Chapter

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

Daniele Bregoli, Marco Ciro Liscio, Noura Nabiti and Paolo Sospiro

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

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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 CO_2 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	*Identification* 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
	Acquisition 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	*Organization* Organizing codes: Language, Document Type, Source Type, Subject area, Journals titles, Exact keywords.
	Purification 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	*Evaluation* Analysis method: Content analysis of representative results.
	Reporting 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**.

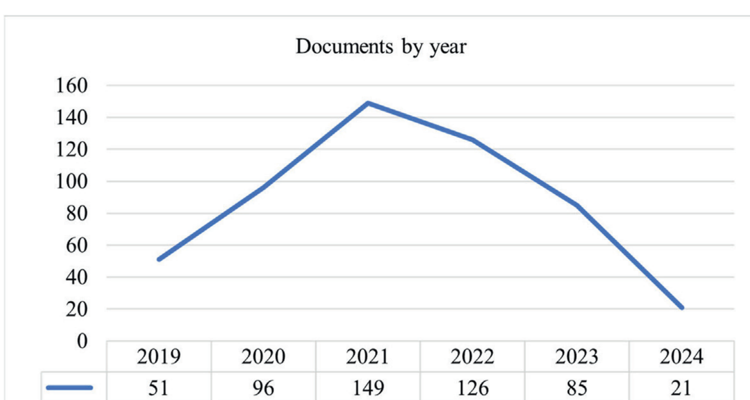

Figure 1.
Documents by year. Own elaboration based on Scopus results.

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**).

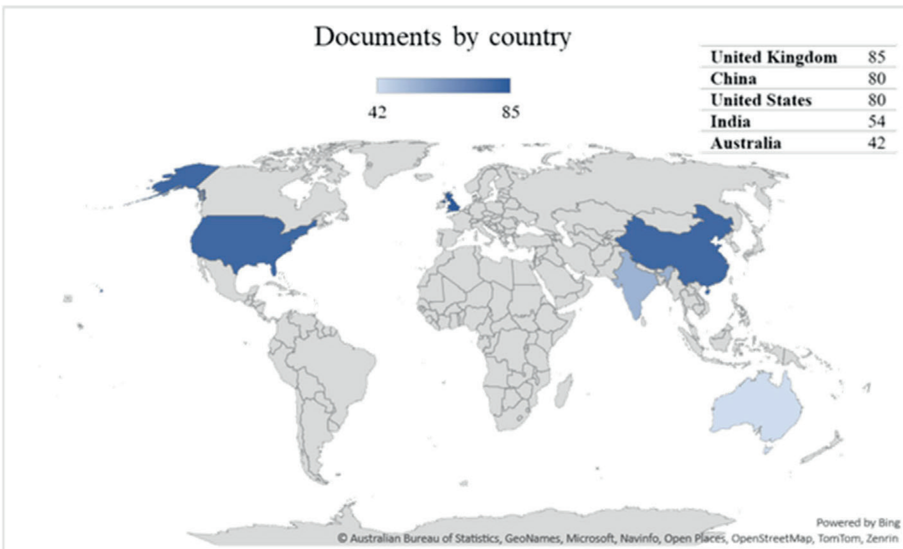

Figure 2.
Documents by country. Own elaboration based on Scopus results.

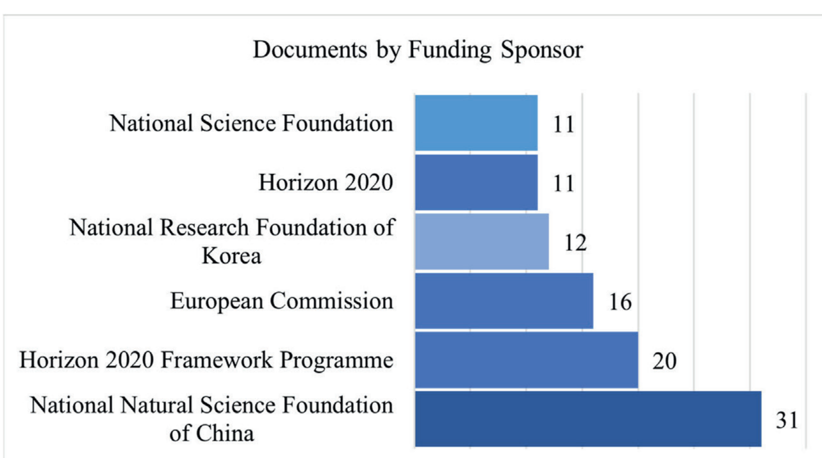

Figure 3.
Documents by funding sponsor. Own elaboration based on Scopus results.

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	• Citizen acceptance and involvement • Government support for Smart City initiatives	• Emphasis on citizen participation in Smart City development • Integration of participatory approaches in decision-making
Data	• Security and management of data • Exchange of enormous amounts of sensitive data	• Addressing security concerns in data management • Developing technologies for privacy preservation in data exchange
Security	• Ensuring security in Smart City systems • Risks of neglecting social considerations and community values in data-driven approaches	• 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)	• Contribution of Smart Cities to specific SDGs • Potential adverse effects and financial challenges	• Emphasizing Smart Cities' positive contributions to achieving SDGs • Exploring challenges and addressing them through transparent governance mechanisms
Sustainable Development	• Balancing economic development with green spaces and environmental preservation • Challenges in establishing emission baselines	• 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	• Difficulty in integrating renewable energy resources for environmental sustainability	• Building energy simulation and machine learning algorithms
Cybersecurity in Smart Grids	• Ensuring robust cybersecurity for smart grids	• 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	• Data protection and integrity in smart grids integrated with communication networks	• 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	• Enhancing energy efficiency and responsiveness to demand in smart cities	• 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	• Ensuring security and privacy in the context of smart grids	• 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	• Reducing carbon emissions through EV adoption	• Adoption of electric vehicles (EVs) as a measure to reduce carbon emissions •
Real-Time Traffic Monitoring and Congestion Reduction	• Challenges in effective traffic management and congestion reduction	• Integration of mobile computing, IoT, and big data for real-time traffic monitoring, reducing congestion
Bike-Sharing Systems (BSS)	• Effective management challenges in bike-sharing systems	• 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	• Transition from ownership to access in the sharing economy	• 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	• Enhancing safety, traffic conditions, and convenience in urban mobility	• 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	• Data security and implementation costs associated with blockchain in urban mobility	• 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	• Surge in human population causing challenges in waste management	• Proposed method comprising three modules to improve waste management efficiency
Solid Waste Treatment	• Global challenge in managing solid waste due to urbanization and industrialization	• 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	• Waste collection being a significant portion of the total budget in waste management systems	• 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 circeular 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.

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Conflict of interest

The authors declare no conflict of interest.

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