preservation in data exchange
Security	<ul style="list-style-type: none"> • Ensuring security in Smart City systems • Risks of neglecting social considerations and community values in data-driven approaches 	<ul style="list-style-type: none"> • Use of Blockchain for auditability, transparency, and decentralization in Smart Cities • Caution against relying solely on data-driven approaches in city planning
SDGs (Sustainable Development Goals)	<ul style="list-style-type: none"> • Contribution of Smart Cities to specific SDGs • Potential adverse effects and financial challenges 	<ul style="list-style-type: none"> • Emphasizing Smart Cities’ positive contributions to achieving SDGs • Exploring challenges and addressing them through transparent governance mechanisms
Sustainable Development	<ul style="list-style-type: none"> • Balancing economic development with green spaces and environmental preservation • Challenges in establishing emission baselines 	<ul style="list-style-type: none"> • Incorporation of green spaces and efficient urban infrastructure in Smart City planning. • Focus on Urban Green Total Factor Energy Efficiency (GTFEE) through Smart City Projects (SCP)

Table 2. Challenges and solutions recognized regarding SC.

propose a Long Short-Term Memory (LSTM)-based attack detection, ensuring the robustness of smart grid systems. Samuel et al. [35] explore blockchain applications for secure blockchain-based energy trading for residential homes, employing innovative consensus protocols and privacy mechanisms to promote sustainability and efficiency.

Furthermore, Khan et al. [36] delve into challenges related to smart grids integrated with communication networks, proposing a scheme that ensures data protection and integrity, maintaining security even in the event of compromised smart meters or central control centers.

These innovations help to optimize energy usage, security, and privacy in smart cities.

Table 3 offers an overview of issues and solutions recognized.

4.2 Mobility in SC

Smart cities aim to enhance urban living through technological advancements. The adoption of electric vehicles (EVs) reduces carbon emissions. Integration of mobile computing, IoT, and big data enables real-time traffic monitoring, reducing congestion. Additionally, digital forensics enhances security [21].

Bike-sharing systems (BSS) play a crucial role but face challenges in effective management. A model, utilizing real data from London's BSS, demonstrates practical

Theme	Challenges	Literature solutions
Incorporating Renewable Energy in Smart Grids	<ul style="list-style-type: none"> • Difficulty in integrating renewable energy resources for environmental sustainability 	<ul style="list-style-type: none"> • Building energy simulation and machine learning algorithms
Cybersecurity in Smart Grids	<ul style="list-style-type: none"> • Ensuring robust cybersecurity for smart grids 	<ul style="list-style-type: none"> • LSTM-based attack detection • Exploration of blockchain applications for secure energy trading with innovative consensus protocols and privacy mechanisms
Smart Grids Integrated with Communication Networks	<ul style="list-style-type: none"> • Data protection and integrity in smart grids integrated with communication networks 	<ul style="list-style-type: none"> • Proposal of a scheme ensuring data protection and integrity, maintaining security even in the event of compromised smart meters or central control centers
Optimization of Energy Usage	<ul style="list-style-type: none"> • Enhancing energy efficiency and responsiveness to demand in smart cities 	<ul style="list-style-type: none"> • Adaptive energy controllers based on real-time sensor data • Exploration of blockchain applications for secure blockchain-based energy trading for residential homes
Security and Privacy	<ul style="list-style-type: none"> • Ensuring security and privacy in the context of smart grids 	<ul style="list-style-type: none"> • Innovative consensus protocols and privacy mechanisms for secure blockchain-based energy trading • Proposal of a scheme ensuring data protection and integrity in smart grids integrated with communication networks

Table 3.
 Challenges and solutions recognized on the smart grid subtopic in SC.

effectiveness and potential contributions. The objective spans technical, social, transport-related, and economic dimensions. A comprehensive understanding of BSS is essential for political decision-makers and system managers. Studies indicate positive effects on health and cycling promotion. Moreover, acknowledging the business model and operational challenges associated with bike-sharing is crucial because they may give rise to urgent issues such as vandalism and overproduction of bicycles [37].

The urban mobility sector is undergoing a transformation with the influence of digital platforms, mobile apps, and sharing economy models emphasizing access over ownership. A study [38] analyzing citizen reviews in Milan emphasizes the need for effective communication of digital services across various channels to enhance value for citizens and visitors. Implementing Information and Communication Technologies (ICT) can impact citizens' quality of life and create public value, but it requires radical changes. The shift from ownership to access, a characteristic of sharing economy models, forms the foundation of shared mobility services. Challenges, such as resistance to giving up car ownership, need addressing. The study provides insights into user perceptions compared to public transport. Overall, users are satisfied with the digitalization of mobility services, recognizing contributions to city sustainability.

The integration of blockchain technology in urban mobility and transportation aims to enhance safety, traffic conditions, and convenience. Blockchain can revolutionize ticketing systems, by offering a unified platform. In managing traffic data, blockchain, coupled with IoT sensors, enables real-time monitoring, alerts, and alternative route suggestions. Blockchain's potential extends to promoting sustainability in urban transport by incentivizing citizens to use shared transportation and encouraging vehicles to share real-time traffic information. Despite challenges such as data security and implementation costs, the proposed framework guides planners, policymakers, and stakeholders in developing smarter cities [39].

Table 4 provides evidence of challenges and solutions recognized.

4.3 Waste management in SC

Waste management has become a significant challenge for urban engineers and planners due to the surge in human population. Consequently, there is a need to devise a more pragmatic and advanced approach to overcome these challenges.

The proposed method in this article comprises three modules. This approach improves waste management efficiency, addresses financial considerations, and enhances the quality of waste collection procedures in smart cities [40].

The management of solid waste poses a global challenge, exacerbated by urbanization and industrialization. Monitoring factors influencing waste treatment using a multi-dimensional approach is crucial for energy recovery and disaster reduction. An interesting study proposes methods for managing solid waste, incorporating a robotic segregation device and a combined percolator bed reactor with an up-flow anaerobic sludge blanket reactor, both integrated with IoT devices for real-time treatment process monitoring. The robotic segregation device simplifies waste separation. The proposed combined reactor is designed to sustainably handle landfill leachate. The goal is to enhance environmental and hygienic quality of smart cities, reduce health risks through timely waste collection and alleviate traffic congestion [41].

Addressing the challenge of solid waste collection and transportation, municipalities strive to develop solutions. In current waste management systems, waste

Theme	Challenges	Literature solutions
Electric Vehicles (EVs) Adoption	<ul style="list-style-type: none"> Reducing carbon emissions through EV adoption 	<ul style="list-style-type: none"> Adoption of electric vehicles (EVs) as a measure to reduce carbon emissions
Real-Time Traffic Monitoring and Congestion Reduction	<ul style="list-style-type: none"> Challenges in effective traffic management and congestion reduction 	<ul style="list-style-type: none"> Integration of mobile computing, IoT, and big data for real-time traffic monitoring, reducing congestion
Bike-Sharing Systems (BSS)	<ul style="list-style-type: none"> Effective management challenges in bike-sharing systems 	<ul style="list-style-type: none"> Model utilizing real data demonstrating practical effectiveness and potential contributions of BSS Acknowledging business model and operational challenges, such as vandalism and overproduction
Transformation in Urban Mobility	<ul style="list-style-type: none"> Transition from ownership to access in the sharing economy 	<ul style="list-style-type: none"> Analysis of citizen reviews emphasizing effective communication of digital services to enhance value Use of Information and Communication Technologies (ICT) to impact citizens' quality of life and create public value
Blockchain Technology in Urban Mobility	<ul style="list-style-type: none"> Enhancing safety, traffic conditions, and convenience in urban mobility 	<ul style="list-style-type: none"> Integration of blockchain technology for revolutionizing ticketing systems and managing traffic data Blockchain coupled with IoT sensors for real-time monitoring, alerts, and alternative route suggestions
Challenges in Blockchain Implementation	<ul style="list-style-type: none"> Data security and implementation costs associated with blockchain in urban mobility 	<ul style="list-style-type: none"> Proposed framework to guide planners, policymakers, and stakeholders in addressing challenges and developing smarter cities

Table 4.
 Challenges and solutions recognized on the mobility subtopic in SC.

Theme	Challenges	Literature solutions
Efficiency in Waste Management	<ul style="list-style-type: none"> Surge in human population causing challenges in waste management 	<ul style="list-style-type: none"> Proposed method comprising three modules to improve waste management efficiency
Solid Waste Treatment	<ul style="list-style-type: none"> Global challenge in managing solid waste due to urbanization and industrialization 	<ul style="list-style-type: none"> Proposal of methods, including a robotic segregation device and a combined reactor with IoT devices for real-time monitoring Aim to enhance environmental and hygienic quality in smart cities, reduce health risks, and alleviate traffic congestion
Optimizing Waste Collection and Transportation	<ul style="list-style-type: none"> Waste collection being a significant portion of the total budget in waste management systems 	<ul style="list-style-type: none"> Development of a mixed-integer linear programming model to enhance collection efficiency, reduce costs, and minimize emissions Significant cost savings and carbon emission reduction demonstrated by the model

Table 5.
 Challenges and solutions recognized on the waste management subtopic in SC.

collection constitutes a significant portion of the total budget. The primary source of carbon emissions in this process is the vehicles used for transporting municipal solid waste (MSW). The key factors influencing operational cost of waste collection and transportation are the distance traveled and fuel consumption. Solid waste collection is connected to many United Nations' SDGs. To enhance collection efficiency, reduce costs, and minimize emissions, a mixed-integer linear programming model was developed. It demonstrated improvement along with significant cost savings and a carbon emission reduction [42].

Table 5 offers an overview on the recognized challenges and solutions.

5. Conclusions

In conclusion, this study underscores the transformative potential of smart cities as a paradigm shift in urban development, harnessing innovative technology to enhance sustainability, efficiency, and the quality of urban life. Through a comprehensive review of the literature following the SPAR-4-SLR protocol, the study has delved into the current landscape of smart city initiatives, focusing on energy, mobility, and waste management aspects.

In the realm of energy, the prioritization of smart grid integration has emerged as a key strategy, offering promising avenues for optimizing energy distribution, bolstering renewable energy adoption, and enhancing overall efficiency. Similarly, the study has highlighted the transformative impact of autonomous vehicles and micro-mobility solutions on urban transportation networks, offering potential benefits such as reduced pollution, congestion, and improved accessibility. Moreover, the evaluation of waste management practices in smart cities has revealed the adoption of technology-enabled approaches to minimize waste generation, streamline collection processes, and promote recycling and circular economy models.

This research underscores the imperative of fostering interdisciplinary collaboration among diverse stakeholders, including policymakers, academics, urban planners, and industry experts, to drive forward the development of sustainable and efficient urban environments. By synthesizing the insights garnered from this study, stakeholders are poised to gain a deeper understanding of the multi-faceted challenges and opportunities intrinsic to smart city initiatives, thereby facilitating informed decision-making and the formulation of impactful interventions aimed at shaping the cities of tomorrow. Through concerted efforts and collective action, stakeholders can collectively pave the way toward the realization of inclusive, resilient, and sustainable urban ecosystems that cater to the evolving needs and aspirations of urban populations worldwide.

Acknowledgements

The author would like to acknowledge the support in the revision of this chapter of Salik Ahmed, Nhat Bang-Do, Francesca Colella, and Bintang Shafaa Auliana Jaya.

Conflict of interest

The authors declare no conflict of interest.

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Chapter 3

The Impact of ICTS in the Development of Smart City: Opportunities and Challenges

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Abstract

The pervasive influence of Information and Communication Technology (ICT) has significantly transformed the global landscape, emerging as a pivotal element in ensuring safety and security. According to the 2017 United States Census Bureau, the anticipated world population is projected to reach 8.5 billion by 2030, with further estimates indicating an increase to 9.8 billion by 2050 and 11.2 billion by 2100. Presently, over half of the global population resides in urban areas, witnessing a substantial influx of rural migrants seeking enhanced opportunities, education, and an elevated quality of life. Cities are grappling with the challenge of accommodating this unprecedented surge, surpassing their infrastructural, security, and service capacities. Consequently, urban centers are compelled to enhance living standards by expanding their capabilities. This requires adopting contemporary ICT methodologies, transforming cities into Smart Cities. These cities efficiently assimilate new residents, improving the overall quality of life through cutting-edge technologies such as smart homes, intelligent energy grids, sophisticated retail systems, and the Internet of Things (IoT). This paper explores Smart Cities, examining prospects and challenges. It delineates fundamental components crucial for their realization, offering insights to guide governmental decision-making in initiating Smart City projects.

Keywords: database, IoE, networking, open data, smart city

1. Introduction

According to Bakici, Almirall, and Wareham, smart cities represent urban environments leveraging communication technologies to enhance the well-being of their citizens and fortify a resilient development framework. A smart city is characterized by advancements in governance, mobility, infrastructure, and overall quality of life, achieved through a synergy of citizen engagement, environmental stewardship, and the strategic deployment of Information and Communication Technology (ICT) tools.

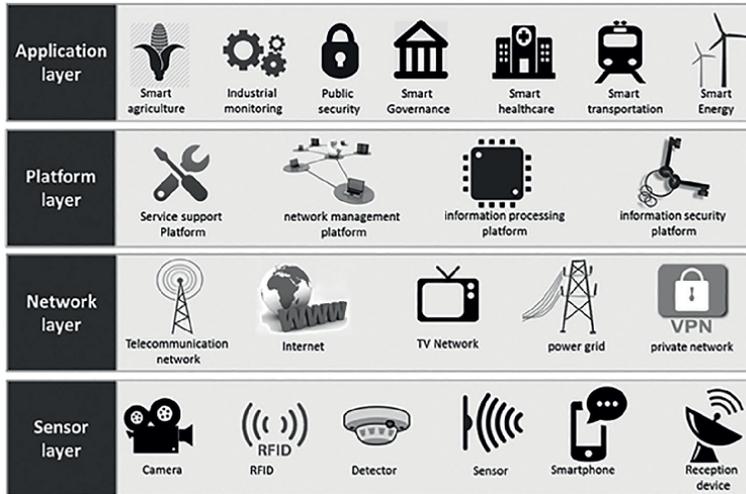


Figure 2.
Four layers of smart city (Xu, 2012).

and enhance sanitation. Furthermore, the adoption of smart public safety systems is anticipated to decrease crime rates and improve emergency response times. Smart healthcare systems hold the potential to enhance access to healthcare services and cut down on costs. Additionally, smart education systems can offer personalized learning experiences, thereby improving student outcomes.

The concept of a smart city revolves around the deployment of pervasive communication technologies and intelligent devices aimed at enhancing urban environments and fostering development [4]. In this framework, the notion of a smart city can be categorized into four distinct levels, as depicted in the **Figure 2**.

In this concept, these four levels, according to Xu, interact with one another. The Sensor layer collects and accumulates information and data in real-time, allowing data handling in the following layer to be more efficient. To acquire data, the Sensor layer frequently employs cameras, RFID, and detectors.

The Network layer comes next, and it is in charge of data and information interchange and transit. The most often used network layer channels are the internet, telephony networks, and television networks. Following this layer is the Platform layer, which incorporates information processing and management via platforms such as business support, network, and cloud computing platforms. The last layer is the Application layer, which allows users to interact with smart services based on data collected in the smart city [5].

Figure 3 depicts the many schemes of a smart city’s technical architecture. These schemes interact with one another through actors (Service Providers, Municipal Departments, and the general public). The Sensor and Network layers form the foundation of the infrastructure (**Figure 3**).

A flowchart of interactions between citizens, governments, and other service providers in a smart city is shown in **Figure 3**.

Citizens are the end users of smart city services, and they interact with the city through a variety of channels, such as mobile apps, websites, and in-person services. They can use these channels to access information about the city, report problems, and provide feedback.

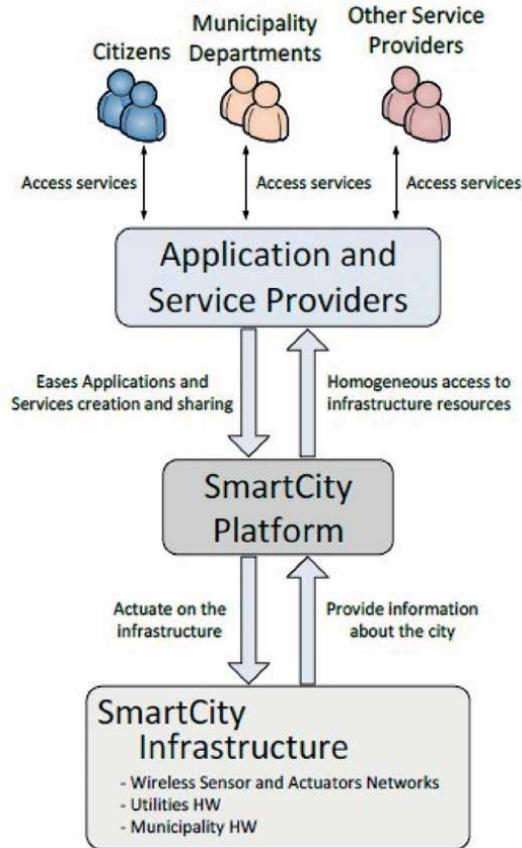


Figure 3.
Smart city actor's interactions [6].

Municipalities are responsible for planning, implementing, and managing smart city services. They interact with citizens to collect feedback and identify needs, and they work with other service providers to deliver integrated solutions.

Other service providers include businesses, utilities, and non-profit organizations that offer a variety of services to citizens, such as transportation, energy, and healthcare. They interact with municipalities to share data and collaborate on smart city initiatives.

The diagram shows how these three groups of actors interact with each other to create a smart city. For example, citizens can use a mobile app to report a pothole to the municipality. The municipality can then use this information to dispatch a crew to fix the pothole. Or, a utility company can use data from smart meters to identify areas where energy consumption is high. The utility company can then work with the municipality to develop programs to help citizens reduce their energy consumption.

Smart city actor interactions are essential for the successful development and implementation of smart city initiatives. By working together, citizens, municipalities, and other service providers can create a more efficient, sustainable, and livable city for everyone.

Here are some additional details about the interactions between the three groups of actors in the diagram:

1.1 Citizens and municipalities

Citizens can use smart city apps to report problems to the municipality, such as potholes, graffiti, or broken streetlights.

Citizens can also use smart city apps to provide feedback on city services and to participate in surveys and polls.

The municipality can use data from smart city sensors to monitor traffic conditions, air quality, and other environmental factors.

The municipality can use this data to make better decisions about how to manage the city.

1.2 Municipalities and other service providers

Municipalities can share data with other service providers to improve the efficiency and effectiveness of city services.

For example, the municipality can share traffic data with a transportation company to help the company improve its bus routes.

Municipalities can also work with other service providers to develop new smart city initiatives.

For example, a municipality might work with a utility company to develop a smart grid that can manage energy consumption more efficiently.

1.3 Other service providers and citizens

Other service providers can use smart city technologies to offer new and improved services to citizens.

For example, a utility company can use smart meter data to offer customers personalized energy-saving tips.

A transportation company has the opportunity to leverage smart city applications for offering real-time updates on bus arrival schedules and enabling customers to conveniently pay for fares using their mobile phones.

The interactions among key players in smart cities are intricate and diverse, playing a pivotal role in the success of smart city initiatives. Collaborative efforts between citizens, local authorities, and various service providers are crucial in shaping a more promising future for everyone.

Illustrated in **Figure 4**, cities are segmented into five layers of application: City resources, services it provides, social policies, infrastructural designs, and the surrounding environment. Each layer is further categorized (refer to **Figure 4**) [5].

The image represents a layered model of a smart city, highlighting the various interconnected components that contribute to a sustainable and thriving urban environment. It emphasizes three primary pillars: economy, environment, and social, each supported by a set of application layers.

1.3.1 Economic pillar

Administration and Economic Actors: This layer focuses on the governance structures, financial institutions, and businesses that drive economic growth and development.

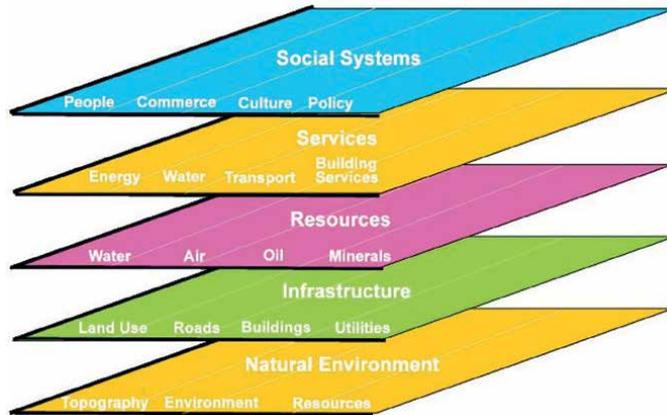


Figure 4.
Application layers in smart cities [7].

1.3.2 Environmental pillar

Resources and Managerial Infrastructures: This layer emphasizes sustainable resource management, including energy, water, and waste, through efficient infrastructure and technologies.

1.3.3 Social pillar

Culture and education: This layer underscores the importance of fostering a vibrant cultural landscape and accessible education opportunities for all citizens.

The diagram illustrates how these pillars are interdependent, demonstrating that smart city initiatives can simultaneously address economic, environmental, and social concerns. By investing in interconnected solutions that tackle these inter-related challenges, cities can create a more sustainable and equitable future for their residents.

A more straightforward representation of an urban system is depicted in (6), comprising three main components, with the smart city component interconnected through Information and Communication Technology (ICT) (refer to **Figure 5**) [9].

The illustration depicts a schematic of the three pillars of smart city sustainability: economics, environment, and social. A number of application layers support each pillar:

- Administration and economic actors in the economy.
- Resources and managerial infrastructures in the environment.
- Social: education and culture.

The graphic also demonstrates how the three pillars are interrelated and how smart cities must aim for balance between them.

Smart city projects, for instance, may stimulate the economy by drawing in firms and creating employment. Through the reduction of pollutants and energy consumption, they can also contribute to environmental protection. Additionally, by improving access to healthcare and education, they can contribute to strengthening the city's social fabric.

The following are some instances of smart city applications that correspond with each of the three pillars:



Figure 5.
Application layers in smart cities [8].

1.3.4 Economy

Smart grid technology to manage energy consumption and reduce costs.
Solutions for intelligent transportation that minimize emissions and enhance traffic flow.
Smart parking systems to make it easier to find and pay for parking.

1.3.5 Environment

Air quality monitoring systems to track pollution levels and identify areas where action is needed.
Water conservation systems to reduce water usage and protect resources.
Waste management technologies that increase efficiency while lowering environmental effect.

1.3.6 Social

Electronic government services to facilitate individuals' access to public services.
People in rural places can receive healthcare through telemedicine services. Intelligent learning environments that enhance student performance. Although they are still in their infancy, smart cities have the potential to have a profound effect on people's lives all over the world. We can make our cities' economies, environments, and social fabrics better with the help of technology, giving everyone a more sustainable and livable future.

2. Objectives

Urban centers wield significant influence over social, economic, and environmental factors, necessitating a focused approach towards three primary goals.

2.1 Energy resource management through the internet of energy (IoE) concept

Efficient management of energy resources is pivotal, guided by the principles of the Internet of Energy (IoE). This entails leveraging interconnected technologies to optimize energy consumption, enhance sustainability, and foster responsible resource utilization.

2.2 Safety and security enhancement

The second goal centers on bolstering safety and security within the urban landscape. This encompasses the strategic deployment of Closed-Circuit Television (CCTV) systems, automated alert systems for residents, detection of anomalous activities, and the provision of real-time information updates as needed. The overarching objective is to create a secure environment for residents.

2.3 Transportation efficiency and environmental preservation

The third goal focuses on improving transportation systems and safeguarding the environment. This involves initiatives to reduce pollution levels, implement energy-efficient street lighting, and mitigate traffic congestion, contributing to a sustainable and eco-friendly urban ecosystem.

2.4 Advancement of educational facilities

Recognizing the critical role of education, there is a need for increased investment to ensure equal opportunities. This encompasses the facilitation of continuous learning through online and remote education modalities, as well as the integration of smart technologies in traditional classrooms.

2.5 Tourism development

Cities aim to harness their inherent resources to attract a greater influx of tourists, thereby contributing to economic growth and cultural exchange. Strategic development initiatives are undertaken to showcase the unique attractions and offerings of the urban landscape.

2.6 Healthcare enhancement for citizens

Embracing new technologies, particularly in the realm of healthcare, is integral to improving the well-being of citizens. This involves leveraging technological advancements to enhance healthcare accessibility, ensuring that citizens have access to proper and timely medical services.

3. Implementation and deployment

A consortium of experts spanning diverse disciplines is essential for the strategic delineation and implementation of smart city initiatives. This interdisciplinary assembly comprises professionals in Economics, Sociology, Engineering, Information and Communication Technology (ICT), and Policy and Regulation. Their collective

expertise is instrumental in addressing challenges inherent in routine urban management and crises, including pandemics.

The impetus behind formulating robust urban transformation strategies and ensuring an unbiased selection of experts — individuals devoid of political affiliations — for pivotal roles in policymaking, decision-making, and implementation teams is twofold. Firstly, it stems from the intricate nature of smart city dimensions and the requisite systemic approach, which demands multifaceted skills. Secondly, it acknowledges the specific capacities and tools imperative for effective realization of smart city concepts.

To streamline the identification and assessment of these experts, a groundbreaking hybrid competency assessment model has been proposed. This model integrates fuzzy logic and a neural network, forming a technological framework to evaluate the competencies of specialists. It takes into account the impact of human factors on personnel selection processes and overall system management.

Complementing this innovative model is a web platform named “Smart City Concept Personnel Selection.” This platform, designed with adaptability in mind, caters to municipal or regional institutions. It facilitates transparent and merit-based selection of qualified personnel, ensuring effective decision-making and judicious utilization of public funds in both routine and emergency scenarios, exemplified by its applicability during crises such as the COVID-19 pandemic (Figure 6) [10].

The algorithm has two main steps: The first step involves identifying the key criteria that are important for assessing the competence of specialists for a particular task or role. These criteria can be quantitative (e.g., years of experience, number of

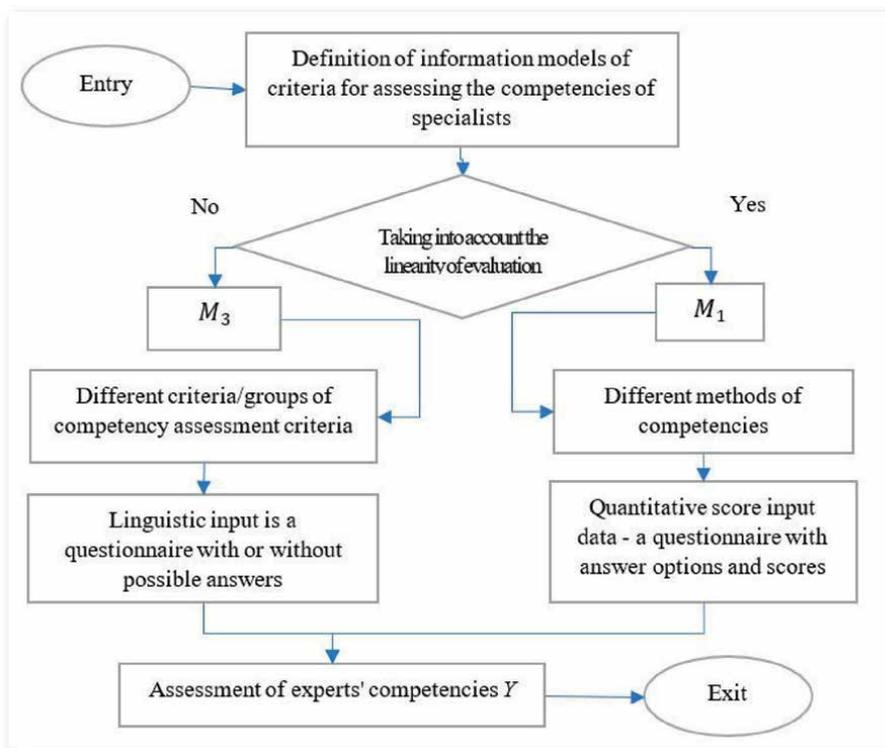


Figure 6. Fuzzy model assessment algorithm for specialist competence [10].

publications) or qualitative (e.g., communication skills, problem-solving skills). Once the criteria have been identified, they are then converted into fuzzy variables. This means that each criterion is assigned a membership function, which defines the degree to which a specialist satisfies that criterion. The second step assesses the experts’ competencies. This step involves using the information models of criteria to assess the competencies of specialists. This can be done using a variety of methods, such as questionnaires, interviews, and performance assessments. Once the competencies of each specialist have been assessed, they are then assigned a fuzzy score for each criterion, and based on the score they are selected.

There are a few other frameworks proposed by academic and industrial sources that illustrate smart cities’ architecture. Among the numerous models put forth, the one advanced by the US National Institute has gained widespread adoption. Characterized as a complex system, often denoted as “A system of systems,” a smart city encompasses diverse entities, including individuals, infrastructure, and process components. The model endorsed by the US National Institute identifies six fundamental components integral to a smart city: Environment, Quality of Life, Citizens, Transport, Economy, and Government.

As highlighted in a 2014 report from the European Parliament Policy Department, 34% of European smart cities incorporate only one of the aforementioned components, emphasizing the diverse configurations within smart city implementations. The evaluation of smart cities from a comprehensive standpoint involves various approaches. Noteworthy perspectives include the integration of an urban Internet of Things (IoT) system, considerations of urban environments, assessments of competitiveness, and evaluations of resilience.

However, to attain an optimal smart city configuration, the integration of several fundamental components is imperative. This integration ensures a holistic and synergistic approach, facilitating the realization of a smart city that effectively addresses the multifaceted challenges and opportunities inherent in urban environments.

4. Fundamental technologies

Smart cities are designed in such a way that involve a number of technologies that can be summarized in **Table 1**.

Technology	Description and functionality
Big data	Early data management and processing tools faced significant limitations in handling vast datasets efficiently. The advent of big data has revolutionized data handling by categorizing information based on volume, variety, and velocity. This classification facilitates essential processes such as data capture, storage, retrieval, processing, analysis, and visualization. Big data plays a pivotal role in advancing smart cities’ functionalities, aiming to achieve sustainability and enhance living standards across all entities within the urban landscape. Its applications extend beyond mere data management, encompassing strategic functions that contribute to the overarching goals of smart city development. These functions are integral to creating an environment that not only accommodates but elevates the quality of life for all residents and stakeholders in a smart city ecosystem [11].
Networking	Network technology allows multiple devices to be connected. Traditional networks such as Bluetooth, ZigBee and RFID. Modern networks such as Wireless networks taken place lately Smart buildings Smart water networks Intelligent transportation, etc.

Technology	Description and functionality
Internet of things	<p>The deployment of wireless sensors in urban environments encompasses a range of applications, including street lighting, parking management, infrastructure monitoring and maintenance, air quality measurement, public safety initiatives, and optimization of traffic flow.</p> <p>Governments are increasingly leveraging the Internet of Things (IoT) to achieve operational efficiency, enhance overall performance, and elevate the quality of life for their citizens.</p> <p>This strategic use of IoT technologies in urban management underscores a commitment to leveraging data-driven insights for the improvement of civic services and infrastructure.</p>
Cloud computing	<p>Cloud computing technologies facilitate seamless network access to shared data resources. The concept of the cloud, in this context, refers to a dynamic resource pool configured to integrate services, applets, and testbeds. The utilization of these resources is influenced by people's social interactions. Consequently, a smart city necessitates a robust IT infrastructure, which is imperative both from a technical and organizational standpoint.</p> <p>The essential functionalities of such an IT infrastructure encompass automatic backup mechanisms and stringent authority management. Additionally, it involves efficient management of computing resources, data storage resources, and network communication resources through distributed storage management. These functionalities are crucial for the optimal operation of a smart city's IT infrastructure, ensuring data accessibility, security, and overall system performance.</p>
Ubiquitous computing	<p>Ubiquitous computing facilitates intricate computations seamlessly embedded throughout the physical world, shielding them from direct user awareness.</p> <p>As articulated by 'Lee,' a smart network assumes various integral roles, encompassing awareness in content and context, automatic network management, programmability, efficient resource management, and ubiquity [12]. These functions collectively illustrate the diverse capabilities of a sophisticated network infrastructure designed to enhance operational efficiency and user interactions.</p>
Cyber security	<p>The privacy of individuals and government officials is a significant concern in smart cities. Such concerns concern people's personal safety. Data manipulation, malicious coding, and eavesdropping are already issues in today's smart cities.</p> <p>Some occurrences, such as the Hacking attack, resulted in 'massive damage' to German steel plants. Estonia was likewise subjected to a full-fledged cyberwar. DDoS attacks on delayed trains in Sweden resulted from sabotage of traffic lights in Los Angeles.</p>

Table 1.
Examples of different ICT technologies for smart city.

4.1 Integrated sensor systems for smart cities

Integrated sensor systems play a pivotal role in the functionality of smart cities, serving as invaluable components within smart control systems. The enhancement of processes is intricately tied to the environmental context, and a cohesive group of sensors serves to imbue the control system with situational awareness. These sensors systematically collect data, initiating a response process that dynamically adjusts based on predefined system programming [13].

In **Table 2**, the classification of sensors encompasses Technical in situ, remote, and human sensors. Technical in situ sensors are characterized by their environmental monitoring capabilities, frequently employed in meteorology and weather forecasting applications. Technical remote sensors leverage satellite technology for thermal and atmospheric measurements. Human sensors, on the other hand, utilize individuals as data sources for activities such as flood mapping, noise measurement, and disaster management. This categorization underscores the diverse applications and technological modalities employed in integrated sensor systems for comprehensive data acquisition and analysis within smart city frameworks (**Table 3**).

Environmental sensors	Environmental sensors play a crucial role in monitoring various aspects related to the environment, providing essential data for informed decision-making. These sensors are instrumental in tracking air pollution levels, detecting heat anomalies, and monitoring flood levels, among other environmental parameters. Their utilization contributes to a comprehensive understanding of environmental conditions, facilitating proactive measures and interventions in the management of environmental factors.
Mobile sensors	Mobile applications designed for disaster management serve as valuable tools for on-the-go measurements in scenarios demanding swift responses. These portable applications are particularly designed to provide real-time data collection and analysis, contributing to reduced response times in critical situations. Their functionality is optimized for rapid deployment and efficient on-site measurements, ensuring a proactive and effective approach in disaster management scenarios.
Remote sensors	Thermal sensors, Aerosols, airborne optics.
Collective sensing	Collective sensing is a strategic approach employed in the management of incidents and disasters, as well as in the analysis of transportation patterns and the detection of disease outbreaks. This method involves the coordinated gathering of data from a variety of sources, facilitating a comprehensive and real-time understanding of the situation at hand. By harnessing collective sensing, decision-makers can derive valuable insights to optimize response strategies, enhance transportation planning, and proactively detect and address potential outbreaks of diseases.
People as sensors	Harnessing human observations as sensors is exemplified in applications such as flood monitoring and disaster or incident management. This method involves the utilization of crowdsourced data, particularly sourced from social media posts, to capture information regarding personal, environmental, or other external abnormalities. By tapping into this collective observational resource, organizations can obtain valuable, real-time insights that contribute to more effective responses and management strategies in the context of floods, disasters, or incidents.

Table 2.
Integrated sensor systems for smart cities [14].

Smart city component	Opportunities	Challenges
Government	The government plays a key role in the Smart City framework, offering opportunities such as Smart Government, intelligent buildings, public safety enhancements, smart grids, and optimized transportation and utility systems. This includes the implementation of advanced technologies like CCTV, GPS tracking, and incident-response systems to reduce and prevent crime.	The governmental component in the Smart City framework encounters significant challenges, including pronounced financial hurdles such as the volatility of energy prices. The substantial investment required for the implementation of modern solutions poses a major financial obstacle. Additionally, the perceived risk associated with investing in cutting-edge technologies may be deemed unfeasible under certain circumstances. Addressing these challenges necessitates strategic financial planning and risk mitigation strategies for the successful realization of Smart City initiatives.
Economy	The economic dimension is a crucial component within the Smart City framework, presenting opportunities that foster increased business prospects and attract investments in innovative solutions. This includes the potential for economic growth through the development and implementation of forward-thinking solutions and technologies.	The economic aspect of Smart Cities faces challenges, notably a lack of investment due to perceived cybersecurity risks in modern technological models. Overcoming these challenges requires implementing robust cybersecurity measures to instill confidence among potential investors.

Smart city component	Opportunities	Challenges
Smart citizens	Smart cities constitute a fundamental component within the broader Smart City framework, presenting opportunities that involve heightened awareness of advanced technologies and energy-efficient features. These initiatives aim to enhance the overall quality of life by fostering a technologically informed and environmentally conscious citizenry.	Smart Cities face challenges like cyberattacks, privacy violations, and a lack of technological awareness in minority communities. Addressing these issues requires robust cybersecurity measures and targeted initiatives for enhanced technological literacy.
IoT management	Promotes data availability and in synch with the various other components of a smart city.	Keeping hardware updated due to data coming from multiple sources. Overcoming connectivity issues. Waiting for government regulations and policies to permit the use of certain services.
Smart Mobility	Reduced traffic jams, reduced environmental and noise pollution energy consumption.	Electricity consumption in electric cars. Increased population growth increases the complexity of smart mobility requirements.
Sensor networks and human sensors	Flood Monitoring Disaster and incident management	Lack of communication infrastructure to link events and monitoring tools. An aggregate method of processing the data.

Table 3.
Challenges and research opportunities [2].

5. Challenges and research opportunities

In this segment, the challenges smart cities must go through will be revealed. Also any future research possibilities will be put into light.

6. Financial sustainability in ICT-driven smart city development

The utilization of smart city initiatives has evolved into a prevalent strategy employed by local governing bodies to improve the quality of services provided, bolster managerial efficacy, and foster citizen involvement in urban decision-making processes. The potential for leveraging data, information, and communication technologies (ICT) to optimize municipal operations holds immense promise. However, the financial viability of smart city initiatives may vary depending on the size and financial circumstances of the respective cities, leading some to perceive them as exorbitant investments with long-term maintenance challenges. To maximize the benefits arising from the intensive utilization of technology and data, city governments should prioritize the development of financially sustainable (FS) smart cities. The evaluation of smart cities' financial sustainability (FS) encompasses not only the temporal performance of local governments in implementing smart city initiatives but also the influence of economic and social contexts on their adoption. These contextual factors, in turn, shape investment decisions and expenditures on ICT infrastructure. Several international organizations have advocated for the adoption of FS strategies and policies within the public sector, serving as collective monitoring tools to reinforce financial discipline and mitigate financial and economic crises [15].

7. Anticipated trends and innovations in smart city research: a comprehensive overview

The forthcoming directions in smart city research encompass a broad spectrum of potential advancements, contributing to transformative developments in urban landscapes. Several key areas are expected to shape the trajectory of research in this field.

7.1 Integration of cutting-edge technologies

The continual assimilation and advancement of cutting-edge technologies, such as artificial intelligence (AI), machine learning (ML), and blockchain, aimed at enhancing the intelligence and efficiency of smart city systems.

7.2 5G proliferation and connectivity

The widespread deployment and optimization of 5G networks, fostering unparalleled connectivity and facilitating the seamless operation of interconnected devices and services.

7.3 Pervasiveness of edge computing

An increased focus on edge computing to process data closer to the source, reducing latency, and augmenting real-time decision-making capabilities in smart city applications.

7.4 Advanced data analytics

Progress in data analytics and predictive modeling, empowering cities to leverage big data for refined urban planning, resource allocation, and decision-making. Heightened Emphasis on Cybersecurity and.

7.5 Privacy measures

The development of robust cybersecurity measures and privacy solutions to address growing concerns associated with increased connectivity and data exchange inherent in smart city ecosystems.

7.6 Sustainable and resilient infrastructure development

Research concentrating on sustainable and resilient infrastructure, incorporating renewable energy sources, efficient waste management, and climate-resilient urban planning to tackle environmental challenges.

7.7 Citizen engagement and inclusive strategies

Emphasis on citizen-centric approaches, fostering increased citizen engagement through participatory platforms, and ensuring social inclusion in the development and implementation of smart city initiatives.

7.8 Establishment of interoperability standards

The formulation of interoperability standards to facilitate seamless communication and integration between different smart city components and systems, promoting a more cohesive and efficient urban environment.

7.9 Advancements in smart mobility and transportation

Continued progress in smart mobility solutions, including autonomous vehicles, intelligent transportation systems, and multimodal transportation options, to enhance urban mobility and alleviate congestion.

7.10 Integration of smart technologies for health and well-being

The integration of smart technologies to address public health challenges, focusing on remote healthcare monitoring, early disease detection, and creating healthier living environments.

7.11 Impact assessment on social and economic fronts

Research into methodologies for assessing the social and economic impact of smart city implementations, ensuring these technologies contribute positively to the well-being and prosperity of diverse urban populations.

7.12 Global collaboration and knowledge exchange

Increased collaboration and knowledge exchange among cities worldwide, fostering shared learning from successful implementations, dissemination of best practices, and collective efforts to address common challenges in the development and management of smart city projects.

These anticipated future directions underscore the dynamic and interdisciplinary nature of smart city research, reflecting the collaborative endeavors of researchers, policymakers, and industry stakeholders working towards creating more sustainable, efficient, and inclusive urban environments.

8. Conclusion

Enhancing the quality of life for citizens and bolstering governmental resources for urban development are pivotal advantages of smart city initiatives. These advancements, however, must be pursued with a steadfast commitment to environmental stewardship, public safety, and fiscal responsibility. This discourse delves into the comprehensive understanding of smart cities, elucidating their constituent elements and the intricate interconnections within the system. The identified challenges are juxtaposed with discerned opportunities, thus rendering the proposition of widespread implementation of smart cities more compelling. It is imperative to underscore that the benefits derived from smart cities far surpass the associated challenges. To successfully institute a smart city, concerted efforts from developers, engineers, and architects are indispensable, with a focus on pivotal domains such as Data Management, Internet of Things (IoT), and the integration of renewable energy resources.

Moreover, the inherent obstacles of security and privacy necessitate innovative solutions. It is imperative to acknowledge that while challenges exist, they are surmountable through the application of cutting-edge Information and Communication Technology (ICT) tools. In summation, the complexity intrinsic to smart cities affords a flexibility that can adeptly address myriad qualitative factors requisite for a contemporary society. Acknowledging the existence of challenges is imperative, yet through innovative approaches and ICT tools, these challenges can be effectively addressed, underscoring the compelling trajectory towards the realization of smart cities.

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Chapter 4

The Impact of Data Security and Privacy Concerns on the Implementation of Integrated Systems in Smart Cities

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Abstract

This chapter explores how data security and privacy issues affect the deployment of integrated systems, in cities. It discusses concerns, such as access, data breaches, consent mechanisms, data profiling, third party data sharing, transparency, data accuracy, cross border data transfers, rights of individuals regarding their data, security measures for data protection, and intrusive technologies, that invade privacy. The chapter thoroughly examines the impact of these concerns on integrated systems by highlighting risks like diminishing trust, legal and regulatory hurdles, and negative effects on individual rights and freedoms. Additionally, it delves into strategies and best practices for addressing data security and privacy issues in smart city initiatives. The importance of involving stakeholders conducting privacy impact assessments implementing privacy by design principles and adopting user centric approaches to mitigate risks and safeguard privacy is underscored. By emphasizing the role of addressing data security and privacy concerns in integrating systems within city's infrastructures provides valuable insights for stakeholders involved in smart city projects. Policymakers and researchers can benefit from this information to navigate the realm of data protection, within the realm of city development.

Keywords: smart cities, integrated systems, data security, privacy concerns, stakeholder engagement, privacy impact assessments, privacy-by-design, user-centric approaches

1. Introduction

Smart cities are quickly adopting interconnected systems that use technologies to improve efficiency, sustainability, and the overall well-being of their residents. These systems, which include linked devices, sensors, and data-driven applications, offer opportunities, for progress. However, concerns about data security and privacy have also arisen as considerations that could impact the implementation of integrated systems in smart cities.

The gathering, processing, and utilization of amounts of sensitive data in smart city projects raise valid concerns about safeguarding individual privacy and data security. With the increasing number of devices and data sharing networks, citizens and stakeholders are more aware of the risks related to data breaches, unauthorized access, surveillance activities, and misuse of information.

This section aims to explore how concerns about data security and privacy affect the implementation of integrated systems in cities. By examining the obstacles faced by stakeholders and assessing the repercussions of measures to protect data, this study aims to shed light on why addressing these concerns is crucial for the growth of smart cities.

To accomplish this goal, this section commences with an examination of existing literature on data security and privacy, within the realm of cities.

It pinpoints areas of focus such as access, data breaches, insufficient consent processes, data profiling, sharing data with third parties, transparency, data accuracy, international data transfers, rights of data subjects, security measures for data protection, and privacy invading technologies.

Expanding on these noted concerns, the document delves into how they impact the deployment of interconnected systems in environments. It delves into the dangers and repercussions linked to compromised data security and privacy like diminishing trust, legal hurdles, and adverse effects on individuals' rights and freedoms.

Moreover, this section delves into approaches and exemplary methods that can tackle worries about data security and privacy in smart city endeavors. It underscores the significance of involving stakeholders conducting privacy impact assessments incorporating privacy by design principles and adopting user focused strategies to diminish risks and ensure privacy safeguarding.

Through offering an examination of how concerns about data security and privacy affect the integration of systems in cities, this section seeks to enhance existing knowledge while underscoring the necessity, for proactive steps to address these concerns.

The results will hold importance for those involved in city initiatives decision makers and scholars providing direction on managing the realm of safeguarding data and privacy, within smart city progress. In essence the study highlighted in this section emphasizes the importance of prioritizing data security and privacy aspects to ensure the moral deployment of interconnected systems, in cities. By handling these issues stakeholders can build confidence protect individual freedoms and support the lasting development of smart cities to enhance the lives of all inhabitants.

2. Overview of smart cities and integrated systems

Smart cities represent a paradigm shift in urban development, utilizing advanced technologies and data-driven approaches to optimize various aspects of urban management and enhance the quality of life for residents. At the heart of smart cities are integrated systems that enable the seamless integration and coordination of diverse urban components and services. This overview aims to provide an introduction to smart cities, their goals, and the pivotal role of integrated systems in optimizing urban management.

Smart cities are urban areas that leverage advanced technologies and data-driven approaches to optimize urban management and improve residents' quality of life. They encompass integrated systems, connectivity, and innovative solutions across

various sectors. The integration of these systems, along with robust data security, privacy measures, and compliance with relevant regulations, is crucial for the successful development and implementation of smart cities.

Sanchez-Iborra et al. [1] provide a wide overview of the opportunities and challenges related to the necessary integration of smart city systems and communication solutions that are already available in the market. They highlight the potential of low-cost and efficient connectivity provided by technologies like LoRaWAN and Narrow Band-Internet of Things (NB-IoT) in fully integrating personal vehicles into smart city environments and enabling mobile urban sensing.

Digital technologies integrated into port logistics are increasingly crucial for port cities worldwide. D'Amico et al. [2] present a systematic literature review that focuses on smart and sustainable logistics initiatives within port cities. They develop a multidimensional framework that integrates enabling factors, domains, and goals to facilitate holistic development in areas such as ecosystem, internal organization, data and security, policy and regulation, finance and funding, and digital and technology.

Initiatives like Smart Cities and the Clean Development Mission launched by the Government of India aim to develop intelligent and sustainable cities. Integrated sensor systems are prerequisites for the practical implementation of smart cities since individual sensors alone cannot meet the complex information demands. The concept of smart cities is critical in providing end-users with increased performance, comfort, visibility, and convenience as cities and infrastructure continue to grow globally.

Anwar et al. [3] extensively discuss the concept of smart cities and Cyber-Physical-Social Systems (CPSS), covering key technologies, challenges, and further development through the use of CPSS. They explore and analyze the main applications of the Internet of Things (IoT) in smart energy systems, including smart industries, smart homes and buildings, and smart cities. The paper also addresses future trends, research directions, and reasons why industries should adopt this technology.

2.1 Goals of smart cities

The primary goals of smart cities are to enhance the quality of life for residents, promote sustainability, and improve the overall urban experience (**Figure 1**). This is achieved through various objectives, as follows:



Figure 1.
Goals of the smart cities.



Figure 2.
Role of integrated systems in the smart cities.

2.2 Role of integrated systems

Integrated systems lie at the core of smart cities, enabling the seamless convergence and interconnectivity of various urban subsystems. These systems integrate diverse components, such as sensors, devices, networks, and software platforms, to collect, analyze, and act upon data in real-time. They facilitate the exchange of information across sectors and enable urban managers to make data-driven decisions for efficient resource allocation, service delivery, and infrastructure optimization.

Integrated systems play a crucial role in optimizing urban management (**Figure 2**).

3. The importance of data security and privacy in smart cities

Ensuring the security and privacy of data is vital when implementing interconnected systems, in cities, which heavily rely on gathering, analyzing, and using volumes of information. Safeguarding these data are crucial to minimize risks and maintain the functioning of smart city operations. Satamraju and Malarkodi [4] suggest a method for authenticating devices and servers through Physical Unclonable Functions (PUFs) in devices to enhance security measures. However, concerns arise about data ownership and protection amidst the growing interest in collecting and utilizing information. Aslam et al. [5] stress the importance of addressing data breaches and leaks underscoring the need for measures. In this regard, modeling techniques are key to identifying threats to data privacy in AI systems and outlining strategies to address vulnerabilities effectively. Despite proposed threat modeling methods like STRIDE, LINDDUN, and PASTA Azam et al. [6] point out their limitations in tackling privacy threats within autonomous systems. These techniques often fall short in aligning with regulations such, as the EU/UK General Data Protection Regulation (GDPR) which're essential for safeguarding individuals data privacy rights and preventing privacy breaches.

To ensure the security and privacy of data, in cities, it is crucial to take an approach. This includes implementing authentication methods being proactive in preventing breaches and adhering to data protection laws.

- Safeguarding personal and sensitive data;

Smart cities collect a vast array of personal and sensitive information ranging from daily activities to health data. Without security measures, there is a risk of access, data breaches, and misuse of these data. This can jeopardize individual's privacy. Expose them to identity theft, fraud, or discrimination.

- Fostering public trust;

The success of cities hinges on the trust and confidence of their residents. If people feel that their personal information is not adequately safeguarded, they may hesitate to participate in city programs. This could result in reduced engagement and limited benefits. Establishing and upholding trust in data security practices is vital for the success and acceptance of smart city initiatives.

- Compliance with legal requirements;

Various regulations like the General Data Protection Regulation (GDPR) in Europe enforce responsibilities, on organizations handling data.

- Ensuring compliance, with these rules, is essential for smart cities to steer clear of consequences, financial penalties, and damage to their reputation. Data security and privacy protocols may lead to compliance issues and legal disputes.

- Risk of discrimination and surveillance;

The interconnected systems in cities facilitate the gathering and analysis of amounts of data, which can be utilized for profiling and automated decision-making. Without safeguards, this could pave the way for behaviors or unjustified monitoring of individuals. Lacking protection for data security and privacy could violate individual's rights erode trust and raise dilemmas.

- Utilization and data exchange;

Smart city ventures often involve partnerships with parties, including private enterprises and third-party service providers. Inadequate measures to safeguard data security and privacy may result in use of data or improper sharing with external entities. This could lead to misuse of information, loss of control over data, and breaches of individuals' privacy rights.

- Diminishing personal autonomy;

Smart cities strive to enhance urban living through data-driven services and interventions. However, inadequate safeguards for data security and privacy might compromise autonomy and authority, over information. If individuals lack safeguards, they may struggle to comprehend, agree to, or oversee how their data are gathered, utilized, and distributed. This limitation, on their independence, could encroach upon their privacy rights.

- Concerns regarding cybersecurity and data breaches;

Smart cities are susceptible to cyberattacks due to their reliance on interconnected systems. Insufficient data security measures can expose vulnerabilities that malicious individuals may exploit, resulting in data breaches, service interruptions, and compromised infrastructure. The repercussions of events can be significant including setbacks, risks to public safety, and harm to the smart city's reputation.

In summary, ensuring data security and privacy is crucial when integrating systems in cities. Insufficient safeguarding of sensitive data can introduce risks, such as access, data breaches, discrimination, erosion of public confidence, legal disputes, and diminished individual autonomy. It is imperative for smart cities to prioritize data security practices, incorporate privacy-focused design principles, and comply with data protection laws. By taking these steps, smart cities can establish trustworthiness safeguarding individual's privacy rights and promote the responsible and ethical utilization of data. This approach fosters the development of cities for the betterment of all inhabitants.

4. Data governance and regulatory frameworks

The management of cities is a diverse issue that demands a deep understanding of the various policies and structures, in place. Drapalova and Wegrich [7] introduced a framework and classification system that encompasses types of smart city policies and governance merging existing studies on smart city governance with business state relation theories from political economy. Tan and Taihagh [8] carried out a review of literature exploring the progress of city initiatives in developing nations including the concepts, motivations, as well as unique factors influencing (and hindering) smart city progress.

Data management and regulatory practices play a role in promoting growth within smart cities. Numerous countries have established guidelines and regulatory frameworks to safeguard data privacy and security while fostering trust. Nonetheless, striking a balance between regulations that promote innovation and those that ensure data privacy and security is an aspect in shaping data governance frameworks for cities. Data governance frameworks centered around citizens that address dilemmas effectively are essential for the lawful utilization of data, in smart cities. Strong data governance structures, combined with open data policies, are being recognized as strategies to encourage innovation and public involvement in the advancement of cities.

Creating rules and structures to safeguard data is crucial, for improving the quality of life through technology in cities. These regulations strike a balance between fostering innovation while also protecting data privacy and security. They form a groundwork for the use and sustainable advancement of technology in urban settings. A holistic approach to managing data frameworks is key to the execution of city projects ensuring that data is handled responsibly and securely.

Data governance frameworks and regulatory actions are pivotal in upholding data privacy and security within cities. These frameworks establish standards, ethical principles, and regulations that oversee how data are gathered, stored, processed, shared, and safeguarded within city endeavors. Developing data governance frameworks that harmonize innovation with data protection is essential for implementing smart city projects and fostering sustainable growth in urban landscapes.

In this part, we will explore existing data governance frameworks and regulatory measures in smart cities and assess their effectiveness.

- The General Data Protection Regulation (GDPR);

GDPR, which has been enforced in the European Union, establishes guidelines for safeguarding information. It places responsibilities on organizations concerning how they collect data obtain consent ensure transparency maintain security measures and uphold individuals' rights. The global impact of GDPRs enforcement beyond EU borders along with its penalties, for non-compliance, has influenced privacy standards worldwide.

While the GDPR is not solely focused, on cities, it does apply to the processing of data in smart city settings. The GDPR has played a role in enhancing privacy protection by increasing awareness promoting transparency and reinforcing individuals' rights. However, its impact on cities can vary due to the intricacies of data management and the necessity for tailored guidance to smart city projects.

- Numerous organizations and groups have developed frameworks and guidelines tailored to cities. For instance, there are the European Commissions "Ethics Guidelines for Trustworthy AI" and the International Electrotechnical Commissions (IEC) "Smart City Privacy and Security Best Practice Standards." These frameworks address issues like data governance, security, and privacy within the realm of cities.

These frameworks offer insights and best practices for managing data in cities. However, their effectiveness depends on how they are adopted and put into practice by stakeholders involved in smart city initiatives—something that can differ from one region or city to another.

- Many countries have enacted regional regulations that deal with data security and privacy concerns in relation to cities. These regulations may cover aspects such as data protection measures, consent procedures, data sharing protocols, and cybersecurity standards and mechanisms, for ensuring accountability.

Examples include the California Consumer Privacy Act (CCPA), in the United States, and the Personal Data Protection Act (PDPA), in Singapore. The effectiveness of regional regulations lies in their ability to establish a framework for data governance in smart cities, which hinges on enforcement, compliance, and adaptability to evolving technological advancements and emerging privacy concerns.

- International standards organizations like ISO (International Organization for Standardization) develop standards concerning data security and privacy. For instance ISO/IEC 27001 focuses on information security management systems, while ISO/IEC 27701 provides guidelines for privacy information management systems. These standards can be applied to city projects to ensure data governance.

International standards offer a recognized framework for data security and privacy with their effectiveness contingent upon adoption by smart city stakeholders and alignment with regulations.

- Data protection authorities (DPAs) are entities entrusted with enforcing data protection laws and regulations. DPAs oversee compliance, investigate

complaints, and impose penalties for violations while providing guidance and support to organizations on implementing data security measures.

- Effectiveness: the effectiveness of DPAs is determined by factors, such as resources, expertise levels, and enforcement capabilities.
- Assessing effectiveness: their active involvement, with stakeholders in cities, can improve adherence and support management of data. Evaluating effectiveness: the success of data management frameworks and rules in cities relies on aspects.
- Awareness and acceptance: the degree of awareness and acceptance of these frameworks by stakeholders in smart cities is crucial for their effectiveness. Education and proactive engagement can boost compliance. Engaging with stakeholders proactively is essential for gaining acceptance. By including stakeholders, in decision making soliciting their feedback and addressing their worries cities can foster a feeling of ownership and teamwork. This involvement can take place through consultations, discussions, advisory boards and other forms of participation.
- Technological adaptability: it is essential for the frameworks to adapt to technologies and changing smart city environments offering practical guidance for safeguarding data within interconnected systems, IoT devices, and emerging data centric technologies.
- Collaboration and standardization: cooperation among stakeholders establishing practices for data management and ensuring compatibility across city initiatives can enhance the effectiveness of regulatory measures.
- Enforcement and responsibility: implementing enforcement procedures penalties for compliance and accountability measures is necessary to ensure adherence to data management frameworks and regulations.
- Privacy oriented design approach: integrating privacy-oriented principles into stages of city projects can strengthen the efficiency of data management frameworks by incorporating privacy and security considerations into the development process.

In conclusion, data governance frameworks along with measures play a role, in safeguarding data security and privacy in smart cities.

Although the current frameworks and rules serve as a base, their success relies on understanding, teamwork, technological flexibility, enforcement, and responsibility. Continuous assessment, improvement, and adjustment of these structures are vital to tackle the changing obstacles and advantages brought about by city projects and to guarantee the ethical handling of data, in city settings.

5. Smart city's challenges in addressing data security and privacy concerns

In years, cities have made advancements in becoming smarter leading to the introduction of programs aimed at enhancing the quality of life with a focus, on

technology Tubaishat and Jouhi [9] offer insights into the security aspects of cybersecurity within cities. However, as cities worldwide undergo transformation, it brings forth concerns related to privacy, safety, health, and security. A clear global strategy is essential for ensuring the growth of cities encompassing viable business models and healthy competition among various smart city environments. Lindgren [10] explores business models in the realm of smart cities and emerging wireless technologies while addressing the obstacles and opportunities linked to increasing urbanization and eliminating poverty.

Addressing security and privacy issues, in cities, requires the expertise of network security professionals. Ilgi and Ever [11] critically examine security challenges related to drone networks evaluating existing solutions found in literature. As smart devices become more complex and interconnected, they bring forth challenges related to safety, security, privacy, and user friendliness. Fu et al. [12] emphasize the interdependence of these challenges and advocate for solutions that address all these aspects simultaneously.

Ahmed et al. [13] delve into the security concerns surrounding city applications and propose solutions utilizing artificial intelligence and machine learning. They discuss efforts aimed at addressing privacy and security issues in areas, like health-care, transportation, and energy management. Privacy, security, confidentiality, and authenticity play roles in managing data within smart city infrastructures. In a study, Chen et al. [14] introduce the Holistic Big Data Integrated Artificial Intelligent Modeling (HBDIAIM) to enhance privacy and security aspects across smart city applications.

Within the realm of cities, the application of Blockchains security mechanisms in IoT based systems is meticulously explored for their importance in ensuring security. Yu and team [15] categorize these mechanisms into three areas within IoT-based cities (smart healthcare, home automation, and agricultural technology) (**Figure 3**).

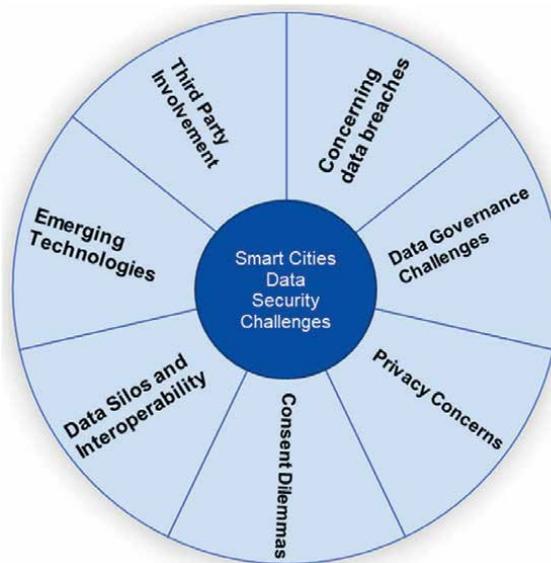


Figure 3.
Smart city's data security challenges.

- **Data breaches:** the growing interconnectedness among components of city systems exposes potential vulnerabilities that malicious actors can exploit. A successful breach could jeopardize infrastructure operations, disrupt services, or compromise resident's personal information. To address these risks effectively, proactive cybersecurity measures like encryption protocols, intrusion detection systems, and routine security assessments are essential, for safeguarding cities against cyber threats.
- **Data governance challenges:** in cities, data are gathered from sources, such as sensors, IoT devices, social media, and government databases. Maintaining data governance among stakeholders and systems can be quite tricky. It involves setting up rules, regulations, and standards for how data are collected, stored, accessed, shared, and kept. Collaboration between government bodies private companies and residents is essential to create enforceable data governance frameworks.
- **Privacy concerns:** the extensive data collection capabilities of cities raise privacy worries. Residents may be concerned about the surveillance potential of sensor networks and the risk of data misuse. Smart cities need to adopt privacy by design principles such as minimizing data collection anonymizing information and restricting its use to ensure that personal details are safeguarded and used for purposes. Open communication about data practices and privacy protections is vital to establish trust with residents.
- **Consent dilemmas:** securing informed consent from residents for collecting and using their data poses challenges in smart city environments. The difficulty lies in making sure individuals grasp the implications of sharing their information while also having control, over it while still benefiting from services driven by data.
- **Smart cities must establish consent processes offer understandable information on data practices and engage in open discussions to address concerns and foster trust among residents.**
- **Data silos and interoperability:** smart cities frequently use systems that generate data in silos. It is crucial to integrate and share data from these silos to gain insights and provide services. However, ensuring interoperability while upholding security and privacy standards can be a task. To facilitate privacy data sharing, smart cities should invest in open data standards, APIs, and data integration platforms.
- **Emerging technologies:** smart cities often embrace technologies like AI, machine learning, and Big Data analytics to analyze amounts of data. While these technologies offer opportunities for insights, they also bring security and privacy risks. For instance, AI algorithms could unintentionally perpetuate bias or compromise privacy if not carefully designed and monitored. To effectively manage these risks, smart cities need to stay informed about advancements conduct risk assessments and implement safeguards.
- **Third party involvement:** smart cities frequently collaborate with vendors for service delivery. However, engaging parties, in data management, poses security and privacy challenges.

Smart cities must create contracts, with suppliers conduct thorough investigations into their security protocols and put in place monitoring systems to verify adherence to security and privacy guidelines. By tackling these obstacles proactively, smart cities can boost data security, safeguard privacy, and foster trust among citizens. This demands a strategy that integrates solutions, policy structures, community involvement, and cooperation among various parties to establish a safe and privacy aware setting, for city driven by data.

6. Privacy concerns in smart cities: surveillance and individual rights

Mann et al. [16] suggest that smart cities have the potential to gain social acceptance. They discuss the progress of city initiatives with a focus, on corporate influence and urban platforms. In a study involving participants from the United States, Kokkoris et al. [17] explore the factors that impact peoples readiness to compromise rights and embrace surveillance in relation to communal responsibilities. Their study expands on research by revealing that perceived communal responsibility is linked to the willingness to accept limitations on rights, privacy infringements, and digital monitoring for public health reasons.

The issue of privacy emerges due to the implementation of video surveillance systems in cities as location data are highly sensitive. Striking a balance between location privacy and functionality presents a challenge that warrants exploration by researchers. Additionally, discussions in policy circles regarding privacy within cities are centered around data protection regulations; however, obstacles exist that could impede their effective application in such projects. Galic and Gellert [18] investigate one obstacle concerning whether data processed in smart city contexts qualify as data, under data protection laws.

Exploring the impact of privacy literacy (OPL), on the privacy worries of Internet users, a study by Prince et al. [19] delves into users understanding of privacy rights and protective measures. They gauge privacy literacy through knowledge about privacy and declarative knowledge about privacy.

The rise of sensors and data collection devices in cities in years driven by both public and private entities has brought about democratic challenges concerning AI surveillance capitalism and safeguarding citizens digital rights to privacy and ownership. Calzadas work in 2021 underscores the significance of citizens' viewpoints and societal responsibility within evolving frameworks. The publication raises the issue of transforming data governance models to promote citizenship via data possession and technological independence. It stresses the importance of urbanism based on platforms, such as data cooperatives.

The advanced data gathering capabilities present in cities, including surveillance methods such as CCTV cameras, facial recognition systems, sensors, and drones, for monitoring areas and collecting information pose notable concerns regarding individual privacy rights. In this context, we examine the privacy issues stemming from these practices within smart city environments.

- *Mass surveillance;*

Smart cities frequently utilize surveillance technologies including closed circuit television cameras (CCTV) facial recognition systems, sensors, and drones for overseeing spaces and gathering data.

While surveillance has the potential to improve safety and enhance resource management efficiency, it also sparks worries, about privacy infringement. The constant monitoring of people's activities in spaces may diminish the sense of anonymity and contribute to a pervasive culture of surveillance.

- *Data. Location information;*

The smart infrastructure in cities comprising interconnected devices and mobile apps gathers location data. This information can be utilized to monitor individuals movements, behavior patterns, and preferences. While such monitoring can facilitate tailored services and urban development planning, it also raises concerns about misuse or unauthorized access to these data. The compilation and examination of location data can unveil details about individuals lives potentially compromising their privacy.

- *Data interconnectivity and profile building;*

In environments data sourced from diverse outlets like transportation systems, energy networks and social platforms can be interconnected and scrutinized to construct comprehensive profiles of individuals. This interlinking of data allows for marketing efforts, personalized services, and urban enhancements. Nonetheless, it also raises apprehensions about the likelihood of discrimination, manipulation, or unauthorized access to details well as the lack of transparency, in the profiling procedure.

- *Informed consent and control;*

Issues, with privacy emerge when people lack information about how their data are collected, used, and shared in smart cities. Without consent processes, individuals may not fully understand how their data are being used and may have limited say over its usage. This lack of control and consent can impede people's independence and violate their privacy rights.

- *Data security and breach risks;*

The data gathering and storage systems in cities pose risks of potential data breaches and unauthorized access. If personal information is compromised, it can result in identity theft, fraud, or other forms of misuse. Proper security measures are essential for safeguarding the privacy of individuals when handling information like records or financial data.

- *Lack of anonymization and de identification;*

Maintaining anonymity and ensuring de identification are vital for protecting privacy in the context of city data collection. However, challenges arise in anonymizing and deidentifying data especially when combining data sources. Risks such as reidentification attacks and unintended data linkages can weaken the privacy safeguards for individuals.

- *Surveillance creep and function creep;*

Privacy concerns escalate when surveillance capabilities extend beyond their intended use or are employed for purposes, beyond what individuals agreed to.

Surveillance creep refers to the expansion of surveillance practices, while function creep occurs when data collected for one purpose are repurposed for uses without individuals knowledge or consent. Both these phenomena can result in an increased scope of data collection and potential privacy violations.

- *Implications, for individual privacy rights;*
- The advanced data collection capabilities of cities have implications for privacy rights, as follows:
 - Right to privacy;

The right to privacy acknowledged by international human rights frameworks safeguards individuals against arbitrary or illegal interference with their privacy. Smart city surveillance and data collection practices must uphold this right by ensuring that individuals have control over their information and are shielded from unjustified surveillance.

- Transparency and accountability;

Smart cities should prioritize transparency and accountability in their data collection methods. Individuals have the right to be informed about what data are being gathered, how they are utilized, and who can access them. Clear data protection policies, consent procedures, and robust oversight mechanisms are crucial, for maintaining accountability and fostering trust.

- Data minimization and purpose limitation;

Smart cities should embrace principles of data minimization by collecting data for valid purposes. They should also adhere to purpose limitation guidelines to ensure that collected data are used solely for the purposes consented to by individuals.

To prevent the gathering and utilization of information, it is essential to incorporate the principles of privacy, by design and default into the development and deployment of smart city technologies. These principles ensure that privacy considerations are integrated from the beginning guaranteeing that privacy protections are ingrained in the design, structure, and operation of systems and services.

- Individuals should have the authority to control their data and provide informed consent for its collection, usage, and sharing. Clear consent mechanisms should be established to enable individuals to make decisions about their data usage and easily revoke consent when needed.

In order to preserve privacy, smart cities should prioritize data anonymization techniques. Furthermore, robust data security measures must be put in place to defend data against breaches and unauthorized access.

In summary, the extensive data collection capabilities of cities pose privacy risks related to surveillance and tracking. It is crucial for smart cities to strike a balance between leveraging the benefits of data-driven services while safeguarding privacy rights. Emphasizing transparency, accountability, and individual control over data is paramount, for city initiatives.

In cities, it is important to follow privacy guidelines such as privacy by design and default data minimization and purpose limitation. Strong data anonymization and security measures should also be in place to address privacy issues effectively. Finding the balance between leveraging data for development benefits and safeguarding individual privacy is key to fostering trust and maintaining ethical data practices, in smart city projects.

7. Citizen perspectives on data security and privacy in smart cities

Peoples perspectives and attitudes are key in influencing how integrated systems are embraced and used in cities especially when it comes to data security and privacy. It is crucial for planners, policymakers, and tech providers in cities to grasp how residents view and react to these issues. The dynamic interaction among residents in cities poses challenges regarding security and privacy. Akhuseyinoglu and Joshi [20] offer insights into the technologies driving city advancements and the associated security and privacy concerns. Smart cities encounter obstacles due to budget limitations diverse stakeholder needs and the growing demand for progress. Liu et al. [21] outline five areas related to private partnerships (PPP) for smart city growth, such as integrating innovation engaging citizens effectively ensuring data security during sharing updating PPP processes and fostering urban sustainability. Safeguarding data security and privacy requires attention at levels of administration and geography. Several studies delve into the risks facing information security within cities emphasizing threats to data security well as the difficulties, in managing personal information effectively.

Concerns regarding privacy, management of cloud servers by parties, and vulnerabilities related to points of failure data flow congestion and challenges in maintaining security and firmware updates for smart devices often arise.

A recent study by Uddin [22] delves into the analysis of blockchain technology advancements for the Internet of Things (IoT) and its applications in eHealth, smart cities, intelligent transport systems, and other domains. The research explores how blockchain can enhance security and privacy in managing scale drone-assisted environmental monitoring activities that offer data for key aspects of smart cities. However, establishing trust among drone operators poses security hurdles such as real-time monitoring concerns, collaborative task execution issues, data privacy matters, and location privacy considerations.

One critical technical feature in cities is the deployment of sensors to gather real-time data. In their work, Khalil et al. [23] provide an updated evaluation of authentication mechanisms leveraging technology to enforce decentralized architectures. This addresses the necessity for reliable data collection processes well as decision-making frameworks across various city functions and citizen requirements. Here are some essential elements to take into account:

- **Trustworthiness and assurance:** the trust resident's place in smart city initiatives significantly influences their willingness to engage with integrated systems. An individual's concerns, about data security and privacy, could diminish trust levels if not appropriately managed.
To establish trust, it is important to communicate, have guidelines for data management, and show a strong commitment to safeguarding resident's personal information.
- **Privacy concerns:** it's natural for residents to be worried about how their personal data are collected, stored, and used in cities. They may fear surveillance, misuse of data, or unauthorized access. Addressing these concerns and integrating privacy-focused principles can help ease worries. Ensure that privacy is a focus in the design and operation of connected systems.
- **Balancing benefits with risks:** residents weigh the advantages of systems against the risks to their privacy. Smart city projects need to highlight the benefits like increased efficiency, better services, and sustainability while also addressing privacy concerns and showcasing measures taken to minimize risks.
- **Empowering control and consent:** residents value having control over their information. They want transparency on what data are gathered, who can access them, and how they will be used. Offering clear consent options and giving residents control over their data empower them to make choices, about their information fostering a sense of ownership and engagement.
- **Education and awareness;** many residents may not fully grasp the complexities of data security and privacy in cities.
- **Educational programs** that inform residents about the advantages, risks, and protections concerning data collection and usage can empower individuals to make informed decisions and foster meaningful conversations.
- **Involving residents,** in decision-making processes and seeking their feedback on data security and privacy issues, can increase acceptance and implementation. By engaging citizens through discussions, citizen panels, or collaborative design approaches, we can develop systems that better reflect their values and needs.
- **Finding the equilibrium** between personalization and anonymization is essential in city systems that offer tailored services based on individual data. Respecting privacy requires understanding residents' preferences for personalization levels and data anonymization practices.
- **Instances of data breaches** or negative media coverage related to data security can significantly influence perceptions. These incidents may heighten worries diminish trust and breed skepticism about the security protocols employed in cities. Open communication during these times is crucial for rebuilding trust.

Considering citizen viewpoints on data security and privacy matters stakeholders, in cities, can address concerns effectively build trust within communities and create integrated systems that meet residents' expectations. Involving community members

as collaborators, in the decision-making process and incorporating privacy-focused methods, can create a welcoming atmosphere for embracing and utilizing integrated systems, within areas.

8. Empowering residents: ensuring personal data control in smart cities

Ensuring that residents are empowered and have control, over their data, is an element in the development and implementation of smart city technology. Foth et al. [24] suggest the Data Care model as a strategy for cities to uphold the license needed for operating smart city technology with a focus on citizen empowerment and personal data control. Similarly, Grünewald and Reisch [25] present survey findings on attitudes toward sharing location data in the UK emphasizing the importance of trust and social perceptions of privacy data in relation to energy services. These results highlight the need for data access, ensuring personal data control to build trust among residents.

Following these principles, Mendoza and Behrens [26] introduce Arbiter, a communication framework based on the concept of a Decentralized Autonomous Organization (DAO) designed to improve city operations while also prioritizing resident empowerment and personal data control.

The importance of allowing residents to have authority over their information cannot be overstated, as it plays a role, in preserving privacy and fostering trust within smart cities.

By focusing on empowering citizens and giving them control, over their data, smart cities can maintain privacy, foster trust, and create a positive living environment for their residents. Here are some key strategies that smart cities can embrace:

1. **Transparent data practices:** smart cities should offer easily accessible information to residents about the data being collected, how they are used, and who they are shared with. This transparency helps residents make decisions about their data and understand how they handled.
2. **Consent mechanisms:** smart cities should have consent mechanisms in place that allow residents to give well-informed consent for data collection and usage. Residents should be able to choose what types of data they are sharing and for what purposes. They should also have the option to revoke their consent at any time.
3. **Privacy by design principles:** smart cities should follow privacy by design principles by integrating privacy safeguards into the design and development of their systems from the start. This includes using strategies to minimize data collection, techniques for anonymizing data, and robust security measures to safeguard information.
4. **Citizen-centered data access:** in cities, residents are empowered through tools and interfaces that allow them to manage their personal data. This can involve user dashboards or mobile apps where residents can check their data control access permissions and exercise rights, like correcting or deleting their information.
5. **Data mobility:** smart cities should make it easy for residents to move their data to platforms or services if they wish. This supports data ownership and grants residents the flexibility to decide how their data are used.

6. Education and empowerment: smart cities ought to invest in public awareness campaigns to educate residents about data privacy rights, risks, and best practices. By offering resources and empowering residents with knowledge, they can make choices regarding their personal data and actively engage in safeguarding their privacy.
7. Robust data protection policies and regulations: smart cities need to establish data protection policies and comply with regulations to protect the personal data of residents. This involves implementing organizational measures for ensuring data security conducting regular assessments and providing channels, for reporting privacy issues or breaches.

9. Involving residents in decision-making for data security and privacy in smart cities

Engaging residents, in the decision-making processes concerning data security and privacy, plays a role in fostering trust ensuring responsibility and aligning city projects with the needs and expectations of citizens. Researchers of [27] delve into areas such as transportation, environment, emergency services, public safety, energy management, and social sensing. They highlight decision-making challenges like balancing safety with service needs addressing security concerns, managing uncertainties involving input, and safeguarding privacy. A growing body of research focuses on security issues, privacy concerns, and risks within smart city environments by shedding light on threats to data security and the complexities of handling information. Valuable insights provided by Ismagilova [28] offer guidance for research endeavors.

To enhance services in cities like amenities and transportation systems, a range of technological solutions including IoT sensors, Big Data analytics tools, and communication networks are being deployed to gather and analyze data. However, this advancement brings about challenges related to optimizing energy consumption practices implementing decision-making mechanisms ensuring data privacy and security facilitating communication technologies as highlighted by researchers [29].

The governance of cities faces risks stemming from technology-related factors, organizational dynamics, and external influences making it vulnerable, to manipulation.

A thorough review conducted by Bastos et al. [30] aims to offer an overview of research studies utilizing smart city infrastructures to enhance citizen involvement, in city management and governance. The review delves into the objectives of these studies, the features of proposed solutions regarding data sources, data quality, and data security, and privacy measures as approaches to encourage citizen participation and the stages of development of reported applications. The findings underscore the emphasis on creating applications that enable citizen engagement empowering them to spot issues and contribute to decision-making processes. Below are some methods that stakeholders in cities can use to involve residents in these procedures:

1. Public consultations: arrange consultations where residents can share their views, ask questions, and voice their concerns about data security and privacy in smart city initiatives. These consultations can be conducted through town hall meetings, open forums, or online surveys. The feedback received can help shape policies, guidelines, and practices.

2. Citizen panels: form citizen panels or advisory groups comprising a mix of residents representing demographics and interests. These panels can offer input and recommendations, on matters related to data security and privacy, ensuring that multiple viewpoints are considered.
3. Utilize design methods that engage residents, in the creation and advancement of city systems and services. This strategy enables citizens to share their perspectives, preferences, and concerns from the start of a project empowering them to participate in decision-making processes.
4. Conduct privacy impact assessments (PIAs) with the involvement of residents. These assessments evaluate the privacy risks associated with city initiatives and suggest ways to mitigate these risks. By engaging residents in the assessment process, their insights and concerns are valued, ensuring that privacy issues are appropriately addressed.
5. Designate privacy: community ambassadors to advocate for resident's privacy rights. These individuals can facilitate discussions between smart city stakeholders and residents educate the community on data security and privacy matters and act as intermediaries during decision-making processes.
6. Implement awareness campaigns and educational programs to educate residents about data security and privacy within cities. These efforts may include workshops, webinars, informational materials, and online resources aimed at helping residents comprehend the implications of data collection and their rights regarding privacy protection measures, in place.
7. Creating channels, for easy communication: set up communication channels for residents to easily reach out with any questions, concerns, or suggestions regarding data security and privacy. This can involve helplines, online chat services, or email contacts. Responding promptly and transparently to inquiries showcases a dedication to engaging with residents.
8. Trial runs and showcases: introduce small-scale pilot projects or demonstrations that enable residents to test and provide feedback on integrated systems before implementation. This method offers examples for residents to assess ask questions about and express their views on data security and privacy aspects.
9. Educational workshops on privacy: arrange workshops and training sessions that equip residents with knowledge and resources to safeguard their privacy in the era. Topics may cover practices in securing data, understanding privacy settings, and identifying potential risks.
10. Transparency in data management: proactively communicate the types of data being collected, their usage, and who can access them. Provide residents with user tools and interfaces, for accessing and reviewing their data, while comprehending how they are shared and utilized.

10. Implications of data security and privacy on service delivery in smart cities

Data security and privacy are factors affecting the delivery of services and the optimization of infrastructure, in smart cities. Issues like limitations on data sharing, trust concerns, and potential disruptions all play a role in this impact. Sengan et al. [31] propose a cybersecurity architecture for cities to bolster cyber physical systems and safeguard public data networks. Their approach involves assessing threats and creating strategies to protect data integrity. In Ma et al's. [27] study, they delve into decision-making challenges in cities across various domains such as transportation, environment, emergency response, energy management, and social sensing. These challenges encompass conflicts between safety and service delivery security measures dealing with uncertainties, involvement in decision -making processes, and ensuring privacy.

The stages of data collection, processing, and storage are susceptible to security breaches that could have consequences. Currently, there is a lack of knowledge for implementing smart city services effectively. To bridge this gap, Naqvi et al. [32] introduce a framework that identifies challenges, within smart city applications, and proposes solutions to address them.

Thoroughly examining the risks associated with IoT-based technology applications, Devarakonda et al. [33] conducted a study based on data extracted from 30 peer-reviewed publications spanning the years 2014–2017. Their findings reveal that smart transportation faces the security and privacy challenges, at 20% closely followed by smart home (19%) and smart cities (18%) when compared to other application areas.

In the shift toward establishing cities through the utilization of information and communication technology (ICT), creating an infrastructure that fosters enhanced connectivity among citizen services, energy resources, economic activities, and governmental functions plays a role in driving economic growth. Sarim et al. [34] propose an approach aimed at enhancing privacy protection through data fusion and service recommendations within city settings. Their methodology involves obfuscating user data to safeguard privacy generating time indices corresponding to the data and transmitting them to cloud platforms for fusion processes and service suggestions.

These research studies underscore the importance of addressing cybersecurity challenges concerning data security and privacy in domains within smart city contexts. By implementing cybersecurity frameworks tackling decision-making hurdles as well as devising innovative strategies and methodologies, smart cities can enhance their capability to safeguard data integrity, ensure user privacy, and optimize infrastructure for the betterment of residents. Now, let us delve into an examination of these factors:

- *Constraints, on data sharing;*

Sharing data is crucial in cities to facilitate collaboration among parties and improve services. However, concerns about data security and privacy can restrict data sharing. Stakeholders may hesitate to share data due to worries about breaches, unauthorized access, or misuse. This reluctance in sharing data can impede the generation of insights and cooperative solutions affecting service provision and infrastructure enhancement.

- *Trust concerns;*

Issues related to data security and privacy can undermine the trust of residents and stakeholders in city projects. If people feel that their personal information is not adequately protected or their privacy is at risk, they might be hesitant to interact with smart city services or provide their data. The lack of trust can impede the collection of comprehensive information making it difficult to optimize infrastructure and deliver services.

- *Possible disruptions;*

Security breaches or violations of privacy could disrupt the operations of cities. A breach could jeopardize systems, interrupt services, and lead to losses. For example, if a transportation system is targeted by a cyberattack, it could cause service disruptions, delays, or safety hazards for passengers. These disruptions not only affect service delivery but also diminish public confidence, in smart city initiatives and infrastructure.

- *Regulatory compliance;*

In the realm of cities, navigating the web of regulations surrounding data protection and privacy is essential. Complying with these rules is paramount, to upholding trust and steering clear of ramifications. Yet the strict privacy regulations can pose challenges in sharing data, utilizing them effectively, and optimizing infrastructure. Finding a balance between following regulations and efficiently providing services is a nuanced task for city leaders and stakeholders.

- *Privacy preserving techniques;*

Smart cities can tackle concerns regarding data security and privacy by employing techniques that safeguard information. Practices like data anonymization, encryption, and differential privacy enable the use and analysis of data while safeguarding privacy. Embracing these methods allows smart cities to foster trust promote data sharing and enhance infrastructure without compromising privacy rights.

- *Collaborative governance;*

Establishing governance structures that promote collaboration among stakeholders is crucial in addressing issues related to data security and privacy. Implementing policies, guidelines, and standards for safeguarding data can help instill trust among stakeholders while ensuring data usage. Collaborative governance encourages involvement, from residents, businesses, academic institutions, and government bodies to make decisions regarding matters concerning data security and privacy.

- *Efficient response strategies;*

Ensuring the safety of cities requires security systems and efficient incident response strategies. This involves incorporating cybersecurity protocols carrying out

security assessments and creating reliable plans, for responding to incidents promptly. Detecting and addressing security issues swiftly can reduce the impact of disruptions. Reassure residents, about the dependability and safety of smart city amenities.

11. Legal and ethical considerations in smart city data management

The implementation of city technologies and the vast gathering of data pose legal and ethical concerns regarding data security and privacy. These concerns revolve around finding a balance, between the interests of the public, individual rights, and the obligations of city authorities and technology providers. It is essential from a perspective to comply with EU regulations on data, data recycling, and safeguarding personal information while managing the extensive processing of citizens data alongside the right to privacy and nondiscrimination. According to Ruiz [35], there are risks associated with breaching this right within smart cities due to the utilization of Big Data and AI.

The pursuit of city progress requires an infrastructure for the era of Big Data. El-Ghalayini and Al-Kandari [36] examine how Dubai upholds and advances infrastructure to sustain its globally acknowledged successful status as a smart city. Nonetheless, the gathering and utilization of information, by city initiatives, present intricate operational and ethical dilemmas that should be investigated through closely monitored trial programs before wider implementation.

Qin and Qi [37] make a contribution, to the realm of governance by exploring the definition and practical implementation of smart cities in the urban development landscape of China. This exploration has brought to light challenges that have impacted the country's legal framework.

Looking into instances, Strover et al. [38] delve into the use of camera technologies, those enhanced by AI and video data collection in various smart cities. They reveal that law enforcement interests, coupled with promises of cost efficiency and environmental management improvements, have been factors driving these systems. Contrary to the belief that automation alone can achieve "smartness" Komninos [39] concentrate on initiatives that truly enhance city's intelligence.

Although ethical discussions around cities have often revolved around data handling including collection, processing, utilization, storage, and sharing, Ehwi [40] advocate for broadening these conversations to encompass decision-making processes within smart city governance and their ethical foundations.

Considering these dialogs Haan et al. [41] conduct a review of works, on smart cities and safety measures. They scrutinize both commercial and policy narratives shaping city projects in Rotterdam while also examining safety practices that may not be explicitly labeled as "smart."

They support the idea of integrating safety measures systematically into discussions, about cities to promote openness, thoughtful consideration, and democratic credibility. In essence striking, the balance between progress, legal adherence, ethical principles, and citizen concerns is essential for the effective and conscientious growth and management of smart cities. Let us delve deeper into these aspects:

- *Public interest;*

The goal of cities is to elevate well-being boost efficiency and tackle urban issues. Data collection and analysis are pivotal in achieving these objectives. Public interest

encompasses advantages like enhanced planning, optimized resource utilization, improved safety, and tailored services. Legal and ethical aspects should acknowledge the benefits that smart cities bring to the community at large.

- *Individual rights;*

Respecting rights forms a core component of ensuring data security and privacy in cities. These rights encompass privacy rights, autonomy, and control over data. Individuals should be empowered to provide consent for data collection, access their data for corrections if needed, and have clarity on how their data are utilized. Balancing interest, with rights entails safeguarding individuals' privacy while handling their data ethically and responsibly.

- *Data protection laws and regulations:*

Laws and regulations related to data protection vary from place to place. Smart cities need to follow these rules to protect peoples rights and maintain trust. These regulations might include getting permission before collecting data, keeping data, to a minimum only using data for purposes informing people about data breaches and having oversight bodies. Following these rules is important for city officials and tech companies.

- *Responsible data governance:*

Smart cities should have practices for managing data in terms of both the law and ethics. This involves following principles that prioritize privacy from the start of checking how privacy might be affected by projects ensuring that data are secure and encrypted and having rules on how data are handled. Responsible data management means collecting, using, and sharing information in a way that respects rights and keeps the public's trust.

- *Transparency and accountability:*

Being open and taking responsibility are key when it comes to dealing with ethical issues. Smart city officials and tech companies need to share details, about how they collect data, handle them securely, and use them. They should also take responsibility if there are any breaches or misuse of information. Being transparent helps build trust lets individuals make choices about sharing their data and provides ways for people to seek help if their privacy is breached.

- *Vendor and technology responsibility;*

In the realm of cities, there is often a partnership, between city authorities and technology providers to set up and oversee city infrastructure. It is vital to make sure that these providers follow ethical guidelines. Contracts should address data security, privacy standards, and accountability in case of data breaches or misuse. City authorities must carefully supervise vendors to safeguard rights and ensure data are used responsibly.

- *Ethical concerns and avoiding bias in algorithms;*

Smart city technologies utilize algorithms and data analysis for decision-making and service optimization. However, if not implemented ethically, these algorithms can introduce biases or discrimination. Ethical considerations should focus on fairness, transparency, and accountability in algorithmic decision processes. Regular evaluations are necessary to detect and address biases, in algorithms ensuring technology use aligns with rights and societal values.

12. Technological solutions for data security and privacy in smart cities

The use of technologies and strategies in the smart cities is crucial, for enhancing data security and privacy. The increasing demand for technology comes with a set of challenges that must be addressed including governance, privacy, and security. To overcome these hurdles, it is essential to establish a security framework in relation to IoT devices.

Various studies have been carried out to assess the security of devices and propose solutions. One study utilized mobile computing to address security issues [42]. Furthermore integrating sustainable infrastructure has been explored as an approach for future cities offering potential benefits compared to isolated methods [43].

Deep learning technologies have emerged as solutions for managing the data produced by sensors in smart cities. These technologies have demonstrated success in tasks such as data summarization, security enhancements, and privacy protection [44]. Despite their effectiveness, concerns about privacy continue to impede the adoption of technology.

Researchers have conducted reviews focusing on applications in smart cities, homes, and healthcare sectors with an emphasis, on security and privacy considerations.

These reviews discuss the difficulties and underscore the importance of addressing privacy issues [45]. Managing Cloud servers, points of failure data flow bottlenecks, and firmware updates, for devices pose additional security and maintenance challenges. Recent progress in Blockchain technology has been examined in relation to eHealth, smart cities, intelligent transport, and other applications demonstrating potential in tackling these hurdles [22].

Innovative technologies and methodologies play a role in enhancing data security and privacy within cities. Overcoming governance, privacy, and security obstacles necessitates a security framework, for IoT devices. Systematic literature reviews have offered insights and countermeasures including the use of computing. The integration of smart and sustainable infrastructure presents benefits compared to approaches. Deep learning-based methods have emerged as leading solutions for managing the data volumes in cities; however, concerns about privacy hinder widespread adoption of IoT technology.

Thorough reviews have delved into applications across sectors with an emphasis on security and privacy considerations. Additionally, Blockchain technology holds promise for addressing challenges associated with Cloud server management, points of failure data flow bottlenecks, and firmware updates, for devices.

Here are a few solutions that can bolster data security and privacy:

- *Encryption methods;*

Encryption serves as a crucial technology, for safeguarding data both in transit and at rest. It works by converting data into a form using algorithms. In the context of cities, encryption can be utilized across types of data including personal details, sensor information and communication channels. Robust encryption methods like encryption standards (AES) guarantee that even if unauthorized access occurs or if data are intercepted, it remains unintelligible (**Table 1**).

- *Secure data exchange protocols;*

Secure protocols for sharing data facilitate controlled and sharing among entities. Access control mechanisms such as role-based access control (RBAC) or attribute-based access control (ABAC) can be deployed to ensure that only approved individuals or systems have access to data. Furthermore, methods like party computation (MPC) enable collaborative data analysis without exposing raw information thereby upholding privacy (**Table 2**).

- *Privacy-preserving techniques;*

Privacy-preserving techniques enable data analysis while safeguarding privacy. For instance, differential privacy involves adding noise or perturbation to the data to prevent deducing individual level details, from outcomes.

Homomorphic encryption serves as a method that allows computations, on encrypted data without the need for decryption ensuring privacy is maintained during data analysis. By implementing privacy preserving techniques, smart cities can extract insights without compromising the privacy of individuals (**Table 3**).

Advantages	Disadvantages
<ul style="list-style-type: none"> • Provides strong protection for data both in transit and at rest. • Converts data into unintelligible form, even if unauthorized access occurs. 	<ul style="list-style-type: none"> • Encryption can introduce computational overhead and potentially impact performance. • Key management and distribution can be challenging.

Table 1.
Advantages and disadvantages of encryption methods.

Advantages	Disadvantages
<ul style="list-style-type: none"> • Facilitates controlled and secure sharing of data among entities. • Access control mechanisms ensure only approved individuals or systems have access. 	<ul style="list-style-type: none"> • Implementation and enforcement of access control policies can be complex. • May require additional overhead for managing access control mechanisms.

Table 2.
Advantages and disadvantages of secure data exchange protocols.

Advantages	Disadvantages
<ul style="list-style-type: none"> • Enables data analysis while safeguarding privacy. • Techniques like differential privacy and homomorphic encryption protect individual-level details. 	<ul style="list-style-type: none"> • Adding noise or perturbation to data may affect accuracy of analysis. • Implementing and configuring privacy preserving techniques can be complex.

Table 3.
Advantages and disadvantages of privacy-preserving techniques.

- *Blockchain technology;*

Blockchain technology provides a tamper-resistant framework for ensuring data security. In the context of cities, blockchain can establish secure data transactions guaranteeing data integrity and reducing reliance on centralized authorities. Through contracts embedded in blockchain platforms, predefined rules can be executed automatically and verified, fostering trust and diminishing the necessity for intermediaries in data sharing and transactions (**Table 4**).

- *Secure IoT infrastructure;*

Securing the Internet of Things (IoT) infrastructure is vital in enabling cities to function amidst potential security and privacy challenges. The implementation of infrastructure involves safeguarding devices, networks, and data transmissions. Practices such as robust device authentication secure firmware updates and utilization of communication protocols like Transport Layer Security or MQTT over SSL/TLS play a role in shielding IoT devices and data from unauthorized access or interception (**Table 5**).

- *Anomaly detection and intrusion prevention systems;*

The deployment of anomaly detection systems alongside intrusion prevention systems is essential for detecting and mitigating threats and attacks, within smart city environments.

Advantages	Disadvantages
<ul style="list-style-type: none"> • Provides a tamper-resistant framework for ensuring data security. • Establishes secure data transactions and reduces reliance on centralized authorities. 	<ul style="list-style-type: none"> • Blockchain implementation can be resource-intensive and computationally expensive. • Scalability and performance issues may arise in large-scale smart city deployments.

Table 4.
Advantages and disadvantages of using blockchain technology.

Advantages	Disadvantages
<ul style="list-style-type: none"> • Ensures the security of IoT devices, networks, and data transmissions. • Robust authentication and secure communication protocols protect against unauthorized access. 	<ul style="list-style-type: none"> • Heterogeneity and large-scale deployment of IoT devices pose challenges for security management. • Legacy systems and devices may lack robust security features.

Table 5.
Advantages and disadvantages of secure IoT infrastructure technique.

These systems utilize machine learning algorithms to analyze network traffic, sensor data, and system logs in time to identify any behavior or suspicious patterns. By detecting and responding to security incidents, smart cities can reduce the impact of breaches and uphold data security (Table 6).

- *Data protection techniques (data masking and deidentification):*

To safeguard information methods, like data masking and deidentification can be implemented. Data masking involves substituting data with fictional values ensuring that the data are still usable for analysis while protecting privacy. Deidentification technique: generalize details from datasets lowering the risk of reidentification. These approaches facilitate data sharing for research and analysis while safeguarding privacy (Table 7).

- *Continuous monitoring and auditing;*

Surveillance and auditing systems aid in maintaining ongoing adherence to data security and privacy regulations. These systems oversee data access, usage, and sharing activities offering insights, into security breaches or policy infractions. Regular audits and evaluations can pinpoint vulnerabilities evaluate the efficacy of security measures and ensure that data security practices are current (Table 8).

Advantages	Disadvantages
<ul style="list-style-type: none"> • Detects and mitigates threats and attacks in real-time. • Utilizes machine learning algorithms to identify suspicious patterns. 	<ul style="list-style-type: none"> • False positives and false negatives can occur, impacting the effectiveness of the systems. • Requires continuous monitoring and updating to adapt to emerging threats.

Table 6.
Advantages and disadvantages of anomaly detection and intrusion prevention systems.

Advantages	Disadvantages
<ul style="list-style-type: none"> • Protects sensitive information while enabling data usability for analysis. • Reduces the risk of re-identification and safe-guards privacy. 	<ul style="list-style-type: none"> • Balancing data usability and privacy protection can be challenging. • Deidentified data may still be susceptible to privacy attacks in some cases.

Table 7.
Advantages and disadvantages of data masking and deidentification techniques.

Advantages	Disadvantages
<ul style="list-style-type: none"> • Offers ongoing adherence to data security and privacy regulations. • Identifies security breaches or policy infractions for timely response. 	<ul style="list-style-type: none"> • Requires dedicated resources for monitoring and auditing activities. • Can introduce additional operational overhead and complexity.

Table 8.
Advantages and disadvantages of surveillance and auditing systems continuous monitoring and improvements systems.

13. Recommendations and best practices for addressing data security and privacy concerns in smart cities

Ensuring data security and privacy, in cities, requires an effort involving various groups such as policymakers, city officials, technology providers, and residents. Researchers have put forward a framework that includes hardware, software, and wireless radio components designed to be adaptable and easily replicated for scenarios. The goal of this framework is to follow established standards and integrate cybersecurity practices to uphold security and privacy standards [46].

As smart cities continue to advance efforts have been made to improve the quality of life through progress. Tubaishat and Jouhi [9] offer an examination of security considerations in cities emphasizing the significance of cybersecurity in this context.

The growing complexity of city systems poses challenges related to safety, security, privacy, and usability. Fu et al. [12] underline the concerning trends linked with devices and networks of devices highlighting the interconnected nature of issues concerning security, physical safety, privacy, and usability. They argue that holistic solutions addressing all these aspects simultaneously are essential.

Privacy, security, confidentiality, and authenticity play roles in city applications. The management interface for city infrastructure must meet standards, in these areas.

In response, Chen et al. [14] have introduced the Holistic Big Data Integrated Artificial Intelligent Modeling (HBDIAIM) strategy to enhance privacy and security, in data management interfaces for smart city applications. Below are some suggestions and guidelines to effectively tackle these issues and promote a privacy-focused atmosphere while fostering trust:

- *Establish clear data governance policies;*

Creating data governance policies is crucial. Policymakers and city officials should develop rules and regulations that define the collection, storage, sharing, and utilization of data in smart cities. These policies should encompass privacy principles, data protection laws, and ethical considerations. Regular updates and evaluations of these policies should be carried out to keep pace with advancing technologies and evolving privacy landscapes.

- *Improve transparency and communication;*

Transparency plays a role in building trust among stakeholders in cities. City officials and technology providers should openly communicate about data collection practices, data management procedures, and the purposes for which data are utilized. Residents need to be informed about the collected data, their usage purposes, and the safeguards, in place to safeguard their privacy. Transparent communication empowers individuals to make decisions regarding data sharing while promoting accountability among all parties.

- *Implementing privacy by design;*

Privacy, by design involves integrating privacy measures into the design and structure of city systems. Policymakers and technology providers should conduct Privacy

Impact Assessments (PIAs) to detect and address privacy risks in the development phase. To safeguard data at all stages, it is essential to incorporate privacy enhancing technologies like encryption, pseudonymization, and access controls. By adhering to Privacy by Design principles, a privacy conscious approach can be fostered to reduce privacy risks.

- *Enhancing data security measures;*

Ensuring data security measures is critical for safeguarding information within smart cities. City administrators and technology providers must implement encryption methods, secure network protocols, and access controls to prevent data breaches. Conducting security audits, vulnerability assessments, and penetration testing is necessary to identify and rectify vulnerabilities promptly. Additionally, having defined data breach response plans in place can facilitate an efficient response during security incidents.

- *Promoting collaboration and partnerships;*

Collaboration among policymakers, city administrators, technology providers, and residents play a role, in addressing concerns related to data security and privacy. Private partnerships can establish frameworks that prioritize both privacy protection and data security for the benefit of all stakeholders.

- *Involving residents in citizen engagement programs;*

Consultations and privacy awareness campaigns can create a feeling of ownership and empower individuals to participate in privacy conscious practices. It is essential to educate residents about their rights the advantages of city technologies and the safeguards in place to protect their privacy. City officials and technology providers should organize privacy awareness campaigns, workshops, and training sessions to empower residents to make choices regarding data sharing and privacy settings. Providing user interfaces and privacy management tools can help individuals effectively control their data and privacy preferences.

- *Conduct regular privacy audits;*

Regular assessments and audits should be carried out to assess the effectiveness of data security measures and privacy protections. Independent third-party audits can offer insights into compliance with data protection regulations practices for privacy and ethical standards. These audits are crucial, for identifying areas that need improvement ensuring accountability and showcasing a dedication to safeguarding privacy and data.

- *Embrace ethical considerations;*

Smart city projects must adhere to principles that prioritize fairness, transparency and accountability. Policymakers and technology providers should focus on preventing biases, discrimination well as unintended negative outcomes.

It is important to establish standards and principles to guarantee the utilization of data and decision-making which helps build trust and gain public approval.

14. Conclusions

Smart cities are transforming development by using technology and systems. By utilizing data-driven methods, smart cities seek to enhance management enhance resident's quality of life and establish resilient urban spaces. Integrated systems are essential, in reaching these objectives by enabling connectivity integrating data and coordinating decision-making across urban areas. As smart cities progress, the significance of integrated systems will grow in shaping cities.

Data governance frameworks and regulatory measures are crucial, for maintaining data security and privacy in cities. While the current frameworks and rules lay the groundwork their effectiveness hinges on awareness, cooperation, technological adaptability, enforcement, and accountability, continuous assessment, improvement ,and adjustment of these frameworks are essential to tackle the changing challenges and prospects brought about by city projects and to ensure responsible data use in urban settings.

By dealing with the current challenges, smart cities can bolster data security, safeguard privacy, and foster trust among residents. This requires a strategy that integrates solutions, policy structures, community involvement, and collaboration among various parties to establish a secure environment that respects privacy, for data-focused urban progress.

Smart Cities residents should have the ability to manage their information can build trust and openness in the data-driven environment. It is important for smart cities to focus on privacy and make sure that collecting and using data follows what residents want and anticipate.

By involving residents in decision-making processes, stakeholders in smart cities can encourage resident participation incorporate privacy concerns into decision-making and cultivate a feeling of ownership among residents concerning data security and privacy, within smart city environments.

The effectiveness of services and the enhancement of infrastructure in smart cities are significantly influenced by concerns regarding data security and privacy. Various factors, such as restrictions on data sharing, trust issues, potential disruptions, and the necessity for regulatory compliance contribute to this influence. Smart cities can tackle these concerns by incorporating privacy protection methods, establishing collaborative governance structures, and investing in security measures and response capabilities. Maintaining a harmonious relationship between data security, privacy, and service enhancement is crucial for the successful execution of smart city projects and the delivery of reliable, efficient, and secure services to residents.

Ensuring data security and privacy, in cities, involves consideration of legal and ethical aspects. It is crucial to strike a balance between interests, individual rights, and the responsibilities of city authorities and technology providers. Adhering to data protection laws, practicing data governance, promoting transparency, and being accountable are key for safeguarding privacy and fostering public trust. The design and deployment of city technologies should be guided by principles to avoid biases and discrimination. By addressing these ethical issues, smart cities can leverage the advantages of data-driven technologies while respecting rights and societal values.

Technological advancements play a role in bolstering data security and privacy in cities. Utilizing encryption methods, secure data sharing protocols, privacy preserving algorithms, blockchain technology, secure IoT infrastructure, anomaly detection systems, data masking techniques, such as continuous monitoring and auditing, can

enhance privacy protection. By embracing these technologies and strategies, smart cities can safeguard information and privacy standards and establish trust with residents and stakeholders while benefiting from data-driven programs.

It is important to consider that the adoption of privacy enhancing technologies should align with the needs and privacy requirements of each city system.

Different technologies may suit purposes and types of data and a holistic approach that combines methods is often needed to ensure strong privacy protection.

Ensuring data security and privacy, in cities, requires a strategy involving policy-makers, city officials, tech providers, and residents. Various frameworks and strategies have been suggested by researchers, such as components and cybersecurity best practices to address these concerns. The advancement of cities has highlighted the importance of security aspects leading to the need for solutions that cater to safety, security, privacy, and usability simultaneously. Moreover, innovative approaches like HBDIAIM (Holistic Big Data Integrated Artificial Intelligent Modeling) are being explored to meet the demanding requirements of privacy, security, confidentiality, and authenticity in smart city applications.

Dealing with these challenges effectively requires an approach. Recommended practices include establishing data governance policies; enhancing transparency; implementing privacy by design principles; implementing data security measures; fostering collaboration; empowering residents; conducting privacy audits; and considering aspects. By embracing these actions, smart cities can prioritize privacy rights and responsible data use while building trust, among stakeholders, strengthening data governance efforts, and encouraging the adoption of privacy-focused approaches.

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Section 2

Smart Cities Technologies



Chapter 5

Internet of Things: The Key Enabler of Smart City Development

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Abstract

The major challenge facing traditional cities is connecting the citizens, the government, the infrastructures including institutional, physical, economic, and social infrastructures to create an ecosystem that enhances efficiency, flexibility, transparency, sustainability, and the overall quality of life for residents. Cities are complex systems that are characterized by massive numbers of organized citizens, government, and different infrastructures. The Internet of Things (IoT) is deemed a good enabler for city development due to its characteristics in interconnecting (physical and virtual) things and acquiring data from them. Therefore, connecting many residents linking transportation, health, education, social infrastructure needs, facilitating communication, improving government performance, and making some aspects of people's lives "smart" are the embodiments of a smart city. Therefore, the ability to collect, analyze, and act upon real-time data from cities is a key factor in transforming traditional cities into intelligent and responsive urban environments. Smart cities leverage IoT technologies to enhance efficiency, sustainability, and the overall quality of urban life. Therefore, this chapter will provide insight on several ways in which IoT serves as a key enabler for smart city development.

Keywords: Internet of Things (IoT), smart city, key enabler, urbanization, infrastructure

1. Introduction

Since a couple of decades ago, communities have been significantly affected by several societal, environmental, and economic crises. Number of residents in urban regions is growing exponentially every year, and according to CISCO [1] in its Smart Cities e-book, more than 60 percent of the world's population will be living in cities by 2050. The prevailing challenges in cities around the globe, however, include job creation, economic development, environmental protection and sustainability, citizens' inclusivity, and social resiliency. These problems arise due to migration and population concentration. Interestingly, metropolitan areas across the globe have been bringing about initiatives that aim to improve the livelihood of their residents, as well as cities' attractiveness and competitiveness through the provision of sustainable urban infrastructure and services. These initiatives brought about the concept

of intelligent cities—that is a precursor to smart cities [2]. Hence, the solution to these challenges could not be far away from the adoption of a scalable system that leverages on information and communication technology (ICT) to enhance quality of living. Cities that adopt this type of solution are regarded as smart cities. A city can be categorized as “smart” when it utilizes digital technology to address urban challenges. As a general term, smart city is a broad concept that encompasses a number of areas such as smart urbanism, smart economy, sustainable and smart environment, smart energy, smart mobility, smart healthcare, etc. [3].

Accordingly, a smart city is a meticulously planned urban environment that relies on digital technology and data-driven solutions to connect, protect, and enhance efficiency, quality of service (QoS), sustainability, and the overall quality of life (QoL) for its residents [4]. This, through robust connectivity, involves the integration of advanced technologies across various domains such as infrastructure, transportation, energy, healthcare, and governance, thereby fostering connectivity and data exchange between different systems while ensuring the resource availability for present and future generations in terms of social, economic, and environmental aspects [4]. Therefore, Smart Cities can be broken into three domains: characteristics, pillars, and infrastructure. Characteristics of a smart city are also known as attributes, while the pillars are regarded as the theme of the smart city as they provide the continuous progression on which an intelligent urban city relies. Consequently, the essential feature that provides the operational platform for smart city deployment is the infrastructure.

2. The evolution of urbanization

Urbanization has evolved through various factors in the course of history, leading to the growth and development of cities worldwide. The roots of urbanization can be traced back to ancient civilizations like Egypt, where settlements emerged as centers of trade, governance, and socio-cultural exchange. The advent of agriculture led to the growth of larger communities, establishing the foundations of early cities. These early urban centers served as hubs for trade, governance, and cultural exchange. During the medieval and Renaissance periods, cities in Europe experienced growth fueled by factors such as trade, craftsmanship, and commerce. Urban centers became hubs for cultural and intellectual activity, marked by the construction of religious centers, universities, and marketplaces. The Industrial Revolution in the eighteenth and nineteenth centuries marked a milestone in urbanization. The shift from agricultural economies to industrialization drove massive migration to cities. This led to the growth of manufacturing centers and the migration of rural populations to cities in search of employment opportunities. In the twentieth century, we have witnessed unprecedented urban expansion due to technological advancements, population growth, rural-urban migration, and economic development. Cities expanded rapidly, leading to the emergence of megacities and what we come to know as the phenomenon of urban sprawl. The development of infrastructure, transportation networks, and modern amenities characterized this era. Megacities, with populations exceeding ten million, became prominent, particularly in Asia, Africa, and Latin America. Some of the factors driving urbanization includes: economic opportunities, infrastructure development, social, and cultural factors as well as governance and government policy. In terms of economic opportunities, cities offer a diverse range of employment opportunities in industries such as manufacturing, services, and technology, attracting migrants from rural areas in search of better livelihoods.

The infrastructure development enhanced urban areas in terms of better access to essential services such as healthcare, education, transportation, and utilities, making them attractive destinations for migrants. Accordingly, the social and cultural factors placed cities as centers of culture, entertainment, and social interaction, offering a vibrant and diverse urban lifestyle that attracts people from different backgrounds. And finally, governance and government policies such as urban planning initiatives play a crucial role in shaping urban growth and development, influencing factors such as land use, housing, transportation, and environmental sustainability. Thus, some of the challenges of urbanization include the following: (i) overcrowding and population density; (ii) housing shortage, affordability, and informal settlements; (iii) infrastructure deficits; (iv) social inequality and marginalization; (v) environmental degradation; (vi) climate changes and vulnerabilities; (vii) resource scarcity; (viii) traffic congestion; and (ix) governance and planning issues. Accordingly, some of the identified solutions to urbanization challenges include the following: (i) urban planning and design, (ii) investment in infrastructure, (iii) social inclusion and equity, (iv) environmental sustainability, and (v) community engagement.

The evolution of urbanization has led to both opportunities and challenges for cities worldwide. Hence, understanding the historical evolution of urbanization and contemporary challenges is crucial for developing sustainable and resilient strategies to address the complex dynamics of urban growth and development. Addressing the complex challenges of urbanization requires holistic and integrated approaches that prioritize sustainability, equity, resilience, and community engagement to build cities that are inclusive, livable, resilient, and sustainable for future generations.

3. Characteristics of smart cities

It is very clear at this point to appreciate that urbanization is the process of population movement and urban growth, while a city is a specific human settlement characterized by high population density, economic activity, and social infrastructure. Therefore, urbanization contributes to the formation and expansion of cities. Accordingly, a smart city, regarded as an intelligent city that leverages digital technologies, comprises four main attributes (see **Figure 1**) including smartness, urbanization, quality of life (QoL), and sustainability. Therefore, a city's strategic intention to upgrade its environmental, social, and economic baseline is an indication of its smartness. While QoL is determined by emotional and financial comfort of urban residents in smart city set-up, urbanization, often defined as the transformation of a town or environment from rural to urban is indicated by the infrastructural, technological, economical, and governance.

Sustainability, on the other hand, is a major aspect of smart city development. Therefore, the widespread attention on sustainability paved the way for the emergence and development of smart cities. Wheeler and Beatley defined sustainability as the capability of a city to maintain a balanced environment/ecosystem while performing city operations. Major sub-attributes under sustainability include infrastructure, governance, pollution and waste, energy and climate change, and socio-cultural issues of health.

3.1 The pillars of a smart city

A smart city is composed of four pillars (see **Figure 2**), which include institutional infrastructure, physical infrastructure, social infrastructure, and economic

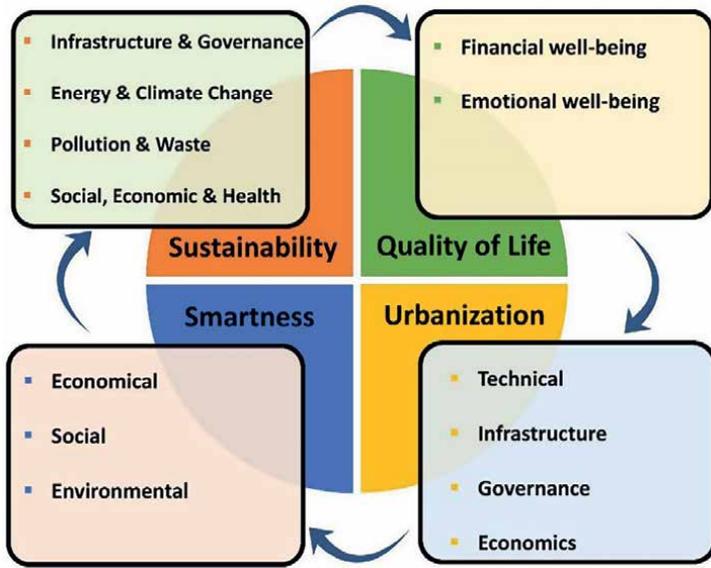


Figure 1. Attributes of a smart city [4].

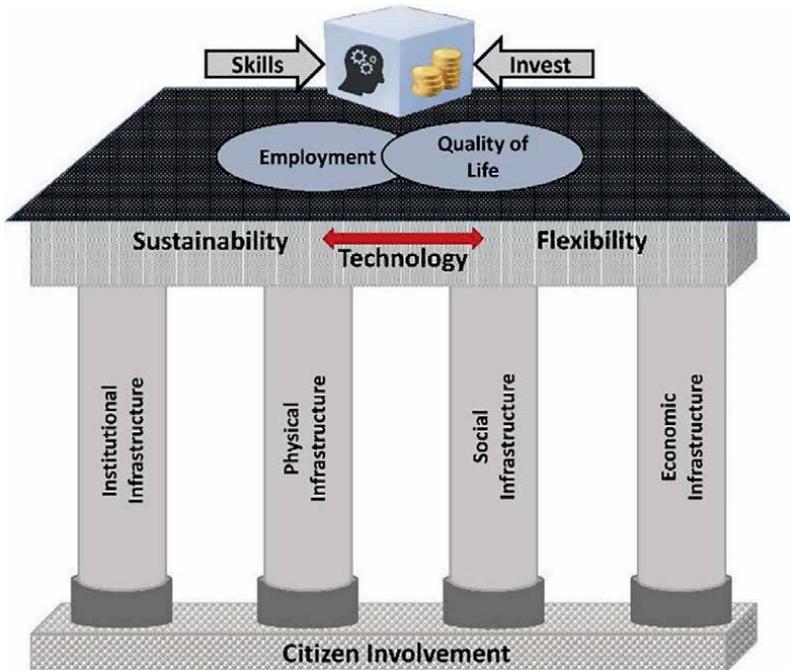


Figure 2. Pillars of smart cities [4].

infrastructure. As suggested by the four-pillar approach shown in **Figure 2**, many literatures contrasted (in number) with the European Union (EU) six-pillar approach; the two approaches; however, resemble each other.

The institutional infrastructure deals with governance; it consolidates civil, private, and public entities as well as organizations to provide an efficient platform for interoperability. Governance ensures a balanced association and participation in public services, social services, and decision making in order to gain the best benefit of human capital for the betterment of the city. Governance plays a crucial role in facilitating coordination between citizens and administrative entities. The institutional framework works in conjunction with regional and central governments to optimize the advantages of smart city initiatives. The natural resources and manufactured infrastructure are the main constituents of the physical infrastructure. This pillar ensures the sustainability of resources for future generations. In a Government Summit held in 2015, the physical infrastructure was further divided into four (4)—smart energy, green buildings, green urban planning, and renovation of buildings and amenities as city planners set to leverage on smart city to mitigate the scarcity of natural resources [5]. The social infrastructure encompasses intellectual and human capital, along with QoL. The awareness, responsibility, and dedication of residents play a pivotal role in promoting the smart city concept. Therefore, this necessitates the adoption of the infrastructure for the development and sustainability of smart cities. The sustainability of smart cities is greatly tied to the social intelligence and awareness of its citizens. As the social infrastructure pillar is centered on people and their connections, it is recognized as a fundamental asset for any smart city. Finally, the economic infrastructure of smart cities, also known as smart economy, covers both micro and macro economies, e-commerce, and e-businesses. It deals with continual and steady economic growth, job/employment opportunities, ICT innovations, services and manufacturing provisions, and integration of advanced technologies to improve QoL.

In generic terms, these pillars of smart cities cover data integration, technology infrastructure, sustainability, efficient urban mobility, citizen engagement, innovation, resilience, security, and privacy, all of which are incorporated with an overarching goal of creating a dynamic and inclusive urban environment that utilizes technology to improve services, promote environmental responsibility, and cater to the evolving needs of its citizen and their communities.

3.2 The key components of a smart city

The key components of a smart city include the following: data-driven decision making, smart infrastructure, sustainability and resiliency, innovative technologies, citizen-centric approach, economic development, governance and policy frameworks, security and privacy, innovation hubs, and inclusivity. These components are summarized below:

- i. *Data-driven decision making*: smart cities utilize data from sensors, devices, and citizen interactions from various platforms to gain insights into urban processes and to inform decision making. Data analytics and visualization tools are used to optimize resource allocation, improve service delivery, and enhance urban planning.
- ii. *Smart infrastructure*: smart cities deploy interconnected systems and infrastructure to enable seamless communication and collaboration between different sectors and stakeholders. This includes smart grids for energy distribution, intelligent transportation systems, and digital platforms for citizen engagement, smart factory, smart hospitality, smart warehouse, smart healthcare, etc.

- iii. *Sustainability and resiliency*: to prioritize environmental sustainability, smart cities integrate renewable energy sources, implement green building standards, and promote sustainable transportation. They also deploy resilience measures to mitigate risks from natural disasters, climate vulnerabilities, and other challenges.
- iv. *Innovative technologies*: smart cities embrace disruptive technologies such as Internet of Things (IoT), blockchain, and artificial intelligence (AI) to create efficient urban environments to facilitate automation, predictive analytics, and personalized services that meet the needs of residents.
- v. *Citizen-centric approach*: smart cities prioritize citizen engagement, empowerment, and inclusivity. They actively involve residents in decision making, process feedback through digital channels, and co-create solutions to address residents' priorities.
- vi. *Economic development*: smart cities foster innovation, entrepreneurship, and economic growth by creating a conducive environment for businesses, start-ups, and talent acceleration. To support digital entrepreneurship, smart cities also provide access to funding and resources, as well as promote collaboration between industry, academia, and government.
- vii. *Governance and policy frameworks*: smart cities cultivate governance structures and policy frameworks to adapt to rapid technological advancements and changing urban dynamics. They prioritize data privacy, cybersecurity, and ethical considerations to enforce the responsible use of technology and protect the privacy of residents.
- viii. *Security and privacy*: smart cities put in place stringent cybersecurity to protect the data and infrastructures of the city. Privacy concerns are strategically addressed to maintain trust among the residents.
- ix. *Innovation hubs*: smart cities often serve as centers for innovation, promoting a culture of technological advancement and entrepreneurship. This attracts talent and businesses, contributing to economic growth.
- x. *Inclusivity*: smart cities are inclusive, and as such, technological advancements are meant to benefit all residents. This includes addressing digital divides and ensuring accessibility for everyone.

4. Foundations of smart cities

The foundations of smart cities incorporate various interrelated pillars that form the basis for their development and operation. These pillars of smart cities are set to create connected, sustainable, and resilient urban environments that enhance the quality of life for residents and promote economic prosperity. These foundations therefore work hand-in-hand to create smart cities that are technologically advanced, socially inclusive, economically vibrant, and environmentally sustainable. They form the basis for improving quality of life, optimizing resource usage, and building

resilient urban environments for the future. Therefore, the key foundations that form the backbone of smart and connected city development include the following:

- a. *Information and communication technology (ICT)*: robust ICT infrastructures are essential for smart cities. These include high-speed broadband networks, wireless connectivity, and communication protocols that enable seamless data exchange between devices and systems. High-speed broadband networks and wireless connectivity form the digital infrastructure facilitating communication between devices and systems. This can be broken into:
 - i. *High-speed connectivity*: smart cities require fast and reliable communication networks in order to connect devices, sensors, and other critical systems. This includes fiber-optic networks, 5G technology, and Wi-Fi hotspots located strategically throughout the city.
 - ii. *Edge computing*: edge computing infrastructure brings processing power closer to the data source. This reduces latency and enables real-time analysis of data generated by IoT sensors and devices.
 - iii. *Cloud computing*: cloud computing platforms provide scalable storage and computational resources for processing large volumes of data generated by smart city infrastructures.
- b. *Internet of Things (IoT)*: IoT establishes a network of interconnected devices. The technology forms the backbone and central nervous system of smart cities – allowing for the connection and communication of sensors, devices, and infrastructure components as well as paving the way for their interoperability and data storage. The IoT enables real-time data collection, analysis, and control of urban systems. Among the major requirements of IoT in smart cities are:
 - i. *Sensor networks*: sensor networks are deployed in smart cities to collect data on various aspects of urban life, such as traffic flow, air quality, temperature, and energy consumption.
 - ii. *Device interoperability*: interoperability standards are set to ensure that different IoT devices and systems can communicate and work together seamlessly, regardless of manufacturer.
 - iii. *Scalability and flexibility*: IoT systems are designed to be scalable and flexible, allowing for the addition of new devices and sensors as the city grows and evolves.
- c. *Data analytics*: data analytics processes and interprets the vast amounts of data generated by IoT devices, providing insights for decision making. Smart cities often rely on data analytics to derive actionable insights from the vast amount of data generated by IoT devices.
 - i. *Data analytics techniques* such as predictive analytics, data mining, and machine learning help optimize resource allocation, improve services, and enhance decision making. Data analytics in smart city development requires:

- ii. Big data processing: smart cities use big data analytics tools to process and analyze the vast amounts of data generated by IoT devices.
 - iii. Data visualization: data visualization tools provide intuitive ways to interpret complex data sets, enabling city planners and decision-makers to identify trends, patterns, and anomalies.
 - iv. Real-time insights: real-time data analytics capabilities allow smart cities to respond quickly to changing conditions, optimizing resource allocation and improving service delivery.
- d. *Smart infrastructure*: smart infrastructures enhance efficiency, sustainability, and the overall functionality of urban systems. Smart cities deploy intelligent infrastructure that incorporates technology to enhance efficiency and functionality. This includes:
- i. Smart grids: smart grids utilize IoT technology to monitor and control electricity distribution, optimize energy usage, and integrate renewable energy sources such as solar, hydro, and wind power.
 - ii. Intelligent transportation systems: intelligent transportation system (ITS) leverage IoT sensors and communication technologies to manage traffic flow, improve road safety, and enhance a seamless public transit system.
 - iii. Smart buildings: smart buildings also incorporate IoT devices and sensors to optimize energy usage, enhance occupant comfort, and enable predictive maintenance of building systems.
- e. *Urban planning and design*: smart city development integrates technology into urban planning and design processes. This involves principles such as:
- i. Mixed land use development: smart cities promote mixed-use development, integrating residential, commercial, and recreational spaces to reduce the need for extensive travel and enhance walkability.
 - ii. Green infrastructure: green infrastructures such as parks, green roofs, and urban forests help mitigate the urban heat island effect, improve air quality, and provide recreational opportunities for residents.
 - iii. Smart growth principles: intelligent cities adhere to smart growth principles such as compact development, transit-oriented development, and sustainable land use practices to create more livable and resilient urban environments.
 - iv. Sustainable architecture: sustainable building practices prioritize energy efficiency and environmentally friendly designs.
- f. *Citizen engagement*: residents' engagement is a vital aspect of smart cities. Initiatives such as;

- i. *Digital platforms*: smart cities provide digital platforms and mobile apps that enable residents to access information, report issues, and participate in decision-making processes.
 - ii. *Community involvement*: community engagement initiatives such as town hall meetings, workshops, and citizen advisory boards give residents a voice in shaping the future of their city.
 - iii. *Data transparency*: open data initiatives make government data publicly accessible, promoting transparency and accountability in city governance.
- g. *Open data initiatives*: smart cities deploy open data initiatives, making non-sensitive data publicly accessible, thereby promoting transparency and accountability. Data transparency fosters innovation and enables third-party application developers to create applications that benefit residents and businesses. Open data initiative incorporates:
- i. *Open data portals*: smart cities establish open data portals where residents, businesses, and developers can access and download government data sets for analysis and use in applications and services.
 - ii. *Application programming interfaces (APIs) and standards*: standardized data formats and APIs enable the usability and interoperability of open data, encouraging innovation and third-party application development.
 - iii. *Data privacy and security*: open data initiatives ensure the protection of sensitive information and personal data, making sure that data is anonymized and aggregated before being made available to the public.
- h. *Cybersecurity*: security is a critical consideration in smart city development. Robust cybersecurity measures are necessary to protect sensitive data, protect against cyber threats, safeguard citizen data and privacy, secure critical infrastructure from potential cyber breaches, and ensure the secure operation of smart infrastructures. The cyber security foundation of smart city development incorporates:
- i. *Secure networks*: robust cybersecurity measures, including secure communication channels and encryption, protect against cyber threats and unauthorized access.
 - ii. *Safeguarding privacy*: policies and technologies are implemented to safeguard citizen privacy and protect personal data.
 - iii. *Threat detection and prevention*: smart cities implement cybersecurity measures such as firewalls, intrusion detection systems, and encryption to detect and prevent cyber threats from compromising city systems and data.
 - iv. *Incident response*: incident response plans outline procedures for responding to cybersecurity incidents, minimizing the impact of attacks and restoring normal operations as quickly as possible.

- v. *Training and awareness*: training and orientation programs promote awareness among residents, city staff, and other stakeholders about cybersecurity's best practices, helping to prevent security breaches caused by human error or negligence.
- i. *Sustainability practices*: smart cities often ensure environmental sustainability by incorporating waste management optimization, and eco-friendly practices such as renewable energy, implementing energy-efficient technologies, promoting eco-friendly transportation, and adopting green building standards to contribute to environmental sustainability. Sustainability practices include:
 - i. *Renewable energy integration*: smart cities prioritize the use of renewable energy sources such as solar, wind, and hydropower to reduce greenhouse gas emissions and promote environmental sustainability.
 - ii. *Energy efficiency measures*: energy efficiency initiatives such as building retrofits, LED street lighting, and smart appliances help reduce energy consumption and lower utility costs for residents and businesses.
 - iii. *Waste management optimization – reduction and recycling*: smart waste management systems minimize waste generation and optimize collection routes for efficiency. Measures here also include the implementation of waste recycling programs to minimize the amount of waste sent to landfills and incinerators, conserving natural resources, and reducing pollution.
- j. *Governance and policy frameworks*: adaptable governance structures and policy frameworks address evolving technological landscapes such as:
 - i. *Adaptive policies*: policies are designed to be adaptable, allowing for continuous adjustment to the evolving technological landscape and urban challenges.
 - ii. *Ethical considerations*: ethical framework addresses the responsible and equitable use of technology, making sure smart city initiatives benefit all residents. Smart city policies address ethical considerations such as data privacy, equity, and social justice to ensure that technology is deployed in a responsible and equitable manner.
 - iii. *Regulatory compliance*: smart cities adhere to regulatory frameworks and standards related to data privacy, security, and interoperability to ensure compliance with local, national, and international laws.
 - iv. *Stakeholder city governance structures* facilitate collaboration and communication between government agencies, private companies, academic institutions, and community organizations to coordinate efforts and achieve common goals.
 - v. *Stakeholder engagement*: smart city governance structures facilitate collaboration and communication between government agencies, private companies,

academic institutions, and community organizations to coordinate efforts and achieve common goals.

- k. *Collaboration and partnerships*: partnership and collaboration fosters innovation and resource-sharing. Collaboration between the public sector, private companies, academia, and community organizations is essential for smart city success. Partnerships enable the pooling of resources, expertise, and innovation to address complex urban challenges.
- i. *Public-private partnerships (PPPs)*: collaborations between public and private sectors leverage resources, expertise, and innovation for comprehensive smart city development. PPPs bring together government agencies, private companies, and nonprofit organizations to collaborate on smart city projects, pooling resources, expertise, and funding to achieve common objectives.
- ii. *Community involvement*: community engagement: smart cities involve local communities and grassroots organizations to involve residents in the planning, design, and implementation of smart city initiatives, ensuring that projects reflect community needs and priorities. Engaging community organizations fosters a sense of ownership and collaboration in addressing local challenges.
- iii. *Academic and industry collaboration*: collaboration between academic institutions and industry partners fosters research and innovation in smart city technologies, driving the development of new solutions and applications.
- l. *Innovation ecosystems*: establishing and/or supporting innovation hubs and research and development centers elicit the creation of a conducive atmosphere for disruptions and implementation of cutting-edge technologies for the development, operation, and sustainability of smart cities.

Creating an environment that fosters innovation is key to smart city development. Innovation ecosystems include:

- i. *Startup incubators and accelerators*: dedicated spaces for startups and accelerators support the development of innovative solutions for urban challenges. Incubators and accelerators provide support and resources to startups and entrepreneurs developing innovative solutions for smart cities, including mentorship, funding, and access to networks.
- ii. *Research and development (R&D)*: R&D initiatives in collaboration with universities and research institutions drive innovation in smart city technologies, fostering the development of new products, services, and methodologies.

5. Internet of Things and its significance in smart city development

The Internet of Things (IoT) is a network of interconnected devices, sensors, and objects that collect and exchange data over the internet without human intervention [6].

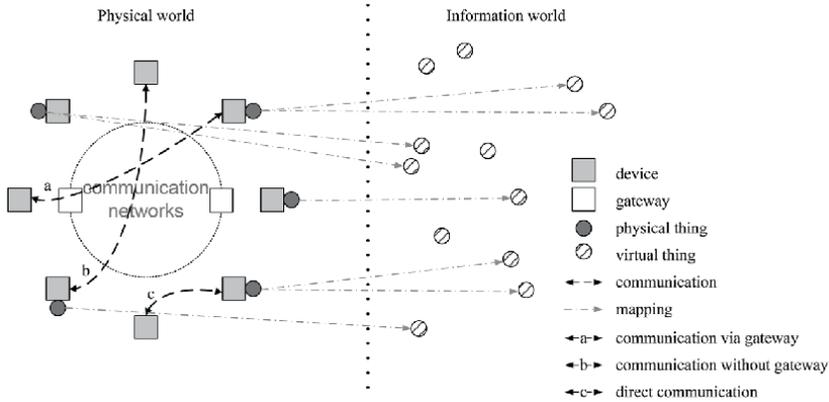


Figure 3.
High-level overview of the IoT [7].

But the International Telecommunication Union (ITU) in 2012 formally defined IoT as an intelligent network of connected (physical and virtual) objects or “things” based on existing and evolving interoperable information and communication technologies (ICT) to facilitate data collection, transmission, storage, processing, and exchange. A “Thing” in the context of IoT is an entity of the physical/information world that has a unique identifier. Where the physical things such as surrounding environment, industrial robots, goods, and electrical equipment exists in the physical world and are capable of being sensed, actuated, and connected, if embedded with electronic sensors. Similarly, virtual things include multimedia content and application software, which exist in the information world and are capable of being stored, processed, and accessed (**Figure 3**).

For the development of smart cities, IoT enables the integration of physical infrastructure with digital technologies and thus plays a crucial role in transforming urban environments. IoT as a key enabler of smart city development, provides the foundation for data-driven decision making, efficient resource management, enhanced residents’ engagement, and environmental sustainability. Through the utilization of IoT technologies, cities can address the complex challenges of urbanization and create more livable, resilient, and inclusive urban environments [6]. Therefore, the significance of IoT in smart city development includes the following:

- i. *Data collection and analysis*: various urban assets such as transportation systems, buildings, and utilities are integrated with IoT devices. They continuously collect large amounts of data in real time. This data includes information on traffic flow, energy consumption, air quality, and waste management. These data provide valuable insights into urban processes, which enable city planners to make informed decisions and optimize resource allocation.
- ii. *Smart infrastructure*: IoT facilitates the creation of smart infrastructure, where physical assets are interconnected and digitally controlled. Smart grids, for instance, use IoT sensors to monitor electricity distribution and optimize energy usage. Intelligent transportation systems (ITS) use IoT to manage traffic flow, enhance public transit, and improve mobility. Smart streetlights

adjust the brightness based on the conditions of the environment, saving energy and enhancing safety.

- iii. *Efficient resource management*: leveraging on IoT, cities are able to monitor and manage resources more efficiently. For example, smart water management systems use sensors to detect leaks, monitor water quality, and optimize irrigation. Smart waste management solutions use IoT devices to track waste collection. These efficiencies lead to cost savings, environmental sustainability, and improved service delivery.
- iv. *Real-time monitoring and response*: IoT devices provide real-time monitoring of urban environments thereby allowing for quick detection and response to emergencies. For instance, air quality sensors can alert on pollution spikes, enabling rapid intervention measures. Smart surveillance cameras can detect suspicious activities and alert law enforcement agencies, enhancing public safety.
- v. *Citizen engagement*: IoT promotes citizen engagement by providing residents with access to real-time information and interactive platforms. For instance, smart city apps allow citizens to report issues, access public services, and participate in decision-making processes. This fosters transparency, improves communication, and enhances overall citizen engagement. IoT-powered public displays provide information on transportation schedules, weather forecasts, and local events, enhancing communication and community engagement. Community Feedback Systems, where IoT facilitates feedback mechanisms, allows residents to provide input on city services, infrastructure, and policies. This collaborative approach helps align urban development with community needs.
- vi. *Environmental sustainability*: IoT contributes to environmental sustainability by monitoring and mitigating environmental impacts. For example, smart sensors can detect water leaks, reduce energy consumption, and optimize waste management processes. By promoting resource efficiency and reducing carbon emissions, IoT helps cities achieve their sustainability goals and combat climate change.
- vii. *Innovation and economic growth*: the deployment of IoT technologies in smart cities creates opportunities for innovation, entrepreneurship, and economic growth. It attracts tech startups, skilled professionals, and investment capital, promoting a vibrant ecosystem of innovation hubs and technology clusters. By promoting collaboration between industry, academia, and government, IoT accelerates urban innovation and drives economic development.
- viii. *Public safety and surveillance*: in Smart Cameras and Sensors, the use of IoT-based surveillance systems enhances public safety by providing real-time monitoring of public spaces. These systems can detect unusual activities, monitor crowd movements, and contribute to crime prevention. Also, in Emergency Response Systems, the use of IoT devices, such as wearable sensors or smart city apps, aids in emergency response by providing real-time location data during incidents. This improves the efficiency of first responders and enhances overall public safety.

6. Conclusion

In summary, we can say that a smart city is a digitally connected urban area that utilizes advanced technologies, data analytics, and innovative solutions to address the complex challenges of urbanization and improve the quality of life for its residents. It integrates physical infrastructure, such as transportation systems, buildings, utilities, and public services, with digital infrastructure, including communication networks, sensors, and smart devices. Therefore, the smart city utilizes IoT sensors, video cameras, social media, and other sources as inputs and acts as a central nervous system, providing the city operator and citizens with constant feedback so they can make informed decisions. Thus, the IoT technology offers a wide range of solutions to address urban/city challenges including robust connectivity, data-driven decision making, optimizing resource allocation, enhancing infrastructure resilience, fostering innovation, and improving the overall quality of life for residents and citizen engagement platforms for a seamless urban experience. By creating interconnected systems and leveraging real-time information, smart cities can proactively tackle complex issues and improve the overall quality of urban living. Also, by leveraging IoT innovations, cities can build smarter, more sustainable, and resilient urban environments that meet the needs of present and future generations.

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Smart Combined Heat and Power System, Using Geothermal Low Enthalpy Resources

*Laurentiu Constantin Lipan, Sorin Dimitriiu
and George Alexandru Florea*

Abstract

Romania is among the European countries that have rich geothermal water resources. Unfortunately, these resources are of medium and low enthalpy, which makes their uses only direct, for space heating, spa treatments, greenhouse heating and other applications in agriculture and fish farming. However, recent regulations regarding the reduction of greenhouse gas emissions and fossil fuel consumption have led to increased research into the possibility of using these low-enthalpy resources for electricity production using ORC technology. The authors present a case study regarding the generation of electricity through ORC technology, using geothermal water with a temperature of 75°C from a geothermal reservoir located in the north of Bucharest, in the perimeter of Moara Vlăsiei locality. The performance of the installation is studied in relation to the working agents that may be used and the cooling medium available. The optimal operating conditions, for which the maximum electrical power is obtained, are also determined. The study is timely, considering the metropolitan projects to realize in the area a heating system using geothermal water and which can have high energy efficiency through its smart combination with electricity production.

Keywords: geothermal electricity, ORC installation, CHP system, geothermal heating, use of low-enthalpy geothermal resources

1. Introduction

Since the dawn of human existence, water has been considered as the primordial element, “Fons et Origo”, being revered as the matrix of all possibilities. From the beginning, our ancestors considered water as the foundation of all cosmic manifestation, the receptacle of all forms and all germs, the waters symbolizing the primordial substance from which all forms are born and into which they all return, by regression or cataclysm. That is why, since ancient times, thermal springs have been shrouded in mysticism, being revered both as a source of health and miraculous powers, and as a source of heat. The need for warmth arose with the beginning of human existence, primarily to create shelters to provide protection against cold periods. This need was initially met by using natural resources, such as the heat of the ground or that

provided by thermal waters. Through the discovery of fire, mankind learned that heat can be obtained voluntarily, through combustion, marking the beginning of the era of using fossil or renewable fuels. The ease of producing heat by burning these resources and at the same time their high availability, however, overshadowed throughout history the interest in using the heat provided by natural geothermal resources.

However, archeological findings have shown that natural geothermal springs have continued to be used for heating and thermal baths throughout time. The earliest uses of geothermal energy have been found to have occurred over 10,000 years ago in North America, where the inhabitants used the hot springs in the various areas for both practical and spiritual purposes, being believed to be endowed by the gods with magical powers of healing [1]. Evidence of these uses has also been found in the ancient Greeks as well as the Romans. Sites dating as far back as the first century (AD) have been discovered, attesting to the use of geothermal energy for heating homes, hot baths and culinary activities, but uses in this regard were limited to locations where hot geothermal water was available naturally in the form of hot springs [2]. The Greek physician Hippocrates (460–320 BC) promoted and highlighted the health benefits of hot baths, and the Roman scholar Pliny the Elder (23–79 AD) wrote about the special benefits of hot mineral baths for people suffering of muscles, joints or paralysis [3].

The discovery and use of fire was a first and huge step towards civilization, but it took approx. a million years for mankind to take a second giant step, the discovery and use of electricity. The first type of electricity, static electricity, was discovered by the ancient Greeks around 600 BC, when they found that rubbing a piece of amber produced an attraction force on the hairs of an animal's fur, but it was not until the sixteenth century that the first generator of static electricity was invented and more types of practical uses appeared. With Alessandro Volta in the early 1800s, electricity became a constant source of energy and the first reliable source capable of continuously producing electricity appeared. From this moment, it was only a step to the other epoch-making inventions that opened the way for the huge technical-scientific development of this field. Today's world is unimaginable without electricity; there is no level of humanity in which electricity does not play one of the main roles.

The eighteenth to twentieth centuries represented the period in which the invention and development of thermal power machines and electric generators allowed the thermal energy produced by burning fuels to be commercially transformed, on a global scale, into electrical energy, continuously and in quantities that would satisfy all consumption requirements. The most affordable and readily available fuels used in power plants are coal, fuels derived from crude oil and natural gas. Although these fossil fuels have been discovered since ancient times, the production of fuels derived from crude oil only began in the eighteenth and nineteenth centuries, when the first refineries were built and the exponential development of the techno-scientific revolution began, which led mankind to the current level of knowledge and technology. The intense and rapid development of means of transport and industrial activities, as well as the huge increase in the world's population, has made the need for energy ever greater, leading to the burning of ever increasing an amount of coal, gas and petroleum fuels, especially for transport and power generation. All these burning processes led to the generation of huge amounts of carbon dioxide which, combined with the reduction of regeneration capacity due to massive deforestation, determined the alteration of the natural balance of carbon dioxide and caused the emergence of the dangerous phenomenon of global warming. This situation, generating of strange climate changes we are facing today, combined with the depletion of fossil fuel reserves, has led humanity to concern more and more about finding solutions to increase energy

efficiency and find sources of alternative energies, that reduce greenhouse gas emissions and in the same time, to meet global energy needs. Based on these considerations, amplified by the oil and gas crisis, the economic recession, as well as various conflicts and international events, the exploitation of geothermal energy resources for the production of heat and electricity has become a particularly promising alternative [4].

The Earth is estimated to have an internal heat content of 10^{31} joules ($3 \cdot 10^{15}$ TWh), about 20% of which is waste heat from planetary accretion; the rest being attributed to past and present radioactive decay of natural isotopes [5]. Geothermal energy is defined as thermal energy that can be obtained in profitable conditions, from internal heat of the Earth, from hot waters or rocks located at depths up to 3000–5000 m below the earth's crust.

Geothermal systems can be classified according to the temperature level into three categories: *high enthalpy systems* (above 180°C), *medium enthalpy systems* (100–180°C) and *low enthalpy systems* (below 100°C).

High enthalpy systems consist of hot rocks generally located at depths greater than 3500 m and are due to thermal anomalies in the Earth's mantle or volcanic activity. Medium and low enthalpy systems are systems made up of hot aquifers located at depths of several hundred meters, up to approx. 3000 m and which is due to the circulation of water between the accumulation zone and greater depths with high temperatures [6].

Geothermal energy can be used directly as a heat source for space heating needs, spa treatments, agriculture and fish farming or indirectly for electricity production.

Currently, according to country reports, geothermal energy is used directly in at least 88 countries. It is estimated that the thermal power currently installed in these countries is approx. 108,000 MW and the annual energy consumption of approx. 1,021,000 TJ (284,000 GWh/year). The fields of use are according to the reported data: geothermal heat pumps (58.8%), swimming pools and thermal baths (18%), direct heating of residential and tertiary spaces (16%), heating of vegetable greenhouses (3.5%), uses in various industrial processes (1.6%), aquaculture and fish farming (1.3%), grain drying (0.35%), other uses (0.45%). The highest amounts of geothermal energy consumed were reported in order in China, USA, Sweden, Turkey and Japan [7, 8].

The use of geothermal energy for electricity production began with the exploitation of the resources provided by high-temperature geothermal systems, above 150°C. These are constituted by natural sources of dry steam or hot water with high pressure that can be vaporized by expansion (flash-steam). The world's first plant to produce electricity using dry geothermal steam was built in Larderello, Italy in 1904, producing enough power to light a few electric bulbs. In 1915, the plant reached a power of 5MW, and currently it is 545 MW [4].

After the Second World War, several geothermal plants with dry steam or flash steam were put into operation: Wairakei—New Zealand (1958–1960, 98 MW), Pathe—Mexico (1959, 3.5 MW) and Geysers—USA (1960, 11 MW). In 1970, research began at Las Alamos, USA, on the production of steam by vaporizing water injected into hot fractured rocks from deep. The project managed to achieve a power of 5 MW, but was stopped due to the generation of seismic movements as a result of the fracturing process. Starting from the results obtained here, it was possible after the 90s to obtain electrical energy on the same principle in other countries: France (Soultz sous Forêt, 1.5 MW), Germany, Japan and Great Britain [9].

High-temperature geothermal resources represent only a fraction of the world's geothermal resources. Many countries do not have high enthalpy resources on their

territory suitable for electricity generation, but only resources of medium enthalpy and in most cases of low enthalpy. Exploiting them for electricity production became possible only after 1950, thanks to the development of ORC and Kalina technologies [10]. The comparative thermodynamic analysis between the ORC and Kalina systems has shown that the ORC system has a better profitability and can also use low enthalpy sources, with temperature levels up to 70–80°C. Basically, the operating principle of the ORC system is the same as the thermodynamic Rankine cycle, the difference being that instead of water, organic fluids are used, which for the pressures required to operate turbines or expanders, the saturation temperatures are much lower than water. The first ORC plants using low-enthalpy geothermal water, built as pilot plants, were built in 1952 at Kiabukwa (Democratic Republic of Congo, 200 kW, geothermal water temperature 91°C) and in 1967 at Paratunka (Kamchatka—USSR, 670 kW, temperature geothermal water 85°C) [11].

Although these first installations have demonstrated that it is possible to produce electricity also from low-enthalpy geothermal resources, using ORC technology, economic profitability can only be achieved if the condensation temperature of the working agent can be maintained at a level down. In 2006, a power plant with two groups of 200 kW each was completed in Chena, Alaska, using water from the thermal springs in the area, with a temperature of 74°C. The plant operates continuously, greatly reducing the cost of electricity and eliminating the previously used liquid fuel (diesel). The plant can be cooled with air or water, depending on the season, and it operates in profitable conditions due to the cold climate, the average annual temperature being –5°C [12]. Also in 2006, a consortium of nine European organizations started a project, LOW-BIN, which aimed to build two ORC installations to produce electricity from low-enthalpy geothermal waters. The project was realized in 2009 by building a 7 MW power plant in Simbach am Inn, Germany, using geothermal water with a temperature of 80°C and by building a 50 kW power plant in Oradea, Romania, using geothermal water with a temperature of 104°C. Both installations were integrated into the local heating system. Both plants operated for a while, reaching design parameters, but were shut down for economic reasons [13, 14].

At the present time, the concern of the entire world is to meet the ever-increasing demand for electricity and the reduction of greenhouse gas emissions resulting from the burning of fossil fuels. The current challenges are to generate electricity from renewable resources, friendly to the environment and generating low carbon dioxide emissions. Low-enthalpy geothermal energy sources satisfy these wants. They are huge, have not been used extensively before and can be used to meet future electricity demand, being sustainable for generations [15]. Many countries have completed or have ongoing projects to use low-enthalpy geothermal energy sources for the production of electricity both for rural electrification and for large units connected to local electricity networks: USA (Chena Project, Alaska, 400 kW), Indonesia (Sarulla Project, Sumatra, 330 MW), Turkey (Atça Project, Denizli, 32.8 MW). In Greece, rich in low-enthalpy geothermal resources, it is expected to obtain a production of approx. 45.43 GWh/year (10% of electricity demand) by exploiting such resources [16].

2. Possibility of implementing a LOW-BIN type project in the Moara Vlăsiei geothermal area, in the north of Bucharest

The geothermal reservoirs from the north of Bucharest (**Figure 1**) are located at a depth range between 1800 and 3200 m. They have a surface determined to date of

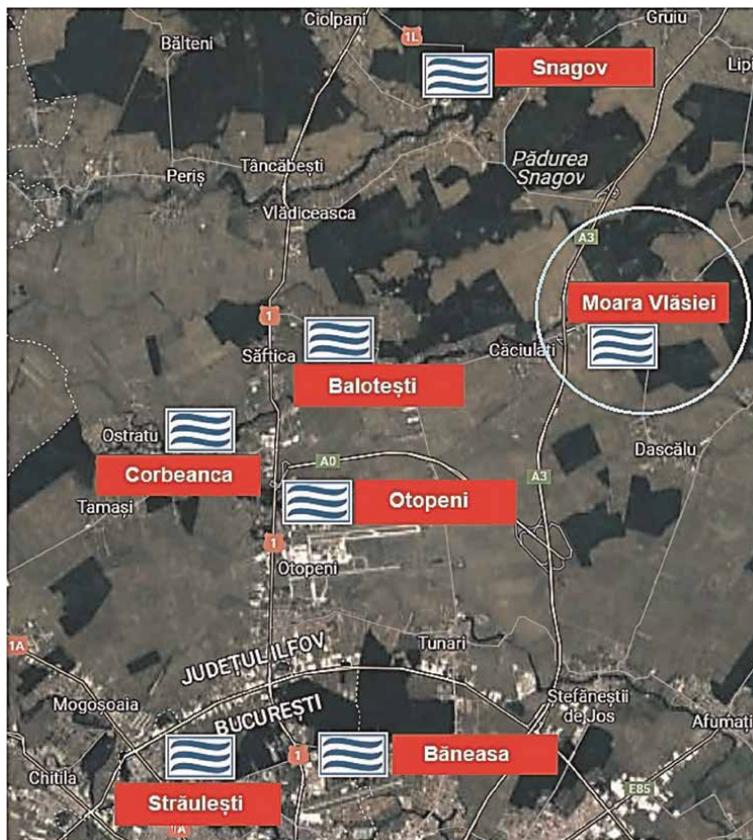


Figure 1.
The geothermal reservoirs in the north of Bucharest (source: Authors' drawing).

approx. 300 km², and the geothermal gradient is between 28 ... 34°C/1 km. The water temperatures obtained through research boreholes are in the range of 58 ... 85°C at the wellhead (the lowest being near Bucharest and the highest near Snagov), and the flow rates are 22 ... 35 l/s. Due to the rather high content of salts (1.5 ... 2.2 g/l) and the high content of hydrogen sulphide (up to 30 ppm), reinjection of waste water into the deposit is mandatory for environmental protection. The geothermal reservoir in the north of Bucharest is not of the artesian type (no pressure in the reservoir) and as a result the extraction must be carried out with the help of bottom pumps, the water level in the wells being approx. 80 mbgl (meters below ground level). To create a pilot station and study its energy efficiency, a borehole that is currently under conservation in the perimeter of the Moara Vlăsiei commune can be used. The borehole has a depth of 3000 m and can provide a constant water flow of 35 l/s, with a wellhead temperature of 75°C, only needing to open it and bring it into working condition.

The commune of Moara Vlăsiei belongs to an area with an average natural hydro-graphic network, represented by several streams known as Cociovaliștea and Vlăsia. Transformed by the Ialomița River into a fluvial estuary through the alluviation of the valley, the Căldărușani Lake was transformed from the union of the Cociovaliștea stream with the Vlăsia stream, both springing from the plain. The depth of the lake registers higher values than those of the Ialomița River. With an area of 224 ha (only

clean water, without reeds), Caldărușani Lake has an average depth of 4.5 m and a maximum of 9–10 m. The lake, with fresh water and with a mineralization of 521 mg/l (NaHCO₃ type), allows visibility up to a depth of approximately 2.5 m. The waves, with a height of 50 ... 80 cm, are formed by the wind blowing at a speed of 34.8 m/sec. Near Grădișteea commune, Căldărușani Lake stretches for a distance of 4 km, of which 1.5 km is clear water, the rest being covered by reeds. The Moara Vlășiei water reservoir is located on the Cociovașiștea valley, from which it is fed, benefiting from the oxygenated water of the river. In the north of the commune, along it, a series of lakes is formed, of which Moara Vlășiei 2 pond is the most famous. It has a total area of 28 ha, being divided into 2 basins: the carp pond, which is 17 ha, and the area called “wild”, with an area of 11 ha. The total length of the pond is about 2 km. The water depth varies between 2 and 4 meters and the bottom is generally silty and there are no submerged trees.

The climate of the area is temperate - continental, with a few days a year below the freezing point, the ponds that are part of the hydrographic system of the Cociovașiștea valley rarely freeze only on the surface. In **Figure 2** are shown the variations in average daily, minimum and maximum temperatures for the period 01.01.2022–30.10.2023.

It can be seen that in recent years, during the cold season, only the night temperatures were slightly below the 0°C limit, while the average daily temperature was never below this value. Characteristic of the area is the fact that during the summer, the maximum daytime temperature of the atmospheric air was within the limits of 30 ... 40°C. This finding is particularly important for the operation of an ORC geothermal plant, because the high temperature of the atmospheric air greatly raises the condensing temperature of the working agent, causing the energy efficiency to

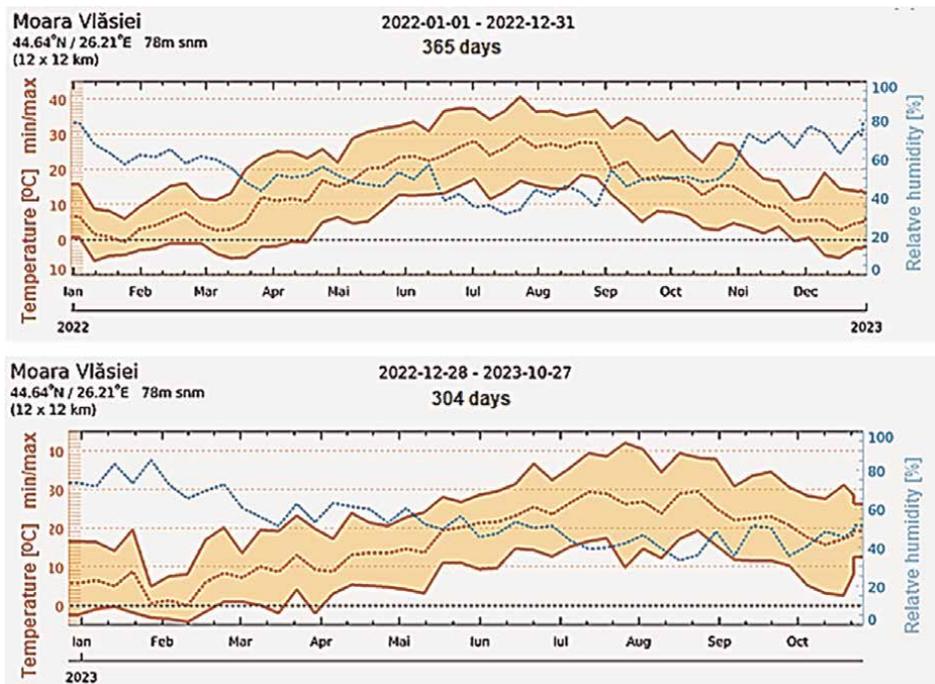


Figure 2. Temperature variation during the period 2022-01-01 ... 2023-10-27 (source: Meteoblue).

decrease drastically. In the conditions where the available geothermal water has a wellhead temperature of 75°C, to obtain a reasonable efficiency of 5... 7%, water cooling of the condensers would be favorable. This, however, requires the authorized design of the adduction and the obtaining of approvals from the Romanian National Water Authority (ANAR), respectively the National Environmental Protection Agency (ANPM) for the use of water from the Cociovașiștea hydrographic basin, when necessary, considering that the lake area makes part of the “Nature 2000” protected area ROSPA0044.

Currently, the General Urban Plan (PUG) of the Moara Vlășiei commune does not make any reference to the possibility or intention of exploiting the geothermal resources located within the commune’s perimeter. As a result, the implementation of a LOW-BIN type pilot plant cannot be coupled with the possibility of harnessing the thermal energy of the water discharged from the plant, which must be re-injected back into the geothermal reservoir. The content of salts and hydrogen sulphide of the water do not allow it to be cooled and discharged into the hydrographic basin of the Cociovașiștea River. Considering that the area is of tourist interest for fishing, ornithological observations, boat walks on the lake and the Căldărușani monastery located in the immediate vicinity, the LOW-BIN type installation for the production of electricity, through the available hot water, could generate in the future the development of relaxation units (thermal baths) or create the prospect of centralized heat supply to the residential sector or public institutions in the area. In this sense, we can cite the Metropolitan Project no. 13 “Utilization of geothermal resources from the Bucharest-Ilfov Region for heating homes” of the Bucharest City Hall, Ilfov County Council, which has as objectives:

- Reduction of CO₂ emissions resulting from the production of thermal energy from conventional sources, by capitalizing on the geothermal resources in the northern part of the Bucharest-Ilfov Region;
- The use of geothermal resources in the Bucharest-Ilfov Region as a source of renewable and non-polluting energy for heating homes in the Territorial Administrative Units (UATs) located in the vicinity of thermal water sources;
- Reduction of home heating costs borne by county citizens;
- Increasing the county’s energy independence from natural gas imports.

The estimated budget of the project is EUR 100 million (including the digging of 4 wells of EUR 5 million each), the period of the works being estimated between 2023 and 2027 [17].

3. Analysis of plant operation and performance prediction

The condenser of the plant can be cooled with atmospheric air or with water.

Water cooling is more favorable because it provides low condensing temperatures and consequently a high expander expansion ratio, while atmospheric air cooling involves higher condensing temperatures and consequently a lower expander expansion ratio. Water cooling is simpler and requires heat exchangers reduced in size and heat transfer surface. Water cooling, however, involves ensuring the necessary flow

rates, which most of the time involves high expenses for deep drilling or the arrangement of adductions, if surface water is used. To these must be added the energy required for the pumps and the approvals from the competent authorities.

Air cooling involves larger heat transfer surfaces and as a result larger dimensions for the heat exchangers, but in return does not require installation costs and environmental approvals. Air cooling, however, is strongly influenced by the temperature of the atmospheric air, which means that during the cold season the operation of the installation is very efficient (maximum power obtained) the condensation temperature of the working agent being low, but during the warm season, as it increases atmospheric air temperature, the condensation temperature of the working agent in the installation increases, which drastically reduces the power obtained at the electric generator. However, this can be improved by using evaporative coolers in the warm season, which combine air cooling with water cooling. The required cooling water being used in a closed circuit, leads to very low consumption that can be provided without problems from local sources. In any case, the organic fluid must condense in the pipes that form the heat transfer surface of the coolers, so that the temperature difference between the condensing agent and the temperature of the cooling air is as minimal as possible, in order to ensure the maximum efficiency of the installation (obtaining a power maximum possible at the generator). There are several types of air-cooled condensers suitable for use in ORC installations using atmospheric air cooling: dry coolers; evaporative coolers that work in wet mode; hybrid coolers that can work both in dry and wet mode; coolers with adiabatic air cooling (adiabatic coolers).

From the point of view of operation, the scheme of the installation and the way of temperatures variations in its evaporator and condenser are identical, the difference consisting in the variation range of the temperature of the coolant, which determines the level of the condensing temperature. During the cold period, the operation of the installation becomes very efficient because the power obtained from the generator increases, the condensation temperature can be reduced as the temperature of the atmospheric air decreases. In warm periods, the use of condensers with evaporative, hybrid or adiabatic cooling allows maintaining the condensing temperature at a level at which the power obtained at the generator is high enough, with a reduced consumption of cooling water. Compared to water cooling, which simplifies the construction of the module, but involves large investments for the arrangement of water intake and discharge, as well as approvals for construction and operation, air cooling leads to good results, the investment being limited only to the purchase of the equipment (the heat exchangers) and ensuring a source of water to supplement the evaporated quantity during the periods when working in a wet regime.

The operation scheme of the module is shown in **Figure 3**. The vapors generator of the installation consists of two sections. The hot geothermal water from the extraction well first enters in the vaporizer itself, where the saturated liquid with state 5 is vaporized, and obtaining superheated vapors with state 1. In the second part of the vapor's generator, the working agent is preheated to the saturation temperature. The temperature to which the geothermal water can be cooled depends on the need to achieve a minimum temperature difference allowed in point 5, at the exit from the preheater (pinch-point), within 3... 5 degrees, this requirement obviously determining the vaporization temperature. The condensing temperature is determined by the temperature of the available coolant, the allowable temperature variation for the cooling medium and the minimum allowable temperature difference at the outlet of the condenser. To avoid the operation of the expander in the wet area, a slight

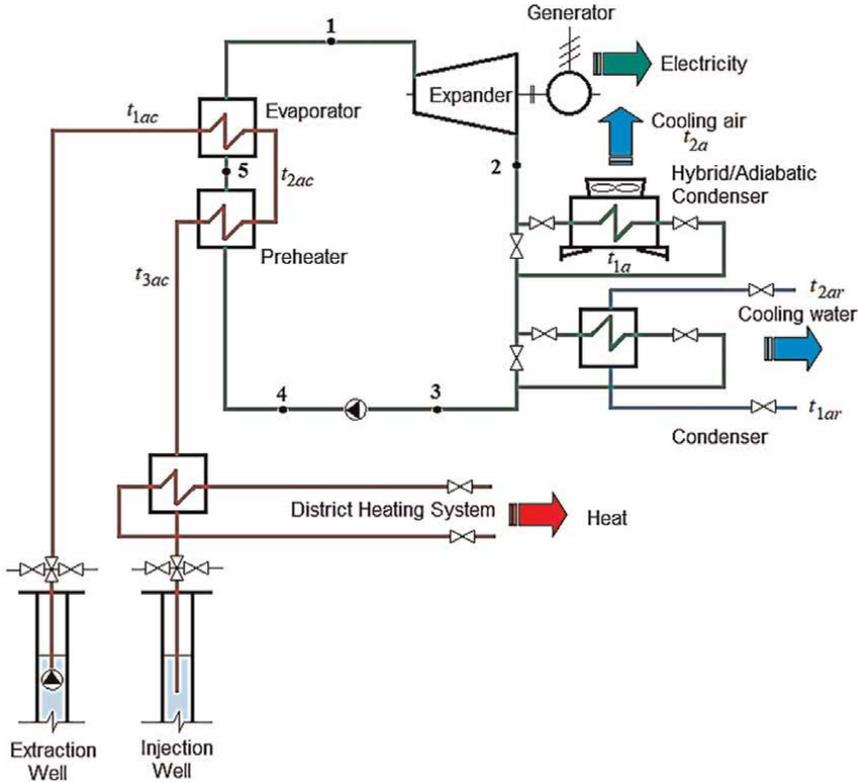


Figure 3.
 Scheme of operation of the installation (source: Authors' drawing).

overheating of about 5 degrees of the vapors at the exit from the vaporizer was considered. Since the vapor state at the exit of the expander is very close to the saturation state, it is not necessary to introduce a regenerative heat exchanger to take the superheating heat, in order to preheat the working agent before entering the vaporizer system. The expansion process in expander was considered adiabatic, irreversible, the internal efficiency of the expander being set to a usual value for turbo type expanders. State 3 of the liquid leaving the condenser was considered saturated liquid state, and the process of raising the pressure in the steam generator feed pump was also considered an adiabatic, irreversible process.

To simulate the operation of the plant under different conditions, the vaporization temperature t_v was considered as the independent variable. The temperature t_{3ac} to which the geothermal water can be cooled is determined from the heat balance equation of the vaporizer, respectively of the preheater:

$$t_{3ac} = t_{2ac} - (t_{1ac} - t_{2ac}) \frac{h_5 - h_4}{h_1 - h_5} [^{\circ}C] \quad (1)$$

in which the temperature of the geothermal water at the outlet of the vaporizer is set so that a temperature difference (pinch-point) $\Delta t_{pp} = 3 \dots 5^{\circ}C$ is achieved here (**Figure 4, left**):

$$t_{2ac} = t_v + \Delta t_{pp} [^{\circ}C] \quad (2)$$

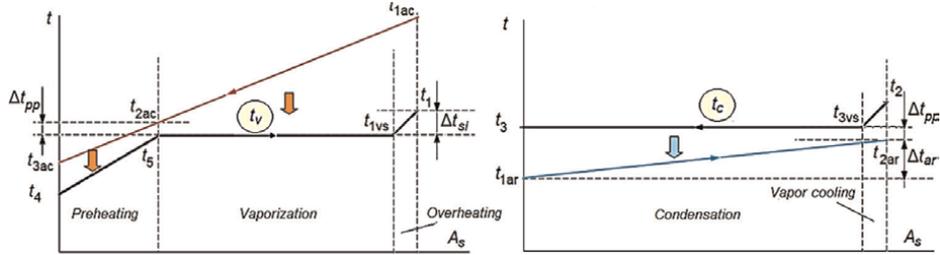


Figure 4. Temperature variation in evaporator and condenser (source: Authors' drawing).

The considered parameter	Value	Unit
Geothermal water temperature at the wellhead	75	°C
Flow of geothermal water	35	l/s
Coolant temperature (depending on the season)	0 ... 30	°C
Minimum temperature difference in the heat exchangers (pinch-point)	3	deg
Overheating of vapors	5	deg
Variation of the coolant temperature	5	deg
The isentropic efficiency of the expander	0.85	
The isentropic efficiency of the circulation pumps	0.75	
Vaporization temperature	40 ... 60	°C
Condensation temperature (depending on the coolant available)	5 ... 25	°C

Table 1. The operating conditions of the plant.

The condensation temperature depends on the initial temperature t_{ar1} (or t_{a1}) of the available coolant, on its temperature variation Δt_{ar} and on the minimum admissible temperature difference at the exit from the heat exchanger (**Figure 4** right):

$$t_c = t_{1ar} + \Delta t_{ar} + \Delta t_{pp} [^{\circ}C] \quad (3)$$

The study of the installation performances, starting from the flow rate and temperature of the available geothermal water, was carried out in two variants: water cooling and air cooling.

According to the operation scheme shown in **Figure 3**, the operating conditions of the plant were considered as **Table 1**.

Figure 5 shows the thermodynamic cycle of the plant, represented in temperature-entropy ($T - s$) diagram, highlighting the energy flows that the refrigerant exchanges with external environment.

The state parameters at the characteristic points of the cycle were calculated according to the algorithm presented in **Table 2**, using the Engineering Equation Solver (EES) calculation environment.

The characteristic sizes of the installation are:

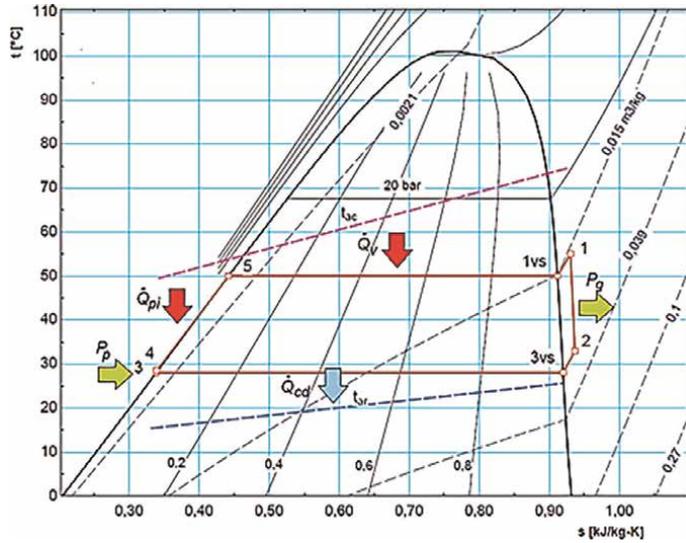


Figure 5.
 Thermodynamic cycle in T – s diagram (source: generated in EES software).

State point	Description	Known state parameters	Functions EES for state parameters
1	Superheated vapors at the inlet of the expander	$p_1 = p_v$ $t_1 = t_v + \Delta t_{si}$	$h_1 = h(p_v, t_1)$ $s_1 = s(p_v, t_1)$
2s	The end of the isentropic expansion process	$p_{2s} = p_c$ $s_{2s} = s_1$	$t_{2s} = t(p_c, s_{2s})$ $h_{2s} = h(p_c, s_{2s})$
2	The end of the actual expansion process	$p_2 = p_c$ $h_2 = h_1 - \eta_{exp}(h_1 - h_{2s})$	$t_2 = t(p_c, h_2)$ $s_2 = s(p_c, h_2)$
3vs	Dry saturated vapors after cooling	$p_{3vs} = p_c$ $x_{3vs} = 1$ $s_{2s} = s_1$	$h_{3vs} = h(p_c, x = 1)$ $s_{3vs} = s(p_c, x = 1)$
3	Saturated liquid at the outlet of the condenser	$p_3 = p_c$ $x_3 = 0$ $t_3 = t_c$	$h_3 = h(p_c, x = 0)$ $s_3 = s(p_c, x = 0)$
4s	The end of the isentropic pumping process	$p_1 = p_v$ $s_{4s} = s_3$	$t_{4s} = t(p_v, s_{4s})$ $h_{4s} = h(p_v, s_{4s})$
4	The end of the actual pumping process	$p_4 = p_v$ $h_4 = h_3 + (h_{4s} - h_3)/\eta_{pp}$	$t_4 = t(p_v, h_4)$ $s_4 = s(p_v, h_4)$
5	Saturated liquid at the outlet of the preheater	$p_5 = p_v$ $x_5 = 0$ $t_5 = t_v$	$h_5 = h(p_v, x = 0)$ $s_5 = s(p_v, x = 0)$
1vs	Dry saturated vapors	$p_{1vs} = p_v$ $x_{1vs} = 1$ $t_{1vs} = t_v$	$h_{1vs} = h(p_v, x = 1)$ $s_{1vs} = s(p_v, x = 1)$

Table 2.
 The calculating algorithm for the values of the state parameters.

- Specific cooling capacity of the condenser:

$$|q_c| = h_2 - h_3 [\text{kJ/kg}] \quad (4)$$

- Specific heat load of the evaporator:

$$q_v = h_1 - h_5 [\text{kJ/kg}] \quad (5)$$

- Specific heat load of the preheater:

$$q_{pi} = h_5 - h_4 [\text{kJ/kg}] \quad (6)$$

- The specific mechanical work of expansion in the expander:

$$l_{exp} = h_1 - h_2 [\text{kJ/kg}] \quad (7)$$

- The specific mechanical work of pumping:

$$|l_{pp}| = h_4 - h_3 [\text{kJ/kg}] \quad (8)$$

- The mass flow of geothermal water has the expression:

$$\dot{m}_{ac} = \frac{\dot{V}_{ac} \rho_{ac}}{1000} [\text{kg/s}] \quad (9)$$

where \dot{V}_{ac} [l/s] is the flow rate of the hot geothermal water well, and ρ_{ac} [kg/m³] is the density of the hot thermal water.

The flow rate of the working agent results from the thermal energy balance of the vaporizer:

$$\dot{m} = \dot{m}_{ac} \frac{c_{ac}(t_{1ac} - t_{2ac})}{h_1 - h_5} [\text{kg/s}] \quad (10)$$

The heat flow received in the vapors generator from the geothermal water (hot source) is:

$$\dot{Q}_v = \dot{Q}_{SC} = \dot{m}(q_v + q_{si}) [\text{kW}] \quad (11)$$

and the heat flow transferred to the condenser (cold source) has the expression:

$$|\dot{Q}_c| = |\dot{Q}_{SR}| = \dot{m} |q_c| [\text{kW}] \quad (12)$$

resulting in the expression for the thermal efficiency of the cycle:

$$\eta_{th} = \left(1 - \frac{|\dot{Q}_{SR}|}{\dot{Q}_{SC}}\right) \cdot 100 [\%] = \left(1 - \frac{|q_c|}{q_v + q_{si}}\right) \cdot 100 [\%] \quad (13)$$

To select the optimal working agent, the operation of the installation was simulated using the EES computing environment, considering several usual agents for ORC installations, considering the variable vaporization temperature in the range of 40 ... 60°C, the coolant temperature being constant and equal to 20°C. The agents

taken into account are presented in **Table 3**. On the one hand, these are agents that have thermodynamic properties that correspond to the use in an ORC installation, under the given conditions, and on the other hand, they are ecological agents, accepted according to “EU Regulation 517/ 2014 on fluorinated greenhouse gases”, having zero ozone depletion potential (ODP) [20].

The simulation results are shown in **Figure 6**. It can be seen that the performance of the installation, the power of the electric generator and the thermal efficiency depend on how the vaporization temperature is chosen:

- Whatever the working agent used, the maximum power of the installation is obtained if the vaporization temperature is chosen around 50°C;
- Agents leading to maximum performance are found to be R134a (HFC) and R1234ze(E) (HFO).

Refrigerant	Group	Critical temperature t_{cr} [°C]	ODP	GWP/CO ₂	Safety group
R123	HCFC	183.7	0.02	9100	B1
R245fa	HFC	154.0	0	858	B1
R134a	HFC	101.0	0	1300	A1
RE170 (DME)	HC	127.2	0	1	A3
R600a	HC	134.9	0	3	A3
R600	HC	154.2	0	4	A3
R1233zd(E)	HFO	165.5	0	1	A1
R1234ze(E)	HFO	109.4	0	6	A2L

Table 3.
 Usual working agents (refrigerants) accepted [18, 19].

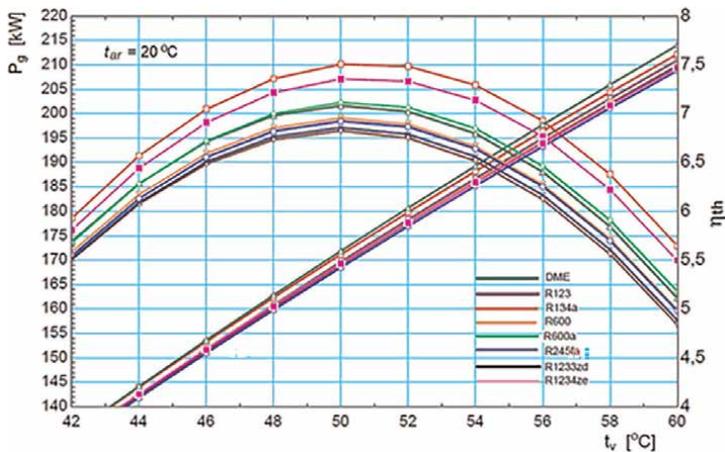


Figure 6.
 Electric generator power and efficiency in relation to the choice of vaporization temperature and refrigerant (source: generated in EES software).

The optimal agent for this installation is considered R134a because it allows obtaining the maximum power (210 kW) for the maximum drilling flow (35 l/s), it has a negligible environmental impact (GWP = 0; ODP = 1300), non-toxic, non-flammable (A1) and is the agent with the greatest use in installations operating after reverse cycles, being easily accessible. Also, on the market there are equipment dedicated to this refrigerant, well designed and tested. The R1234ze(E) refrigerant has quite similar performance but is more flammable and more expensive.

Figure 7 shows the result of the simulation of the plant operation, for the refrigerant R134a, considered the coolant temperature 20°C and the vaporization temperature of 50°C for which the maximum power is obtained.

An important parameter that determines the performance of the installation is the temperature of the cooling agent. If it comes from a deep well, its temperature is constant with values in the range of 10 ... 15°C. However, if it is surface water (river, lake), its temperature is variable and depends on the season, being within the limits of 5 ... 25°C. If the cooling agent is atmospheric air, its temperature, according to the climate of the area, can be in the range of 0 ... 30°C. Changing the temperature of the cooling agent causes a change in the temperature and, respectively, the condensing pressure of the refrigerant. This primarily results in the modification of the expansion

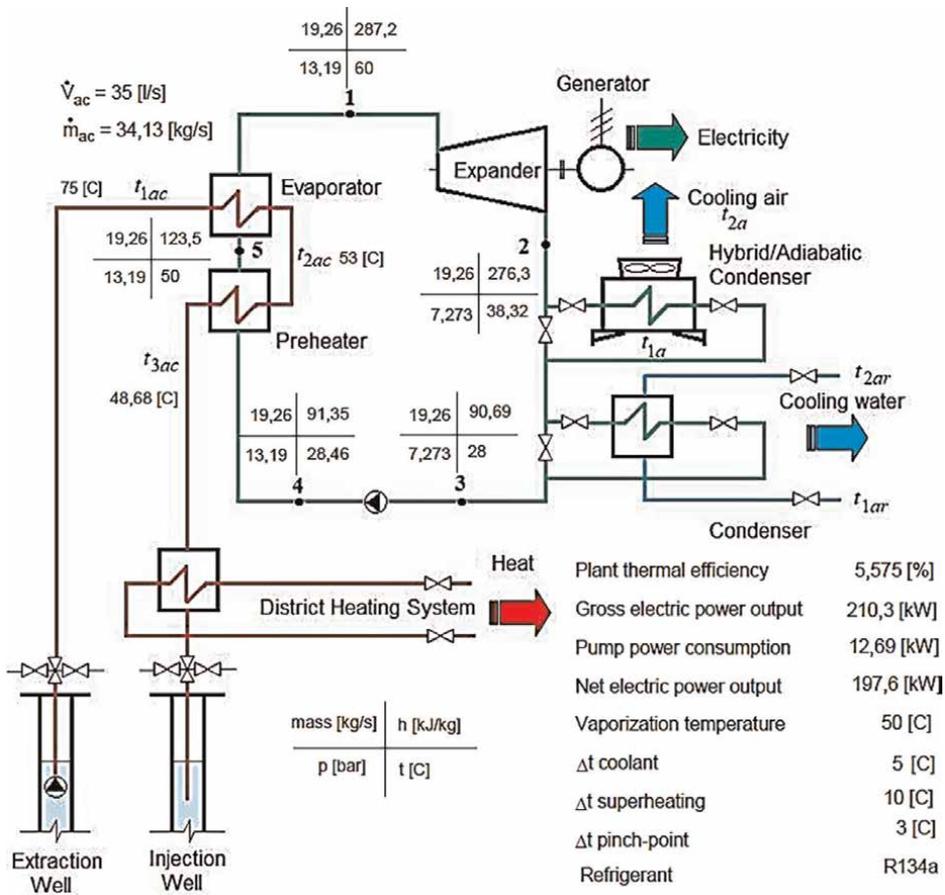


Figure 7. The result of the simulation of the ORC plant operation (source: generated in EES software).

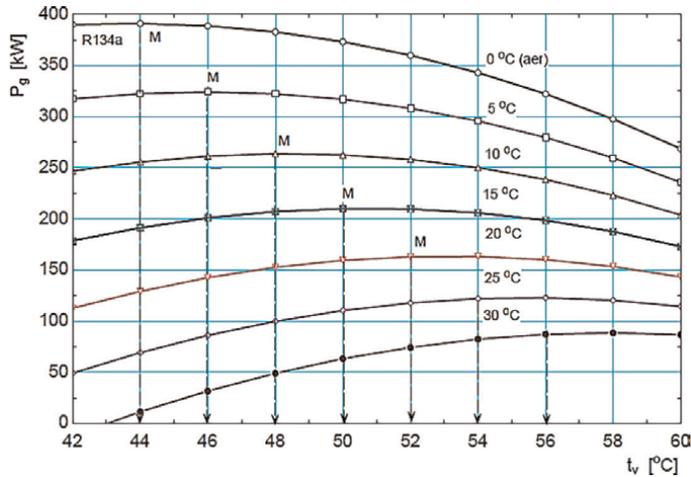


Figure 8.
 Electric generator power in relation to the choice of vaporization temperature (source: generated in EES software).

ratio of the expander and as a result of the specific mechanical expansion work. At the same time, the specific heat load of the vaporizer system also changes, which leads to a change in the flow rate of the working agent. If for each value of the cooling agent temperature, the vaporization temperature changes, it is found that the power at the generator changes according to a parabolic law, presenting a maximum for a certain vaporization temperature. As the cooling agent temperature decreases, the power generated by the plant increases, with maximum power being obtained at lower and lower vaporization temperatures. **Figure 8** shows, for the chosen agent R134a, the variation of the power at the generator in relation to the change in the vaporization temperature.

For cooling water extracted from deep wells with a temperature of approx. 15°C, the plant can produce about 250 kW. For cooling water from surface storage the power produced can vary between 150 and 350 kW depending on the season and for air cooling 75... 400 kW depending on the season also. For the operation of the installation, the cooling water flow must have a fairly large available 150 ... 220 l/s (540 ... 800 m³/h) which could require (depending on local conditions) the use of a closed circuit, with cooling tower. At a temperature of 15°C, the installation operating with a dry condenser (dry cooler) can produce approx. 210 kW. At high temperatures, corresponding to the summer season, the power produced by the generator drops below 100 kW, which does not even cover the energy consumption of the pumps. To keep the power at a reasonable level, at a threshold of 150 kW the condenser must work in the wet evaporating mode. It can be seen that the air flow required to cool the condenser is quite high, being around 250 ... 350 m³/s (0.9•10⁶ ... 1.3•10⁶ m³/h).

Figure 9 shows the variation of the vaporization temperature at which the maximum power of the installation is obtained, as well as the temperature at which the used geothermal water is discharged from the installation, depending on the temperature of the available cooling agent. It can be seen that, in order to obtain the maximum power at the electric generator, the temperature and vaporization pressure must be constantly adjusted according to the temperature of the available cooling agent.

The lower the temperature of the cooling agent, the more power is obtained from the plant and at the same time the geothermal wastewater is discharged with a lower temperature. The discharge temperature of the waste water is in the range of 40 ... 50°

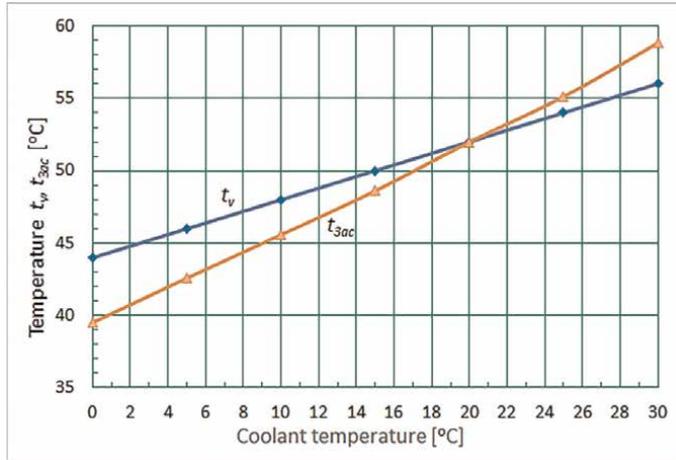


Figure 9. Optimum vaporization temperature and geothermal water outlet temperature depending on the coolant temperature, in maximum power mode (source: generated in EES software).

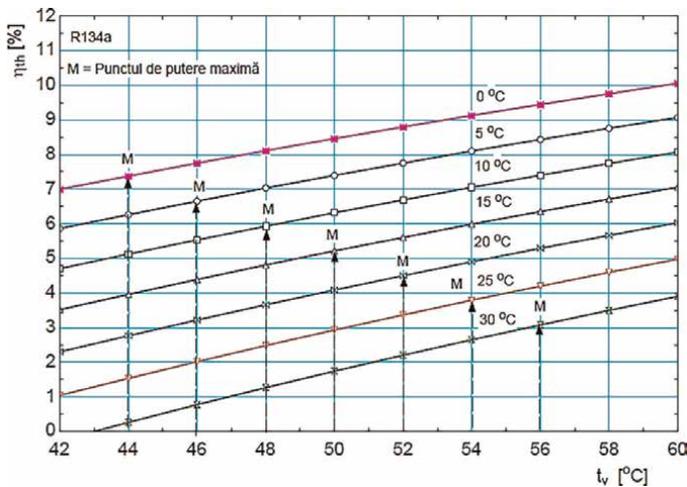


Figure 10. Plant efficiency in relation to the choice of vaporization temperature (source: generated in EES software).

C, depending on the temperature of the cooling agent. At this temperature level, to increase energy efficiency, the wastewater discharged from the plant can be used directly for heating or as a source for a heat pump.

As shown in **Figure 10**, the efficiency of the installation falls within the limits of 7.5... 5% depending on the temperature of the cooling agent, values also reported in the specialized literature for ORC installations that have as heat source low enthalpy geothermal water [21].

4. Conclusions

In Romania there are important reserves of geothermal water with low enthalpy which are currently only used directly for heating or for relaxation and spa treatment

units. This study, as well as others on the same theme, highlights the fact that electricity can also be obtained in the case of these low-enthalpy resources, within the limits of 1500 ... 3000 MWh/year, from geothermal wells with usual flow rates of 30 ... 40 l/s.

The necessary equipment does not raise problems, because the mentioned studies have shown that the most suitable working agent is the classic refrigerant R134a, for which the manufacture of equipment is very well developed. Although this refrigerant is still in use, its replacement in the future does not raise problems because there is developed the refrigerant of the new generation of "green" agents R1234ze (E), which has the same characteristics and allows the same performance.

The main problem, which influences the cost of the investment and its recovery period, is the cooling mode of the condenser. Water cooling is more efficient from an equipment point of view, but requires greater expenditure for the arrangement of the water source, in addition to the expenses related to the operation of the pumps and the necessary environmental approvals. Air cooling requires larger heat transfer surfaces, but requires nothing more than the expenses related to the operation of the fans. However, air cooling is strongly dependent on the atmospheric temperature, ensuring a high efficiency of the installation only in cold periods. In the warm season, the efficiency of the installation can be maintained at an acceptable level by using coolers that can operate in wet mode (hybrid or adiabatic coolers).

In any case, the temperature of the discharged geothermal water is quite high, around 45 ... 50°C, so there is still a high, unused thermal potential. On the other hand, the low thermal efficiency, 6 ... 8%, highlights the fact that more than 90% of the heat taken from the geothermal water is discharged into the environment by cooling the condenser. It is interesting to study how to exploit this low thermal potential by joining this type of installation to a relaxation and spa treatment unit or by integrating the ORC installation into local heating system.

With the help of classic technology (Rankine cycle with steam) only high-enthalpy geothermal resources can be exploited: steam obtained directly from the geothermal reservoir (dry-steam), steam obtained by expanding hot geothermal water with high pressure (flash-steam) or steam obtained by injecting water into hot rocks located at great depth. The huge potential represented by medium and low enthalpy geothermal resources cannot be harnessed by conventional technology for the purpose of electricity production. The Organic Rankine Cycle (ORC) allows electricity to be obtained from these resources as well, being a smart means of producing electricity locally from renewable resources without greenhouse gas emissions. Benefiting from today's chiller and heat pump technology, the cost of equipment investments can be quickly amortized. Moreover, expanders can be made relatively simply by adapting compressors used for refrigerants. The disadvantage of using ORC technology for the production of electricity from medium and low enthalpy geothermal water consists primarily in the very low efficiency, of the order of 4 ... 7%, which makes a large part of the energy of geothermal water remain unused. Also, the electrical power obtained is small (from several tens of kW to several hundred kW), depending on the available flow rates of the geothermal water wells. Also, an important disadvantage is the high cost of drilling and setting up geothermal water wells, which can amount to several million EUR in the case of drilling at depths of 3000 ... 4000 m. In the case of aquifers that cannot be exploited artesian, and which assume the reintroduction of waste water into the geothermal reservoir, the required pumping energy can reach the level of the energy produced by the installation, or even exceed it. Consequently, a careful analysis of local conditions is necessary to determine whether such an installation is economically

justified, even if it is very tempting as an idea and as a challenge. Considering the fact that the geothermal water used still has an important thermal potential, coupling an ORC installation that produces electricity with a system for direct use of this potential (SPA units, greenhouses, fish and animal farms or as an energy source for heat pumps) can constitute an intelligent cogeneration system for urban communities in the vicinity of such resources.

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Vehicle Charging Station through Renewable Energy Technology

Athar Rashid, Syed Atif Naseem and Muhammad Mohsin Aman

Abstract

Fossil fuel is one of the main sources to run the transportation sector of the country. Fossil fuel is also utilized to produce electricity, but consumption of fossil fuel in the transportation sector impacts a huge burden on the economy of the country. It is vital to shift the fossil fuel-based transportation sector toward the renewable energy sources-based electric vehicle having the charging batteries. In this paper, a charging station, through renewable energy technology, has been discussed along with charging batteries of different categories as a power source to fulfill the requirement of demand/supply of electricity to the transportation sector. In addition, the vehicle parking charging station can also be utilized as a vehicle-to-grid power station, where the vehicle becomes a power source in a contingency or in a high demand by supplying electricity back to grid.

Keywords: renewable technology, charging station, battery storage, vehicle power source, fossil fuel, vehicle to grid

1. Introduction

Transportation sector is one of the important sectors of any country, in which economy is heavily dependent on fulfilling the requirement of transportation fuel by importing the fossil fuel from an oil-rich country. Ito and Penner [1] provide valuable data regarding the emission of carbon black and particulate organic matter (POM) through fossil fuel burning and biomass burning. The research also discusses the amount of warming due to the burning of biomass, biofuel, and fossil fuel. Capellán-Pérez et al. [2] discuss the depletion of fossil fuel and estimate the energy required through fossil fuel until 2050. The research also calculates the carbon dioxide (CO₂) concentration and provides a solution to replace the fossil fuel through a renewable energy technology, that is, solar energy sources and wind energy sources. It also develops an energy, economic, and environment model related to system dynamics and discusses the potential of utilizing renewable energy technologies for the transportation sector. Narasipuram and Mopidevi [3] discuss the limitation of an internal combustion engine and its impact on environment and human health. In addition, the research also explains the various design aspects of configuration of a charging station in order to meet the requirement of the transportation sector. Jia et al. [4] discuss the sizing and siting of an electric vehicle charging station and its variables to meet the

charging demand and abstracts the structure of road network. Through the graph theory, it solves the problem of demand supply of electricity to the transportation network. Domínguez-Navarro et al. [5] explain the design related to fast charging station of electric vehicles through renewable energy sources and storage system. The paper uses the Monte Carlo method and genetic algorithm to optimize the charging station to charge any vehicle within 15 minutes. Similarly, Christophe Guille and George Gross [6] study the conceptual framework for the vehicle-to-grid implementation as a distributed energy resource to provide and fulfill the requirement of demand energy on the distribution network during off-peak period. The vehicle to grid also generates and stores energy during the day time and provides the electrical power to grid, when required. Electric vehicle when interconnected to grid, in order to charge the battery, will serve as a new load, and the electrical distribution system must supply the power to the electric vehicle. However, battery electric vehicle (BEV) when interconnected to grid is more than a load, and it can work as the bidirectional energy transfer from grid to vehicle and vice versa. For reliable operation of distribution network, battery electric vehicle integrated to a grid allows it to serve as a power generation source as well as a storage device for a certain period of time in order to fulfill the requirement of energy demand, improving reliability of network, reducing carbon emission, and thus protecting the environment from pollution.

A battery or batteries of a single vehicle is a small resource to provide the energy back to grid, during the peak shaving period. In this regard, a charging parking station is vital where a number of vehicles can be parked and by harnessing their batteries to get full benefit when interconnected to grid as generation/storage device or load. During night at off-peak period, the charging of vehicle can be done, and thus the load leveled without increasing the supply demand from the grid. Similarly, during the day, the parked BEV will become a power generation resource and fulfill the requirement during contingency or peak shaving energy. In this way, the battery electric vehicle can act both as a load and as a power generation source/storage device. Christophe Guille and George Gross [6] and Benjamin K. Sovacool et al. [7] also discuss the power industry's capacity and capability to accommodate the new type of load for the battery electric vehicle or plug-in hybrid vehicle (PHEV). Moreover, the study also shows to introduce or replace the 25% of internal combustion engine of vehicle to BEV/PHEV, and it will be required to install around 160 power plants, if the owner of each BEV/PHEV plugs in his BEV to grid at 5 pm in the evening. However, by introducing the low-cost slab to the consumer by charging the batteries of BEV at off-peak period, that is, late evening/night, can eliminate the requirement of installation of a new power plant through fossil fuel utilization. Further More, by using the solar sources, wind sources, and hydropower technology, a hybrid power plant can be constructed by utilizing the maximum natural resources and reducing the CO₂ gas emission for a healthy environment and less pollutant, toxic areas and to accommodate the transportation sector by fulfilling the requirement of BEV / PHEV and avoid the dependency on fossil fuel importation.

Vehicle-to-grid interconnection can provide a backup power, support load balancing, charge the batteries during off-peak period, and maintain the hourly electrical demand along with utilizing the capacity of a distribution network. Benjamin K. Sovacool et al. [8] discuss the financial, environmental, social, and consumer benefits by reducing the greenhouse gas (GHG) emission, when BEV can be interconnected to a renewable energy-based power plant. In addition, the barriers and challenges are also highlighted, that is, control and communication, financial hurdles, and negative environmental externalities. The research also explains the sociotechnical system for

transportation and how it is consisting of regulations, policies, maintenance, distribution network, industry structure, fuel infrastructure, and road infrastructure. Furthermore, the dimensions of the sociotechnical system for vehicle-to-grid interconnected transition are covered in the domain of financial, technical, social-environmental, and consumer behavioral aspects.

2. Renewable energy sources-based power plant for charging station

Renewable energy sources-based power plant will be consisting of a solar power plant, a wind power plant, and a hydropower plant to fulfill the requirement of the transportation sector. A hybrid renewable energy sources-based power plant can be utilized in two ways, which are defined below:

- Renewable energy sources-based power plant for charging station and electric storage batteries.
- Renewable energy sources-based power plant for car parking charging station and vehicle-to-grid interconnection.

2.1 Renewable energy sources-based power plant for charging station and electric storage batteries

For an electric vehicle, renewable energy source-based power plant is required in order to remove the burden of importing the fossil fuel to run the transportation sector. **Figure 1** elaborates the car charging station, in which renewable energy technology, a hybrid system, is the main source to provide the energy/power to a car charging station, in which one battery electric vehicle is allowed only a 15-min duration to fully charge its batteries. In addition, the charging station should have standalone batteries like lithium-ion batteries, lead-acid batteries, or fuel cell to store the extra energy produced by hybrid power plant in order to utilize it during contingency or peak saving period. The sizing of battery for a renewable energy power plant Eq. (1) is very important in order to run the transportation at night when the sun is not present to produce the enough electricity for BEV.

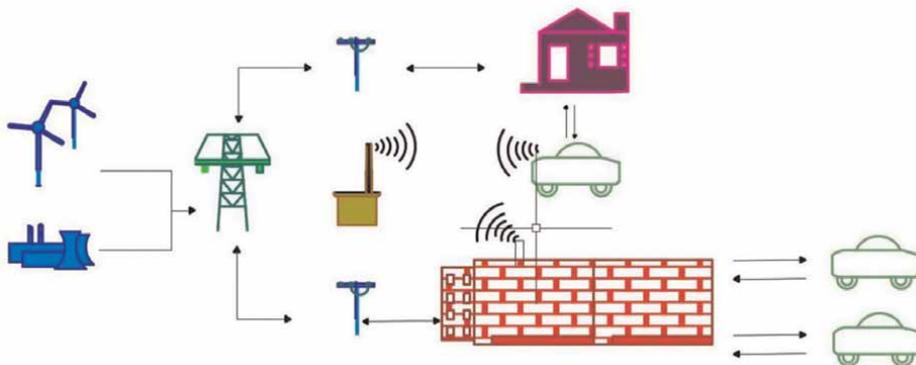


Figure 1.
Vehicle charging station and vehicle parking station.

$$\text{No. of batteries} = \frac{\text{load to be operated in Watt – hours (WH)}}{\text{battery power in WH}} \quad (1)$$

$$\text{No. of batteries} = \frac{\text{load to be operated in Watt – hours (WH)}}{\text{battery capacity}^* \text{ derating factor}} \quad (2)$$

It is interesting to note that, in a fast charging station, BEV has a maximum 15-min duration to fully charge the batteries and leave the charging station accordingly, whereas standalone charging batteries also receive the extra energy from renewable energy power sources present in the car/vehicle charging station.

2.2 Renewable energy sources-based power plant for car parking charging station and vehicle-to-grid interconnection

Chargeable car parking station through renewable energy technology is vital to provide a bidirectional flow of power. Battery electric vehicle will be charged at daytime by parking it in the charging station and thus become a power source during peak shaving period and at night.

Car parking charging station is a place in which the consumers of BEV can park their car for a long period of time in order to connect it with the grid. After the charging of BEV is completed at the parking station, the BEV can be used as a power source to fulfill the requirement of energy demand in the charging station or grid. Thus, the consumer who had parked their vehicle in a chargeable car parking station will get a net profit by providing the energy back to grid or chargeable charging station during high demand of electricity.

3. Life cycle assessment (LCA) of vehicles with different energy sources

Life cycle assessment (LCA) is a systematic approach to evaluating the environmental impacts of a product, process, or activity throughout its entire life cycle, from raw material extraction to disposal. The goal of LCA is to assess the environmental aspects and potential impacts of a product or system and provide a comprehensive understanding of its environmental performance. Key aspects and principles of Life Cycle Assessment include:

- A. *Cradle-to-Grave Perspective*: the LCA considers the entire life cycle of a product, from raw material extraction (cradle) to end-of-life disposal (grave).
- B. *System Boundaries*: defining the limits of the system under study to ensure a comprehensive assessment while avoiding unnecessary complexity.
- C. *Functional Unit*: the LCA evaluates environmental performance per unit of functional output, allowing for a comparison between different products or processes providing similar functions.
- D. *Data Quality and Sources*: the accuracy and reliability of LCA results heavily depend on the quality of data and the transparency of data sources used in the assessment.

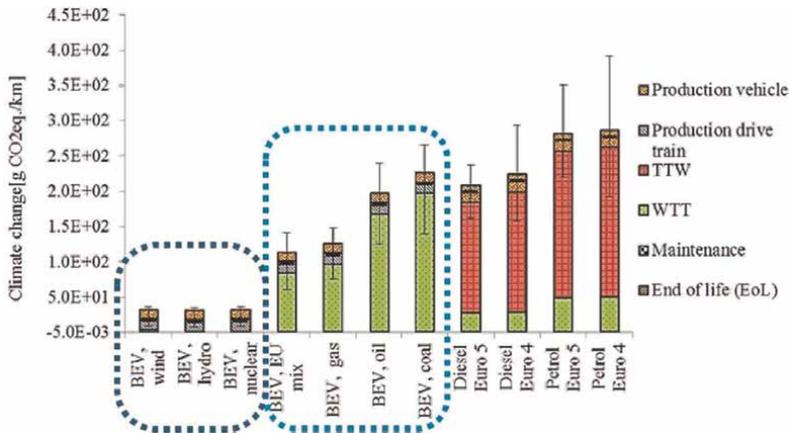


Figure 2.
 Life cycle assessment (LCA) of vehicle with different energy sources.

The life cycle assessment is widely used in various industries to support sustainable decision-making, product improvement, and policy development. It helps identify environmental hotspots, assess the environmental impact of different options, and guide efforts toward more sustainable practices and products.

Figure 2 illustrates the equivalent carbon dioxide emissions (g CO₂eq./km) from a lifecycle assessment of different types of vehicles, taking into account emissions from various stages of the vehicle's life.

Graph can be broken down in three parts,

3.1 Right side: combustion engine cars

This section represents the emissions associated with traditional combustion engine cars. It includes emissions from vehicle production, well-to-wheel emissions from the fuel (from extraction to combustion), vehicle maintenance, and end-of-life recycling. The high emissions for combustion engine cars highlight the environmental impact associated with the use of fossil fuels.

3.2 Middle part: battery-electric cars (charged from emitting sources)

This segment shows the emissions for battery-electric cars when charged from different emitting electricity generation sources. It includes emissions from vehicle production, well-to-tank (WTT) emissions associated with the electricity generation (from the point of electricity production to the charging station), tank-to-wheel (TTW) emissions during vehicle operation, vehicle maintenance, and end-of-life recycling. The emissions are lower compared to combustion engine cars, but they are influenced by the emissions from the electricity generation source.

3.3 Left part: battery-electric cars (charged from non-emitting/renewable sources)

This part displays the emissions for battery-electric cars when charged from nonemitting or renewable electricity generation sources, such as wind, hydro, or

nuclear power. It includes the same components as the middle part but with electricity generated from nonemitting renewable sources.

The emissions are significantly lower, and in the case of renewable sources, the graph suggests that the net life cycle emissions are further reduced, with well-to-tank emissions reduced to zero.

Interpretation:

- The graph underscores the environmental benefits of electric vehicles (EVs) compared to traditional combustion engine cars.
- It highlights that even when EVs are charged from a fossil fuel-dominated electricity grid, their overall emissions are lower.
- The most significant reduction in emissions occurs when EVs are charged from nonemitting or renewable sources, leading to minimal well-to-tank emissions and a further reduction in overall life cycle emissions.
- The conclusion emphasizes the importance of using renewable sources of electricity to charge electric cars for achieving the greatest environmental benefits.

In summary, the graph illustrates the positive impact of electric vehicles on reducing carbon emissions, particularly when powered by renewable energy sources, supporting the case for a cleaner and more sustainable transportation system.

4. Type of electric vehicle

Electric vehicle depends upon charging batteries along with the electric motors installed in order to run smoothly for a longer period of time. There are many types of electric motors produced by different manufacturers, namely, induction motor to vary its speed, permanent magnet synchronous motor, and switch reluctance motor. Electric vehicle is of three types:

4.1 Hybrid electric vehicle (HEV)

Battery packs were introduced in a hybrid electric vehicle along with internal combustion engine, a two-power source car to fulfill the requirement of consumers by reducing the greenhouse gas emission by running for a longer period of time. The performance and functionality of a hybrid electric vehicle remained the same as compared to that of a conventional electric vehicle that utilizes internal combustion engines. Today, Honda and Toyota are producing HEV in a series type HEV or parallel type HEV.

Electric motor in a series type hybrid electric vehicle is energized through a generator that is driven by engines. Series type hybrid electric vehicle is suitable for city type drive, in which internal combustion engine is utilized to run smoothly and efficiently to control the start and stop of the car. Whereas, a parallel hybrid electric vehicle is suitable for highway type drive, in which the internal combustion engine provides a maximum efficiency by consuming less amount of fuel.

When a series or parallel type hybrid electric vehicle is connected to a charging station, a building, a charging park, or a hotel, the vehicle can charge and discharge the battery pads of an electric vehicle. The formula to calculate the maximum power of HEV is given below:

Where:

$$P_{\text{vehicle}} = P_{\text{ideal}} + \eta_{\text{charger}} + \eta_{\text{inverter}} + \eta_{\text{other}} \quad (3)$$

P_{vehicle} = maximum power of V2B (vehicle to building)

P_{ideal} = actual power of charging station

η_{charger} = charger efficiency

η_{inverter} = inverter efficiency

η_{other} = loss of power and battery leakage

4.2 Plug-In electric vehicle (PEV)

Plug-in electric vehicle (PEV) is an improved version of the hybrid electric vehicle, in which the capacity of a battery pack is increased in order to reduce the dependence on fossil fuel consumption for running a vehicle for longer period of time. Charging station infrastructure is required to charge the battery pack of PEV for its smooth performance and longer running period. In this regard, regenerative braking phenomenon was introduced to recharge the high capacity battery while running the vehicle for longer period of time.

For reliable operation of an electric motor installed in PHEV, a bidirectional dc-dc convertor is integrated between battery packs and electric motor in order to increase its efficiency and performance for running a vehicle longer period of time. Charging station infrastructure is required at different locations or at a certain distance in order to bring the PHEV in the market and replace the hybrid electric vehicle. Charging station will also be utilized as parking charging station, in which electric vehicle becomes a power source by providing back the energy to the grid during contingency and peak shaving period through its lithium-ion battery and nickel-metal hydride battery (NiMH).

4.3 Battery electric vehicle (BEV)

The latest and more advanced form of an electric vehicle is a battery electric vehicle that is completely free to utilize the fuel through internal combustion engine and fuel tank. Battery electric vehicle has a large capacity of storing energy in order to run the BEV for longer period of time having a maximum efficiency and performance. **Figure 3** shows that battery pack, which consists of lead-acid batteries, lithium-ion batteries, and nickel-metal hybrid batteries, can increase its capacity by adding a fuel cell or a supercapacitor. Tesla, a world renown company, has established its manufacturing plant to produce a mass production of battery electric vehicles in order to reduce the dependency on fossil fuel consumption and greenhouse gas emission.

Battery electric vehicle can be used as a power source when connected to grid and its efficiency is high as compared to those of HEV and PHEV. Through fast charging station, the reliability of BEV will be increased along with the provision of good acceleration. Battery electric vehicle can also be used to store a large amount of energy and return back this storage energy to grid during contingency and peak shaving period.

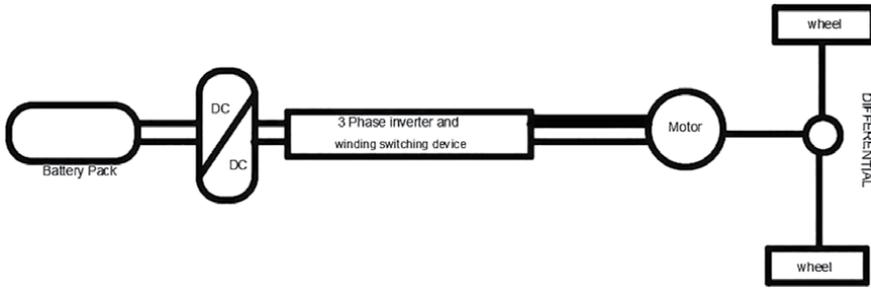


Figure 3.
Electric vehicle with lithium-ion battery.

A charging station infrastructure is required in order to fully replace the PHEV and HEV. With the passage of time, the high cost of energy storage batteries will be reduced, and thus the overall cost of BEV will be minimized and become cost-friendly to the people. The distance covered by a battery electric vehicle will be increased by adding a fuel cell to existing batteries.

5. Types of batteries for electric vehicle and renewable energy sources

- There are many types of energy storage systems (ESSs), which are developed by countries like China, Australia, Japan, USA, Spain, etc., in order to store the energy produced by a fossil fuel-based power plant along with renewable energy sources for a longer period of time and utilize it during the peak shaving period. The reliability and sustainability of energy through grid can be increased by storing the energy in an electricity storage system and thus minimize the risk of failure of grid resulting in complete shutdown of the power grid.
- Electricity storage system is divided into six categories, in which energy storage for power grid is produced through renewable energy sources along with electric vehicle to store the energy in order to run the EV smoothly for longer period of time and provide maximum efficiency and performance.
- **Figure 3** defines the six types of energy storage systems suitable for power grid storage system along with electric vehicle in order to increase the reliability and capacity of a storage system. For power sector, the world's top 10 countries considered and deployed the battery storage energy technology, pump hydro energy storage technology along with thermal energy storage technology in order to provide the reliable, secure, and sustainable energy to the consumer by improving the System Average Interruption Duration Index (SAIFI) and System Average Interruption Frequency Index (SAIDI) of transmission/ distribution network. Following are the global capacity shares for the energy storage systems utilized in their power grids by developed countries:
 - Chilled water thermal storage capacity: 4%
 - Heat thermal storage capacity: 4%
 - Ice thermal storage capacity: 2%

- Molten salt thermal storage capacity: 7%
- Other thermal storage capacity: 15%
- Electrochemical capacitor: 4%
- Flow battery: 2%
- Lead-acid battery: 3%
- Lithium polymer battery: 0%
- Lithium-ion battery: 59%
- Nickel-based battery: 2%
- Other electrochemical: 19%
- Sodium-based battery: 08%
- Sodium sulfur battery: 03%
- Vanadium redox flow battery: 00%
- Compressed air storage: 41%
- Flywheel: 59%

6. Electricity storage technologies' working principle

In this section, each electricity storage technology has been briefly explained by highlighting its working principle.

6.1 Pumped hydro storage

Pumped Hydro Storage process effectively functions as a large-scale battery, allowing energy to be stored when it is abundant and inexpensive and then released when it is needed, helping to balance the supply and demand of electricity on the grid. Pumped hydro energy storage is considered one of the most mature and reliable forms of grid energy storage, with many facilities around the world already in operation. It is valued for its ability to provide large-scale, long-duration energy storage, making it particularly well suited for helping to integrate intermittent renewable energy sources like wind and solar into the grid.

6.2 Compressed air storage energy (CAES)

Compressed air energy storage (CAES) is a technology used to store energy generated at one time for use at another time. It involves compressing air and storing it in underground caverns or containers, then releasing it to generate electricity, when

needed. CAES systems offer several advantages, including large-scale energy storage capacity, relatively low operating costs, and the ability to provide grid stability and support renewable energy integration. However, challenges, such as finding suitable underground storage sites and managing energy losses during compression and expansion processes, need to be addressed for widespread adoption.

6.3 Fly wheel energy storage (FWES)

Flywheel energy storage (FES) is a technology used to store kinetic energy in a rotating mass (the flywheel) and then convert it back into electrical energy, when needed. Flywheel energy storage systems offer several advantages, including high efficiency, rapid response times, and long lifetimes with minimal degradation. They can be particularly useful for providing short-duration energy storage and grid stabilization services, such as frequency regulation and peak shaving (**Figure 4**).

6.4 Lead-acid battery systems (LABS)

Lead-acid battery systems (LABS) are a type of rechargeable battery commonly used for energy storage in various applications, including automotive, uninterruptible power supplies (UPS), backup power systems, and renewable energy storage. Lead-acid batteries are popular in many applications due to their cost-effectiveness and reliability, particularly in situations where energy density and cycle life are not critical factors. Ongoing research and development efforts aim to improve the performance and sustainability of lead-acid battery technology while reducing environmental impacts.

6.5 Flow battery systems (FBS)

Flow battery systems (FBS) are a type of rechargeable battery technology that stores energy in two electrolyte solutions contained in separate tanks. These solutions are pumped through a cell stack where they undergo electrochemical reactions to store or release energy.

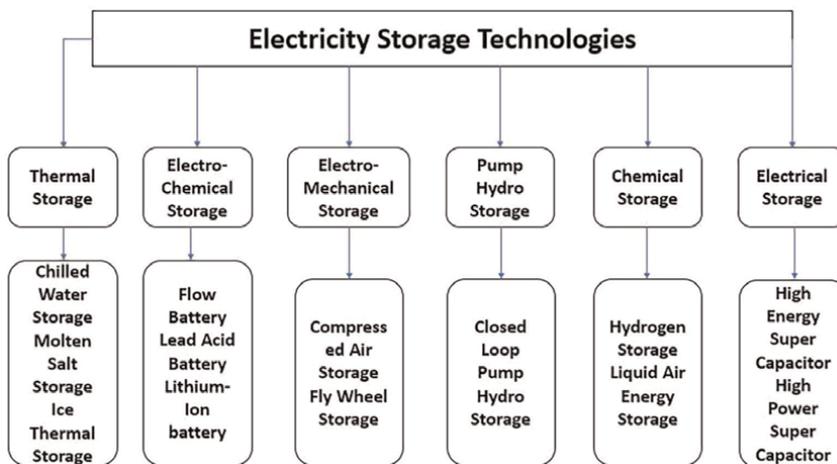


Figure 4. Electric storage technologies.

Flow battery systems offer several advantages, including scalable energy storage capacity, rapid response times, and long cycle life. They are particularly well suited for applications requiring large-scale energy storage, such as grid-level energy storage, renewable energy integration, and backup power systems. Additionally, flow batteries can be discharged completely without damage, unlike some other battery chemistries.

6.6 High-temperature battery systems (HTBS)

High-temperature battery systems (HTBS) refer to a category of rechargeable battery technologies that operate at elevated temperatures, typically above 100°C (212°F). These batteries utilize materials and electrolytes capable of withstanding high temperatures, which can offer advantages, such as improved energy density, power density, and cycle life, compared to conventional batteries operating at room temperature.

Ongoing research and development efforts aim to further improve the performance, efficiency, and cost-effectiveness of high-temperature battery systems for various applications, including stationary energy storage, electric vehicles, and aerospace applications.

6.7 Hydrogen storage

Hydrogen storage refers to the methods and technologies used to safely and efficiently store hydrogen gas for various applications, including transportation, energy storage, and industrial processes. Hydrogen is a versatile and clean energy carrier, but it has low energy density by volume and typically requires compression, liquefaction, or chemical storage to be stored effectively.

Hydrogen storage has its own advantages and limitations in terms of energy density, efficiency, safety, and cost. The choice of storage method depends on factors, such as the specific application, required storage capacity, infrastructure availability, and economic considerations. Ongoing research and development efforts aim to improve the performance and cost-effectiveness of hydrogen storage technologies to facilitate the widespread adoption of hydrogen as a clean and sustainable energy carrier.

7. Policy to shift transportation sector from fossil fuel utilization to renewable energy sources-based power plant

In this section, energy storage policy related to transition of transportation sector from fossil fuel utilization toward renewable energy sources-based power plant and electric vehicle mass production is briefly explained in order to deploy energy storage technologies with renewable energy resources.

7.1 Charging station and car parking charging station, enabling direct financing from independent investors in renewable energy power sources and other zero emission technologies

A German based “Renewable Energy Technology Act” need to be adopt to define the fixed tariff to produce clean energy through renewable energy sources. Transportation sector, which is heavily dependent on importing the fossil fuel to run the

transportation sector of any country, can shift its policy toward electric charging station and car parking charging station through the utilization and production of electricity through renewable energy sources.

7.2 Eliminating all subsidies given to a consumer by importing the conventional fuel for transport sector

Countries should have clear cut strategies and goals to eliminate all subsidies that are given to a consumer by importing the fossil fuel for the transportation sector. Economy of any country relies heavily on the subsidy that is given to a customer to import the fossil fuel and run the transportation sector. In this regard, the cost of importing the solar panel along with its accessories should be minimized to promote the benefits of producing clean energy and define the fixed tariff, i.e., on-peak period and off-peak period energy produced through renewable energy sources.

7.3 Tax exemption for investment in renewable energy technology and energy storage technologies for the transport sector

Electric vehicle and charging station/car parking charging station is a newly emerging market and the conventional vehicle will be replaced through a battery electric vehicle. Storage electrical energy is one of the key benefits for the transportation sector to utilize it, when needed. In this regard, a tax-free policy should be implemented in order to promote the clean energy producing culture along with an energy storage system to fulfill the requirement of electricity for the transportation sector.

7.4 Introducing carbon tax

Fossil fuel-based power plant and transportation sector including the conventional vehicle to produce the carbon, exceeding the alarming point, should be imposed carbon tax. In this regard, carbon credit project and certified emission reduction (CER) program should be implemented to shift the policy toward producing electric energy / clean energy through renewable energy sources along with net zero carbon energy produced through electric vehicle.

7.5 Research and development work for optimal sizing of charging station and car parking charging station along with renewable energy sources and storage to fulfill the requirement

Awareness, training, and research/development work requires to fulfill the requirement and design of fast charging station and car parking charging station. Global warming is one of the key topics concerned, in which harmful gases emit from a coal-based power plant and from the transportation sector. GHG (greenhouse gases) measurement should be incorporated in the policy to continuously monitor it and implement the same in CER projects through carbon credits in order to avoid levying of and imposition of carbon tax.

7.6 Establish charging stations at parking slots, hotels, malls, commercial areas, and garages

Suitable location for car parking charging station includes hotels, airports, malls, and garages where an electric vehicle can be connected to the grid station by supplying back energy to grid if required. Similarly, a policy should be developed to offer the facility free or give it as subsidy to a customer by providing back energy to grid when its electric vehicle is connected to grid for a certain period of time and its battery is fully utilized by the grid.

7.7 Reducing the cost of battery eventually reduces the EV price

Electric vehicle's price will be reduced if its batteries cost, that is, lithium-ion battery and fuel cell cost, should be down. A clear policy should be developed to replace the conventional vehicle through electric vehicle by promoting the net zero carbon energy culture, healthy environment, and free of electric charge for BEV if connected to grid for a certain amount of time.

8. Conclusion

Globally, the transportation sector is heavily dependent on fossil fuel to run the internal combustion engine of a vehicle, separate from a fossil fuel-based power plant, to run the economy of any country. These conventional vehicles are responsible for producing greenhouse gases that are already damaging and changing the climate situation globally. In addition, a vehicle chargeable parking station is also vital to store the energy and regenerate the energy when required by any charging station or grid.

The United Nations Industrial Development Organization (UNIDO) should promote the culture of adopting an electrical vehicle globally by constructing the vehicle charging station and vehicle parking chargeable station. This step should be undertaken along with reducing the cost/price of a battery electric vehicle in order to replace it through a conventional vehicle that is the main source of climate change and produces greenhouse gas emissions to environment.

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Chapter 8

Cybersecurity Threats and Mitigations Related to Smart Cities Operation

Menachem Domb and Yehuda Shnaps

Abstract

Smart cities are managed and controlled through comprehensive and complex information systems. The main characteristics of smart cities are expressed in the massive reliance on computerized systems, which comprise large, distributed databases, integrated complex software systems, WAN with a vast number of terminals connected to the Internet and cloud computing, and physical systems fully computerized and remotely controlled. Smart cities are more likely to be sophisticated and more affluent than common cities, making them attractive to cybersecurity attackers motivated by theft and benefits stealing, such as ransom. The concept of smart cities is catching attention across the globe, and it is important in per context of emerging economies. It is inevitable to assume that smart cities incorporate all kinds of system vulnerabilities, which are more likely to be known and exploited by malicious cybersecurity attackers. This chapter elaborates on the leading cybersecurity risks more likely to be encountered in smart cities. We present current concepts and technologies available for mitigating them and provide a comprehensive solution for safe, smart cities.

Keywords: smart city, cyber threats, cyber-attacks, smart living, smart economy, cyber threats, EV security

1. Introduction

Smart city's main goal is to raise the quality of life standard of its residents to a new level by utilizing its resources more effectively and generating an intelligent ecosystem utilizing digital technology, aiming to provide inventive city transport networks, better water supply, waste disposal, light and heat buildings, user-friendly financial services, residents' engagement in decision participation, safe environment with accessible public areas without restrictions, and making smart citizens of a smart city. Smart cities connect people to data networks, evolving structures involving people, technology, and policies that impact privacy and security, encouraging the development of new innovative cybersecurity protocols for smart cities. Policy guidelines in smart cities are required to guarantee the security, integrity, and secrecy of smart governance. City governance services are more complex and advanced, requiring the awareness of increased cyberspace security risks using more sophisticated technology and infrastructure. Hence, risk identification and mitigation are part of

all domains in governance systems. Authorities and administrations aim to arrange city-wide interventions using IoT systems to build an integrated ecosystem for the entire city. It requires a high degree of responsibility for the tasks to be completed and well-managed IoT systems, assuming a vast technical background by professionals in the field. Governance service providers adopt a culture of security and information confidentiality as part of their services [1].

Smart cities decided to cope with public issues with the help of technology and the prudent management of natural resources. Smart city systems provide management tools generating people networks, infrastructure, companies, and resources to achieve sustainable economic development, high quality of life, and general well-being for most citizens. A key tool for data collection in smart cities is the Internet of things (IoT) networks with embedded electronics, software, sensors, and connectivity for exchanging data with servers, centralized systems, and connected devices using communication systems. IoT data is collected from sensors, assembled, and sent to various applications executed locally or in the cloud. The rapid evolution and distribution of smart devices embedded within typical smart city services become a preferred and easy target, exposing them to cyber-attacks. These services apply to transportation, health care, water, electricity, and other municipal services.

In smart governance, municipal authorities aim to deploy IoT-based applications to build an ecosystem for the full smart city managing a substantial number of mutual and parallel tasks involving interactions among the municipality and residents [2]. Technology is necessary to coordinate and manage these systems, such as an ICT-based system that offers the elements necessary for smart governance for managing the following: 1. Permission hierarchy model. 2. Follow-up on assignments. 3. Inclusion to facilitate data interchange 4. Integration with future ICT components. 5. Privacy and safety processes [3].

We focus on technological solutions for security policies as part of regular personal and community behavior. We utilize a cybersecurity perspective that smart city designers can translate and develop elements that can be integrated within their design to better deal with cyber-attacks and violation of personal privacy and practical cybersecurity approaches. We examine the characteristics of cyber threats related to these domains involving advanced emerging technologies. The rest of this chapter is comprised as follows. The next section outlines the main security challenges a typical smart city encounter. Section 3 lists the main security vulnerabilities typical to smart cities. In section 4, we continue with common solutions and tools required for securing smart cities, and in section 5, we describe several detection mechanisms to discover cyber-attacks in the context of smart cities. In sections 6, 7, 8, and 9, we describe several emerging technologies and developments in the cybersecurity domain. We conclude this chapter in section 10.

2. Security vulnerabilities of smart cities and mitigation strategies

The immense spread and growth of automation in every aspect of life improved significantly human life, such as technology, digital computing, electronic devices, smartphones, and data transmission networks. However, it also caused the evolution of cybercrimes that have become a major threat. Modern cities are open and oriented to adopt innovative technologies to improve their operation, services, transportation, water, electricity, data transmission, supply chain, and overall system resilience.

Implementing embedded security systems, Firewalls, cryptography, and more are mandatory to protect this rich digital environment.

Smart cities become vulnerable to cyber-attacks due to their widespread connectivity and remote-control operations using communication networks, which are public and may be accessed by cyber-attackers [4]. Smart cities are expected to detect any cyber-attacks, such as DDoS, and react immediately, stopping their progress and recovering damages. A city cyber-attack could exploit an IoT device and use it as a gateway, penetrating the attacked subject and changing, corrupting, and erasing data. It may also stop or manipulate system operations such as traffic lights, public transportation, street lighting, power grids, water supply, and other services. Regardless of how emerging technologies alter these essential systems. Smart cities use analytics to automate and optimize the synchronization of a wide range of services, monitor the surrounding impact, and improve city performance. This information is required for the applications that centrally oversee intelligent and public area lighting, using distributed IoT and sensor inputs. Good lighting helps improve residents' safety and traffic management, reduce accidents, better parking, and reduce crime. The following are listed vulnerabilities per service.

Traffic management: Using cameras to provide traffic balance, reduce traffic congestion, allow instant changes in traffic lights, close roads, provide detour alternatives, and prioritize emergency navigation.

Parking: Provide available parking, reservation information, payment, discover violations, messaging and warning drivers, and automatic ticketing. Real-time and AI-based distributed systems targeting immediate reactions to citizens' requests and emergency calls. A research team hacked and manipulated wireless traffic lights. A polish teenager hacked the city's tram, and four have been injured. Active and passive cyber-attacks compromise the security of smart cities' applications. Sabotage, manipulation, and espionage are the main motivations of cyber-attacks. A passive attack aims to get information, such as the configuration and behavior of the system and its architecture of the victim's system, without changing it. Active attacks affect the system's operation by modifying and injecting malicious data. This section outlines security vulnerabilities in various smart city applications. In the next section, we outline mitigation concepts.

Distributed Denial of Service (DDoS): The purpose is to prevent the system's normal operation and destroy its availability in smart cities. The attacker tries to overwhelm the network's resources with bandwidth-consuming attacks such as attacks. In smart cities, the impacts of DoS attacks on any system that provides centralized monitoring.

Malware: applications whose testing stage is incomplete, are utilized to bypass security measures and access control gates, take control of the central monitoring system, damage system machinery, and manipulate system parameters.

Eavesdropping: Unauthorized sniffing and manipulating of the transmitted data over the institution network, stealing the institute network map, and applying changes to the traffic behavior, weakening network integrity and security, causing users confusion, privacy violation, wrong decision making, and causing financial damages.

Masquerading: The attacker tries to steal, change, or damage data.

False information (FI): Attackers spread fake messages on social media, impacting people's behavior.

Message modification: The attacker is manipulating transmitted messages, distorting inter-user conversations, and spreading wrong data causing uncertainty leading to dangerous actions that may be taken at the personal and community levels.

Traffic analysis (TA): Attackers attain critical traffic information, such as time-tables and routing maps, and intentionally disrupt the normal behavior of the transportation system.

Data injection attack (FDIA): Occurs when attackers manage to get operational measurements from various critical smart city systems, such as public transportation schedules and power plant monitoring thresholds, and make changes impacting the normal systems' behavior, causing service disruptions.

Exploitation of home security loopholes: Home devices, smart living gadgets, and IoT may compromise security, enabling hackers to attack or violate privacy and expose account information. People control their smart homes, making them a valuable database for hackers.

To cope with it, mapping and analyzing the hazards identify the risks associated with smart home systems and ways to reduce risks.

Embedded IoT devices: They collect data, such as traffic management and real-time response systems, to improve city operations. They are balancing smart cities and cybersecurity. IoT devices could be better with built-in security mechanisms due to their limited computing power.

Objects can be scanned or sensed, such as thermostats, domestic appliances, security cameras, and lighting systems connected to the public communication network, remotely monitored and accessible to attackers. The security of IoT could be better due to the lack of computing power, memory, and storage, which allows very minimal security protection. Its spread generates a large attack surface and multiple vulnerabilities, inviting attackers who take over the control of a lighting system, raising severe consequences for personal safety.

3. Securing smart cities

Connected devices are expected to be protected by comprehensive IoT security solutions. Practical, simple, yet secure solutions that OEMs and services can easily and widely adopt seem adequate based on their assurance of executing code solely generated by the device OEM or a trusted party. Secure boot technology is used to avoid the replacement of firmware with harmful devices. It ensures that IoT devices can only communicate with authorized services. Mutual authentication is applied when any device connects to the system, ensuring the data comes from a legitimate and authenticated source. The data is then analyzed to detect security violations. Frequent key replacement prevents service disruption. Distributed Denial of Service attacks are critical security threats and attacks on smart cities. BoT-IoT with embedded random forest (RF) and decision tree (DT) is a recommended detecting tool for DDoS attacks, achieving 91% success. According to NIST, an IoT-enabled framework in smart cities addresses cybersecurity and data protection. Clear IoT data use and privacy policies improve security awareness to prevent cyber-attacks.

At the same time, there must be boundaries around. Secure privacy in smart cities oversees the data of all its residents; synchronized credentialing is mandatory to avoid weak points and protect all residents' personal information. City staff should define how connected devices behave. When devices are activated, their encryption measures should be active at all links up to the destination. Smart technology, connectivity, and applications should be able to meet residents' needs where cybersecurity is well-considered and managed. Smart transportation systems improve the safety, speed, and reliability of accessibility. Modern and sustainable transportation systems

provide scheduling, selection of the optimized route, driver's license recognition, car parking searching, and safety-related applications in smart transportation facilities, which are more likely to be crowded due to their high living style. IoT reduces accidents due to initiative-taking actions in detecting human errors, and affordable IoT systems for estimating road network safety are implemented; some even use IoT technologies for smart mobility in smart city scenarios. IoT-based solutions, such as smart traffic, parking, and mobility solutions, are employed in transportation leading to safer streets. Here are a few projects: a transportation system that recognizes and monitors buses by inter-messaging. It uses IoT, radio frequency identification (RFID), general packet radio services (GPRS), (GIS), and (GPS). Another project embeds temperature and humidity sensors to monitor automobiles and buses. A recent project suggests a real-time traffic monitor using collected data to identify roadway issues. An intelligent application with embedded IoT, using Intel Edison and Raspberry Pi, minimizes the damaged packets and incorporates encryption for decreasing surface attacks. One more project integrates D-switches and software-defined networking (SDN) and inserts a high volume of deterministic virtual private networks (DVPN), preventing congestion, interference, and DDOS, reducing buffer size in D-switches, improving speed communications, and encrypted packets within a DVPN are quantum-safe encryption due to the use of lengthy encryption keys.

Integrate transportation safety applications, creating a vehicular ad hoc network (Vanet), complemented with secured privacy applications, provides a communication platform interconnecting vehicles reporting congestion, accidents, and road surface conditions to other cars. However, there are several security and privacy problems, particularly location privacy. We may add Group signatures to provide conditional privacy preservation. The vehicle's previous communications and positions are unlikable and saved—a simple conditional privacy-preservation system using hash-chain algorithms to provide identity monitoring using on-road instant local revocation verification. A vehicle receiving a message from another vehicle authenticates the sender's certificate. The receiver requests the roadside unit to review the message if the sender lacks credentials. The roadside unit will issue a valid certificate if the information is correct. Otherwise, the vehicle is added to the revocation list. Another tool is a multi-level architecture that reduces attacks on the road communication system. Autonomous cars also manage new attack types like Ransomware, IoT, Botnet, and DDoS. Because cars are interconnected, attacks spread further, increasing the overall risk. Developing secured traffic systems, modeling the secured integration of automated vehicles and road infrastructure, engaging vehicles with pedestrians where traffic signals are missing, and interconnecting vehicles via wireless communications. Interconnect vehicles using wireless communication are exposed to cyber-attacks, such as the "Sitbit" attack, where fake identities are placed to change traffic light timing by utilizing existing flaws in traffic signal control systems, causing significant delays, excess fuel consumption, air pollution, and traffic congestion. An assessment model for cyber-attacks on autonomous vehicles is proposed to evaluate the transportation system's performance, considering the following parameters: number of attacked cars, intensity, efficiency, safety, emissions, and fuel consumption. It concludes that the negative impact on traffic flow grows as the number of cyber-attacked vehicles and the severity of attacks increases. It reduces capacity and increases rear-end collision risk, air pollution, and fuel consumption.

Trains are the most used in modern cities. With the automation of railway operations, the increase in the number of passengers, and the integration with other

transportation methods, the railway industry is experiencing adaptation changes in its operation processes and infrastructure. It is transitioning from a standalone system to an open platform, using off-the-shelf standard elements and increasing networked control and automation systems accessible remotely via networks. This change raises its vulnerability to cyber-attacks and its attractiveness to cybercriminals to focus on ticket machines, WiFi communication, and passenger information screens. Safe traffic assumes complete visibility, identification, and mitigation of threats to the signaling system, telecommunication, and operations management. For example, we may locally disconnect the system from its cables by adding an SDN switch. The SDN switch should detect ARP spoofing, and the system remains undiscovered to man-in-the-middle attackers. Railways are exposed to physical attacks, and hence, they are equipped with a tamper resistance box that encapsulates the hardware and controls the equipment against cyber-attacks. Smart environment applications quantify and analyze vast parameters such as climate, green spaces, city cleanliness, movement initiatives, contamination level, optimal resource management, and environmental actions. Results show quality improvements in public spaces, facilities, and life and strengthen security in areas. Smart cities collect traffic congestion, energy utilization, air, and building quality, analyze it, and issue a corresponding pollution report. Wireless sensor networks (WSNs) monitor the natural environment, detect natural disasters, and enhance security awareness. Voice-activated devices are used everywhere and at home, allowing disabled and older people to operate with minimum energy [5], or using mobile phones to interpret voice commands [6]. **Table 1** outlines the generic mitigation methods to cope with each security risk dimension. In this chapter, we elaborate on mitigations having a technological perspective and practical deployment.

Dimension	Mitigation methods
Infrastructure vulnerabilities	Facility review, discovery, and assessment Risk management plan.
Data privacy	Ethical violations
Network vulnerabilities.	Ongoing monitoring Privacy by design and hiding real ID when it is not required.
Access control	Data minimization
IoT devices	Transparent data practices and user control and rights
Human behavior	Risk assessment and deployment of prevention systems.
Security standards and regulation	Encrypt all transmitted data using symmetric and asymmetric methods Intrusion detection, authentication, and authorization mechanisms. Secure device management Role-based access controls-RBAC3 Adoption of a variety of biometrics. Secure access controls and protocols Secure communication protocols Security monitoring Education and ethical guidelines Behavioral analytics and predictive models Collaboration and partnerships Community engagement Adoption of international standards Smart grid security standards Articulate with local and national frameworks

Table 1. Security dimensions and their corresponding generic mitigation methods [7].

4. Attack detection and mitigation systems for smart cities

Most cybersecurity alert methods rely on attack detection methods, such as intrusion detection systems (IDS) and Firewalls. However, they could be more effective since detection rules are out-of-date and limited to single-step attacks [8]. The attackers developed workarounds, and the detection time increased. Deep learning and knowledge graph-based cyber-attack detection methods are less popular due to their lack of explanations. However, recent developments of XAI try to complement AI with explanations such that AI will be comparable to other methods and will be reasonable and expected to some extent. Nevertheless, AI-based cybersecurity systems, deployed in smart cities, are popular. We can already find machine and deep learning that are integrated into cybersecurity defense systems. In parallel, attackers try hard to look for new attack strategies, methods, and technologies, which accelerates the need to react promptly. One of the advanced analysis models used is MDATA graph matching, a cyber-attack detection approach, incorporating a dynamic model using temporal-spatial data. It activates several modules, knowledge extraction, construction of MDATA graphs, vulnerabilities, and multi-stage attack identification. Experiments show its effectiveness of 90% and performance of 14ms. Artificial intelligence (AI) is a spreading and expanding concept and technology in modern times. It imitates the human brain to oversee real-life issues. It is implemented in many domains, such as robotics, smart cars, prediction, e-commerce, navigation, human resources, health care, agriculture, gaming, automobiles, social media, and marketing. AI security is leveraging AI to detect and respond to cyber threats and attacks early based on historical activities. AI embedded in drones and blockchain technologies enforces security in smart cities. Emerging technologies such as AI, blockchain, and drones are important in smart cities, especially regarding security and regional monitoring [9]. The use of drones supports the intelligent city concept with all its advantages. Drones are used in smart cities for assorted services, such as surveillance, traffic control, monitoring public areas, package delivery, detection of malicious activities, and more. AI-based drones enhance surveillance everywhere, assisting in detecting security-related events. Drones with embedded machine-learning capabilities enable the prediction of jamming attacks by applying Q-learning [10, 11] and DQN [12]. Attacks such as intrusion, DDOS, and traffic blockage are managed by a variety of algorithms [13–15]; while other research focuses on threats to private and agencies [16, 17].

5. Artificial intelligence-enabled (AI) cybersecurity defense for smart cities

Drones are equipped with quality software, wireless communication systems, and data exchange protocols, have cybersecurity vulnerabilities, and have a high probability of cyber-attacks, making them sensitive to cyber threats [18]. Despite this, reality proves that drones have limited computing resources, forcing the need to balance security and performance, and compromising cybersecurity. Drones rely on wireless protocols for communication with ground control stations and other connected devices, which hackers can target. Therefore, strong measures should be implemented to cope with potential cyber-attacks and sensitive data and maintain their reliability and security. Vulnerability to hacking is one of the primary concerns. Malicious actors attempt to gain access to drone systems, manipulate their flight controls, or compromise their onboard sensors and cameras. Drones suffer from all typical attacks applicable to their structure and behavior, such as MITM and DDoS.

The evolving progress of drones has played a significant role in smart cities. However, at the same time, there are concerns related to cybersecurity, privacy, and public safety. Malicious entities can use drones for cyber-attacks and threats [19]. It is complicated to identify harmful drones. The dependency of drones on GPS makes it vulnerable to GPS spoofing, data stealing, change of date and time, and operations interference. GPS spoofing is transmitting distorted coordinates and false signals, deflecting the drone from its course, and synchronizing with the attacker's signals, changing the drone's GPS control system to be fully controlled by the attacker. Civilian drones are easy to attack due to their lack of authentication methods [20]. For example, a GPS spoofing attack forced a drone to follow a route set by the spoofer, proving that such an attack was technically and operationally feasible. Communications' DDoS is applied by using the air-cracking script to perform the attack, sending a De-authentication key, and the drone memory fills the control. The controller avoided reconnecting to the system, causing the drone to crash. It is a DOS attack that crashes the drone in a STRIDE configuration. Password cracking attacks against passwords have demonstrated an increase in more connected devices. Password cracking in commercial drones disclosed positive security flaws, is an authentication intrusion, and this attack is an identity spoofing. An open WiFi attack relates to drones with free WiFi, providing many users access to the network and leading the team to hijack the drone successfully. In addition, the device allows multiple user connections so that multiple unauthenticated users can control the drone with no way to verify the drone's owner. SDK threat disrupts the privilege escalation scheme by allowing access to inaccessible features for unauthorized users; attackers track user authentication information and modify some codes, allowing malicious users to execute the operations of legitimate drone users. Telnet attack occurs when the intruder is using Telnet, gaining direct access to the drone, and changing files and scripts to interfere and restart the drone by deactivating the motor, causing it to drop. The drone was deactivated by accessing the operating system file system via Telnet (Busy Box). The user ID and password and many drone executables identified the data. This attack demonstrates an interruption as an attempt to divulge information as sensitive data are collected and sent to the attacker by an authorized user to hijack the drone. Drone packet spoofing uses a Python script that mimics a drone controller.

WiFi is the communication standard between the ground station and the drone, which can be hijacked due to the lack of encryption, allowing the drone to connect, hack, and perform remote man-in-middle attacks. A de-authentication attack on drones is done by using aircrackng20. A passive search for the wireless network is conducted. After a network is detected, packets from that wireless network are filtered and analyzed to discover user addresses. Accordingly, the attacker executes a de-authentication attack, where the network users are de-authenticated, resulting in disassociating packets to connected users, disconnecting them, and losing the connection between the users and the drone, severely impacting businesses and residents who depend on drones for their ongoing lifestyle. Several immediate actions may reduce the impact. Having an alternate emergency communication network, cluster network stations, and applying strict inter-clustering message passing to delay the attack from further spreading, implementing penetration detection methods, monitoring the ratio of the number of de-authentication transactions per time frame, and having a hazard call when this number crosses a threshold, encrypt all transmitted messages.

6. Access control using biometric technologies

Smart cities have their systems interconnected and thus accessible to all city members based on their predefined rights and needs. This wide surface attack attracts attackers and becomes a challenge to smart city security personnel. To minimize this risk and prevent unauthorized people from accessing any smart city system, a strong access control system should be implemented. The best method for preventing unauthorized people from penetrating city systems is using biometrics technologies. There is a wide variety of reliable biometric methods that may fit to cope with many kinds of penetration attempts. The various biometric methods are divided into physical and behavioral as depicted in **Figure 1**. Fingerprint matching is the most used biometrics-based technology due to its convenient collection stage, reliability, and acceptance by the average person. Recent developments in biometrics suggest a fingerprint collection by a 1000DPI electronic reader, whose fingerprint image includes thousands of sweat pores, presented as white dots on top of the ridges. This addition of dots allows the digitization of the entire fingerprint-matching system. Its' accuracy and reliability are much higher than in the classical pattern-recognition minutia-based approach. A face image matching method suggests collecting about 48 features from the image, such as inter-pupil distance, nose-to-chin distance, and more. Another proposal is using hyperspectral cameras to generate multilayer images, extracting attributes from each layer, and constructing a systematic unique code associated with the person appearing in the image. One more face authentication approach is by reconstructing a 3D image from two 2D images taken in parallel by two adjacent standard 2D cameras. The reconstruction process includes hidden attributes injected into the 3D final image.

Table 2 associates each biometric technology with seven characteristics, enabling us to decide which technology is the best to be deployed in each situation. We can also use **Table 2** to decide which biometric technologies complement each other and

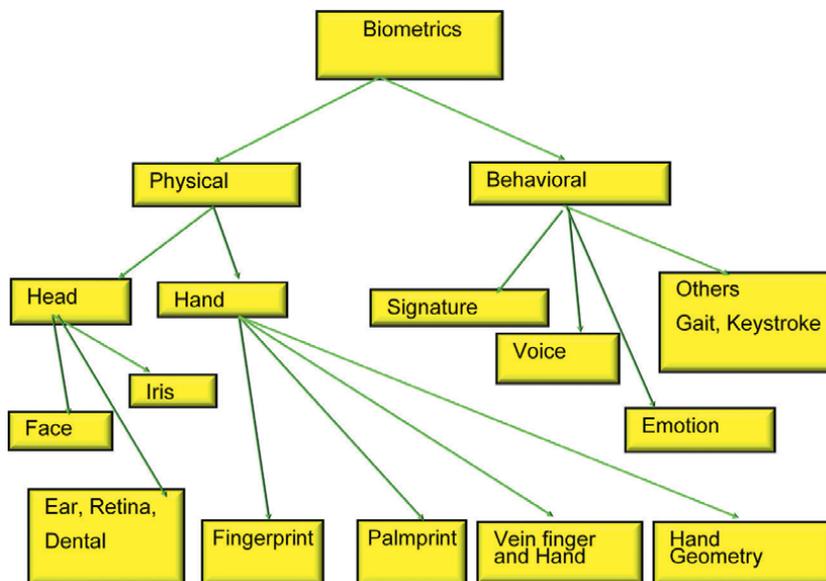


Figure 1.
Taxonomy of biometrics technology.

Biometric identifier	Universality	Distinctiveness	Permanence	Collectability	Performance	Acceptability	Circumvention
DNA	H	H	H	L	H	L	L
Ear	M	M	H	M	M	H	M
Face	H	L	M	H	L	H	H
Facial thermogram	H	H	L	H	M	H	L
Fingerprint	M	H	H	M	H	M	M
Gait	M	L	L	H	L	H	M
Hand geometry	M	M	M	H	M	M	M
Hand vein	M	M	M	M	M	M	L
Iris	H	H	H	M	H	L	L
Keystroke	L	L	L	M	L	M	M
Odor	H	H	H	L	L	M	L
Palmprint	M	H	H	M	H	M	M
Retina	H	H	M	L	H	L	L
Signature	L	L	L	H	L	H	H
Voice	M	L	L	M	L	H	H

Table 2.
Characteristics of biometrics.

can be fused to generate a combined robust technology with improved accuracy. The fusion of technologies can be done in three levels, at the features collection stage or the decision stage.

7. Cybersecurity for electric vehicles (EV) in smart cities

The development of electric vehicles and smart grids generated the vehicle-to-grid (V2G) technology, which involves pushing unused power from the car into the smart grid. Smart power grids are used for exchanging information and allocating resources between customers and a grid, enabling the flow of electricity between them, and introducing the V2G technology that enables pushing EV battery energy back to the grid. EV integration into smart cities is important for developing sustainable transportation solutions and reasonable security and privacy risk mitigation. User data and privacy concerns increase with the use of sensors that collect personal ID, charging logs, driving habits, locations, car data, personal data breaches, and crypto jacking. Due to these threats, the confidentiality and privacy of user data are at continued risk [21]. The more we make EVs sustainable by introducing cameras, tracking devices, and sensors, the more we add to cybersecurity threats. The city's power grid utility servers are vulnerable to malware attacks from other EVs. Local attacks are mutual cyber threats to the smart grid, with malicious actors using techniques such as jamming, DDoS, controller malfunction, and load alteration attacks. Cybersecurity in smart cities is classified into passive and active attacks. Passive attack in a smart city refers to accessing information

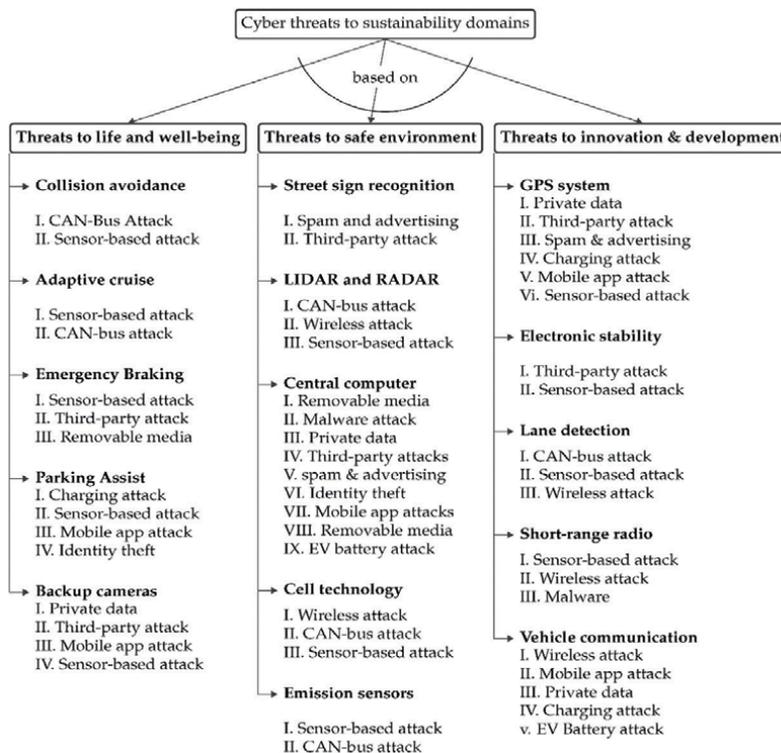


Figure 2. Security threats to EV sensors [22].

or systems without disrupting normal functioning [22]. These attacks target the vulnerabilities of communication networks, sensors, data repositories, and control systems. **Figure 2** depicts the potential threads on EVs. Attackers exploit weaknesses to access data, monitor activities, or gather information for further malicious activities. Active cyber-attacks mean disrupting operations, manipulating data, or causing damage to critical infrastructure components. The attacker may employ hacking, malware, social engineering, or denial-of-service attacks to weaken the security and integrity of smart city systems. Attacks on smart cities are detected using interactive visualization and false alarms. Communication, infrastructure, data, and stakeholders (ACIDS) is a framework to identify threats in the various layers of a smart city system. The proposed layered approach improved the overall security of a smart city system. Malicious actors utilize EVs and the grid to cause wide-area blackouts, attacks on communication protocols between EVs, chargers, and back-end systems that are vulnerable to tampering, cyber-attacks on home charging units, and phasor measurement units (PMUs) for power grid's reliability and safety. Anonymous certificates have used to conceal the identity of users that each vehicle node store anonymous certificates to use different public-private key pairs in each authentication process. Mitigating these attacks is done by authentication using bilinear mapping technology to ensure that the communicating peer entities have legitimate identities and can effectively resist spoofing attacks. Another proposal uses a key protocol for mutual authentication without revealing the user's identity or using mobile IP communication and a mobile agent IPv6 protocol by employing blind signatures based on the RSA algorithm and incorporating built-in tag technology, which could also ensure traceability for vehicles. **Figure 2** depicts the mitigation actions against the threats to EV operations.

A pairing-based authentication protocol is used to ensure the confidentiality of communication, protect the identity of vehicle users, and prevent vehicles from being tracked by malicious attackers. A dynamic privacy-preserving and lightweight key negotiation protocol for V2G in SIoT, which could resist attacks such as impersonation, offline password guessing, man-in-the-middle, replay, and tracking, has been added. A lightweight authentication protocol using non-singular elliptic curves is added to eliminate issues of untrusted third parties in V2G networks. Simultaneously, a secure two-party protocol was used to negotiate the system's universal key between third-party entities and the dispatch center, preventing internal attacks. A fog-based billing identity authentication reduces the interaction frequency between users and cloud servers and improves authentication efficiency.

8. Quantum computing and blockchain applications for smart cities

Advances in IoT, big data, cloud computing, social media, and smart meters contribute to the advancement and realization of smart utilities [23]. IoT smart nodes comprising devices, sensors, services, applications, and real-time communications became a critical industry component. Quantum computation, information, algorithms, communication, and information processing devices enable the implementation of quantum hardware to deliver security-enhanced protocols that impact future technologies in computation, communication, cryptography, and information theory. Blockchain is a technique to achieve decentralized and secure data management with tamper-proof immutability and traceability. Advanced quantum computing and communication technologies mitigate cloud storage and data transfer risks. Applying smart utilities requires networking and communication infrastructures,

data collection and analysis, crowdsourcing technologies, policies, regulations, and information security. IoT devices like water networks are embedded in critical infrastructure sensitive to cyber-attacks. Thus, it is important to continually monitor utility networks to eliminate attacks on IT and OT: management and optimization of water utility services. Blockchain technology for safe communication among smart devices is a solution to security breaches. Quantum walks are considered nonlinear mappings of elements to the set of probability distributions. This property and the high sensitivity to changes describe discrete quantum walks as discrete-time and discrete-valued chaotic systems. Quantum communication channels are used to exchange decryption keys between senders and receivers. The exchanged key parameters are required for message encryption, decryption, and authentication processes. Each blockchain unit contains a hash value linked to the previous and current block. QHF with public key parameters generates the hash value for linking each block in the chain with the previous one. The framework assumes that each stakeholder on the blockchain system has a validated profile and key parameters for each node. Security analysis is used in the evaluation of cybersecurity systems (Figure 3).

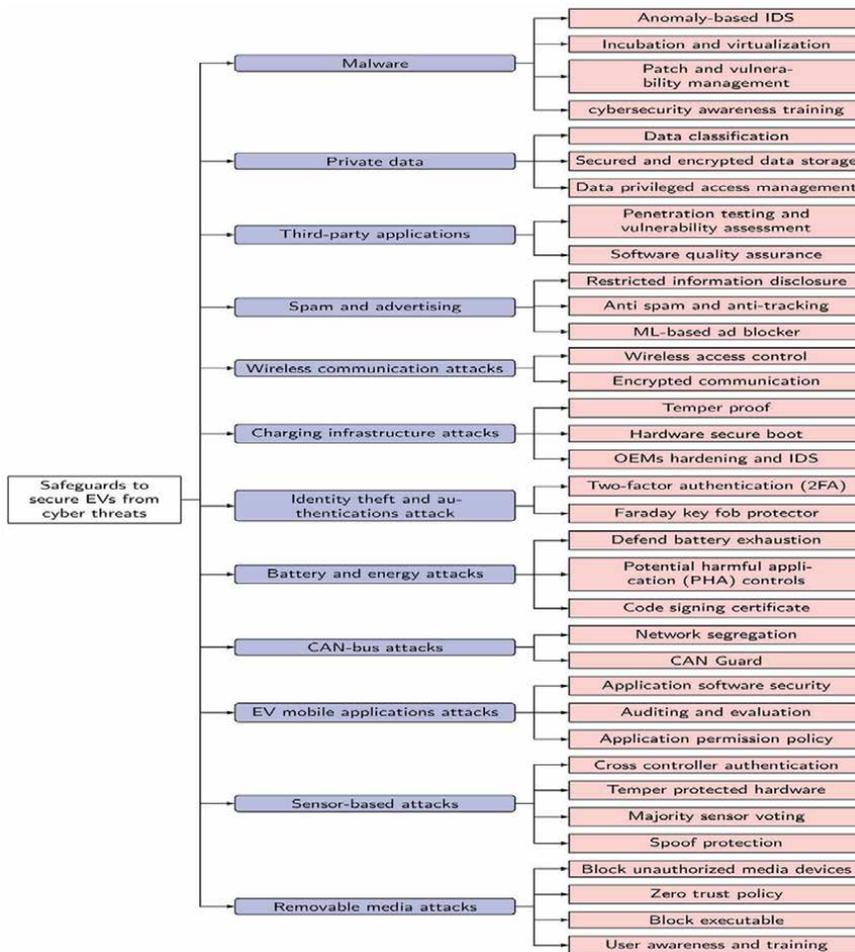


Figure 3. Safeguards against cyber threats to EVs [23].

9. Conclusions

Smart cities are the result of the maturation and accessibility of advanced technologies available for integration in all aspects of life, such as data communication, telecom, IoT, electronics, automation, and computerized physical equipment. The complete reliance on automation and communication causes hostile elements to take advantage of the exposure to automation to infiltrate significant municipal systems causing functional damage, intentional disruptions, and financial extortion. Therefore, smart cities should integrate cyber and privacy solutions to ensure the interoperability of all elements that form the city's infrastructure and processes. In this chapter, we described the main security issues related to smart cities. In the beginning sections, we focused on common security threats we can typically find in the context of smart cities. In the rest of the chapter, we introduced emerging aspects related to new threats and new mitigations. Sustainability and security are two concepts that smart cities maintain and keep advancing. However, we noticed that these concepts contradict each other, and as we enhance sustainability, we decrease security accordingly. To settle this conflict, we are required to increase our efforts in looking for more ideas required to mitigate cybersecurity-increasing risks and cyber-attacks. In future work, we will continue our follow-up on developments in security threats and sophisticated attacks. And accordingly, explore solutions and technologies for mitigating advancement.

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Edited by Pier Luigi Mazzeo and Paolo Spagnolo

In a rapidly urbanizing world, the concept of “smart cities” represents the future of urban living. These cities aim to harness advanced technologies to create environments that are efficient, sustainable, and responsive to the needs of their inhabitants. But what does it take to build a smart city? And what challenges must be overcome to realize this vision? *Smart Cities - Foundations and Perspectives* is a comprehensive guide that explores the intricate process of developing smart cities. The book is organized into two key sections. The first section, “Smart Cities Opportunities and Challenges”, takes you through the initial stages of smart city development, with a focus on real-world examples like Saudi Arabia’s ambitious smart city projects. It discusses the critical areas of energy, mobility, and waste management, offering a clear view of the evolution of these cities and the hurdles they face. In the second section, “Smart Cities Technologies”, the book delves into the technological backbone of smart cities. From the Internet of Things (IoT) to renewable energy solutions and cybersecurity measures, it covers the cutting-edge innovations that are essential for creating intelligent urban environments. Written by leading experts in the field, this book provides invaluable insights for policymakers, urban planners, technologists, and anyone interested in the future of cities. *Smart Cities - Foundations and Perspectives* is not just a blueprint for building smart cities—it is a call to action for creating urban spaces that are secure, sustainable, and inclusive.

Published in London, UK

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