

Artificial Internet of Things, Sensor-Based Digital Twin Urban Computing Vision Algorithms, and Blockchain Cloud Networks in Sustainable Smart City Administration

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Abstract: The aim of this paper is to synthesize and analyze existing evidence on interconnected sensor networks and digital urban governance in data-driven smart sustainable cities. The research topic of this systematic review is whether and to what extent smart city governance can effectively integrate the Internet of Things (IoT), Artificial Intelligence of Things (AIoT), intelligent decision algorithms based on big data technologies, and cloud computing. This is relevant since smart cities place special emphasis on the involvement of citizens in decision-making processes and sustainable urban development. To investigate the work to date, search outcome management and systematic review screening procedures were handled by PRISMA and Shiny app flow design. A quantitative literature review was carried out in June 2024 for published original and review research between 2018 and 2024. For qualitative and quantitative data management and analysis in the research review process, data extraction tools, study screening, reference management software, evidence map visualization, machine learning classifiers, and reference management software were harnessed. Dimensions and VOSviewer were deployed to explore and visualize the bibliometric data.

Keywords: sustainability; Internet of Things; smart eco-city; big data technology; e-administration



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1. Introduction

Smart cities are characterized by several key features that distinguish them from traditional urban cities: cutting-edge technology integration, data-driven decision-making, resilience sustainability, urban mobility modeling, digital infrastructure and connectivity, citizen engagement and empowerment, and collaborative governance simulation. The use of environmental data analysis and remote sensing technologies through the convergence of the Internet of Things (IoT), big data, and artificial intelligence (AI) [1] determines the real-time application of sustainable and efficient waste management practices and renewable energy transition both in smart cities and eco-cities.

In recent years, AI technologies have become an integral part of public administration, promoting intelligent city governance and providing comprehensive solutions. Public administration, by AI-based data processing, can optimize economic competitiveness and performance, bureaucratic procedures [2], and mobility in sustainable smart cities. The use of IoT innovation in smart city management [3] can influence the design of innovative services and solutions for citizens. Also, IoT technologies and big data analytics can monitor urban operation decision-making through AI design and planning functions, optimizing environmental sustainability and citizens' quality of life across smart eco-cities [1].

Smart city governance develops on economic competitiveness [4] and civic engagement in terms of renewable energy sources, waste and environmental footprint decreases, green buildings, and ecological transportation systems. Digital technologies can assist in sustainable circular and sharing economy development [5] with regard to production and infrastructural design through citizen engagement. Urban resilience improvements [6],

by monitoring and controlling procedures, shape smart city strategic plans. Augmented environmental monitoring and organizational governance mechanisms [7] can harness AI-based technologies, digitization, and automation to optimize urban sustainability and reduce systemic social risks.

Integrating AI into the policymaking process can increase the efficiency and transparency of public administration. Big-data-driven technologies [8] can shape environmentally sustainable city design, planning, the decision-making process, and operational management in smart urbanism. Urban ecosystem sustainability [9] and resilience planning support land-use policymaking and informed decision-making, for harmonious and balanced environmental management decisions; the urban ecosystem's sustainable development and resilience; and environmental awareness and ecological conservation. In this context, decision-making processes regarding the development of the urban system [10] can be improved by using methods of prediction and urban digital twins.

This systematic review aims to clarify whether connected and resilient urban system functionalities, computer simulation network performance algorithms, and development planning mechanisms and practices can shape social norms and decision-making processes across a distributed IoT-blockchain cloud infrastructure in sustainable smart cities. Thus, the following three topics were addressed: whether IoT green governance, AI data-based mobile communication systems, and urban digital twin technologies can assist in sustainable smart city planning (RQ1), whether deep learning forecasting and prediction tools, sensing and big data technologies, and self-organizing spatial–social network and decision support systems can assist in the environmentally responsible governance of smart cities and sustainable urbanism (RQ2), and whether cloud computing technologies, blockchain and AI-driven sustainable urban mobility, and computer simulation network performance algorithms can assist in cost-effective smart city management and resource optimization (RQ3). This systematic review develops the previous literature in terms of visual modeling and deep-learning-based sensing technologies, spatio-temporal fusion and cloud computing algorithms, smart spatial planning and virtual reality modeling tools, and remote sensing and real-time predictive maintenance systems configuring IoT-based smart city environments and big-data-driven urban geopolitics. Our specific contribution is in cumulating and analyzing the recent literature covering cognitive data visualization and geospatial mapping tools, simulation modeling and deep-learning-based computer vision algorithms, and urban sensing and data-sharing technologies for smart urban governance and networked environments.

The manuscript includes the following sections: Methodology (Section 2), Source correlation analysis (Section 3), IoT green governance, AI data-based mobile communication systems, and urban digital twin technologies for sustainable smart city planning (Section 4), Deep learning forecasting and prediction tools, sensing and big data technologies, and self-organizing spatial–social network and decision support systems in environmentally responsible governance of smart cities and sustainable urbanism (Section 5), Cloud computing technologies, blockchain and AI-driven sustainable urban mobility, and computer simulation network performance algorithms for cost-effective smart city management and resource optimization (Section 6), Discussion (Section 7), Specific contributions to the literature (Section 8), Limitations and further directions of research (Section 9), Practical implications (Section 10), Opportunities, challenges, and gaps according to the selected literature (Section 11), and Conclusions (Section 12).

2. Methodology

The methodological framework applied in this systematic review is the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA), and with its web-based Shiny app flow design, the search outcomes and screening procedures were integrated (Figure 1). A quantitative literature review was performed in June 2024 across ProQuest, Scopus, and the Web of Science with these search terms: “smart cities” + “sustainability” + “artificial intelligence” for published original and review research, between 2018 and 2024,

with 59 final sources remaining for analysis. We selected only original articles and reviews published in English, considering the top 20 most-cited papers covering the debated topics (Table 1).

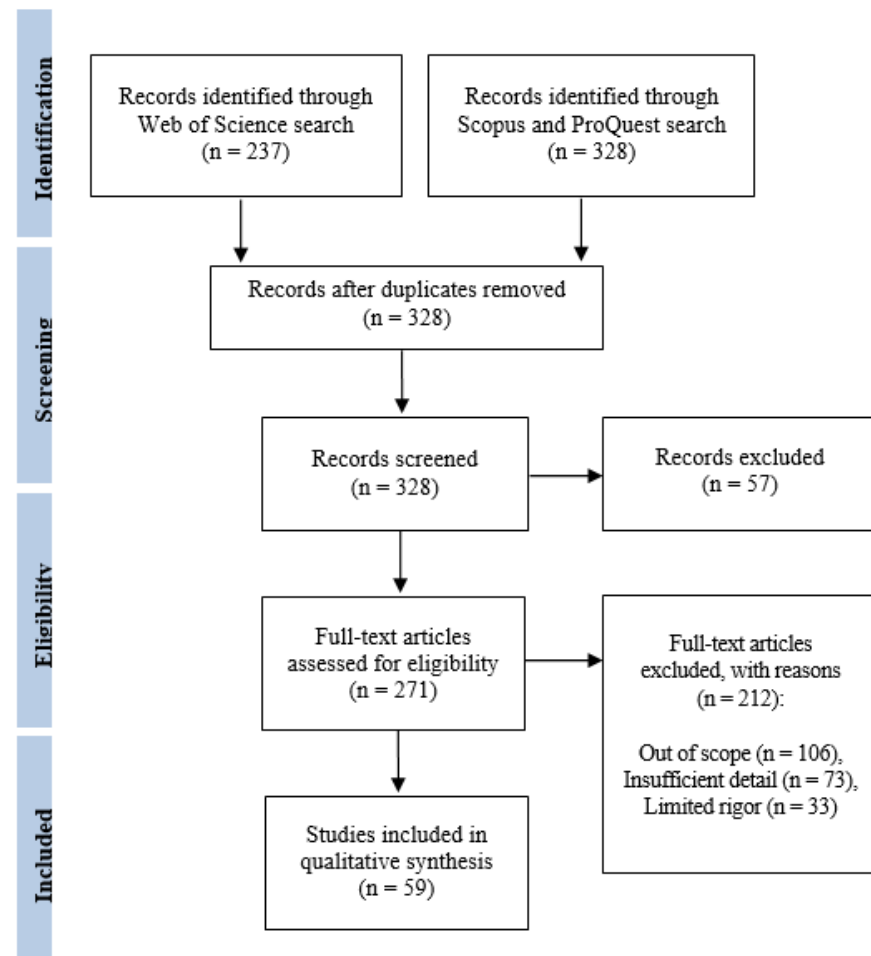


Figure 1. PRISMA flow diagram describing the search results and screening. (PRISMA Checklist is available in Supplementary Material).

Quality tools used: Abstrackr automates the screening process by analyzing the abstracts of a large number of articles and identifying those that meet specific inclusion criteria. ROBIS provides a structured framework for assessing the risk of bias in systematic reviews, focusing on the following: a. how studies were selected for review and whether there is a risk that certain studies were incorrectly omitted or included; b. the risk of bias associated with the methods used to collect data from the studies included in the review; c. the risk of bias in the process of analyzing and interpreting the data from the studies; and d. assessing the risk of bias in the process of synthesizing the data and interpreting them for general conclusions. CADIMA focuses on data extraction and meta-analysis, and it allows for an automated duplicate removal in the review process. SRDR Plus provides a standard structure, extracting particular types of information, focusing systematically on the study design, and archiving as evidence of the synthesis or process flow. Rayyan is used for screening forms and criteria to fit the specific requirements of the review protocol, and for citation organization and tracking. Dimensions and VOSviewer were deployed to visualize the relationships between different concepts, topics, or areas of study, and for analysis through bibliometric network mapping and layout algorithms (see figures in Section 3).

Table 1. Top 20 most-cited papers covering the debated topics.

No.	Authors	Nationality	Paper Title	Journal Title	Paper Type	Number of WoS Citations	Ref.
1	Mohd Abdul Ahad, Sara Paiva, Gautami Tripathi, Noushaba Feroz	India, Portugal	Enabling technologies and sustainable smart cities (2020)	<i>Sustainable Cities and Society</i>	Original research	223	[11]
2	Saurabh Singh, Pradip Kumar Sharma, Byungun Yoon, Mohammad Shojar, Gi Hwan Cho, In-Ho Ra	South Korea, UK	Convergence of blockchain and artificial intelligence in IoT network for the sustainable smart city (2020)	<i>Sustainable Cities and Society</i>	Original research	217	[12]
3	Abdul Karim Feroz, Hangjung Zo, and Ananth Chiravuri	South Korea, United Arab Emirates	Digital Transformation and Environmental Sustainability: A Review and Research Agenda (2021)	<i>Sustainability</i>	Original research	177	[13]
4	Simon Elias Bibri	Norway	A foundational framework for smart sustainable city development: Theoretical, disciplinary, and discursive dimensions and their synergies (2018)	<i>Sustainable Cities and Society</i>	Original research	137	[14]
5	Victor Galaz, Miguel A. Centeno, Peter W. Callahan, Amar Causevic, Thayer Patterson, Irina Brass, Seth Baum, Darryl Farber, Joern Fischer, David Garcia, Timon McPhearson, Daniel Jimenez, Brian King, Paul Larcey, Karen Levy	Sweden, USA, UK, Germany, Austria, Colombia	Artificial intelligence, systemic risks, and sustainability (2021)	<i>Technology in Society</i>	Original research	111	[8]
6	Sophie A. Nitoslawski, Nadine J. Galle, Cecil Konijnendijk Van Den Bosch, James W.N. Steenberg	Canada, Ireland	Smarter ecosystems for smarter cities? A review of trends, technologies, and turning points for smart urban forestry (2019)	<i>Sustainable Cities and Society</i>	Review	110	[15]
7	Ali Hassan Sodhro, Sandeep Pirbhulal, Zongwei Luo, Victor Hugo C. de Albuquerque	Pakistan, Sweden, China, Brazil	Towards an optimal resource management for IoT based Green and sustainable smart cities (2019)	<i>Journal of Cleaner Production</i>	Original research	101	[16]
8	Christopher Martin, James Evans, Andrew Karvonen, Krassimira Paskaleva, Dujuan Yang, Trond Linjordet	UK, Sweden, the Netherlands, Norway	Smart-sustainability: A new urban fix? (2019)	<i>Sustainable Cities and Society</i>	Original research	86	[17]
9	Arash Heidari, Nima Jafari Navimipour, Mehmet Unal	Iran, Turkey	Applications of ML/DL in the management of smart cities and societies based on new trends in information technologies: A systematic literature review (2022)	<i>Sustainable Cities and Society</i>	Review	83	[18]
10	Hadi Zahmatkesh, Fadi Al-Turjman	Norway, Turkey	Fog computing for sustainable smart cities in the IoT era: Caching techniques and enabling technologies—an overview (2020)	<i>Sustainable Cities and Society</i>	Review	82	[19]

Table 1. Cont.

No.	Authors	Nationality	Paper Title	Journal Title	Paper Type	Number of WoS Citations	Ref.
11	Xia Li, Patrick S.W. Fong, Shengli Dai, Yingchun Li	China	Towards sustainable smart cities: An empirical comparative assessment and development pattern optimization in China (2019)	<i>Journal of Cleaner Production</i>	Original research	81	[20]
12	Azzam Abu-Rayash, Ibrahim Dincer	Canada	Development of integrated sustainability performance indicators for better management of smart cities (2021)	<i>Sustainable Cities and Society</i>	Original research	73	[21]
13	Laura Belli, Antonio Cilfone, Luca Davoli, Gianluigi Ferrari, Paolo Adorni, Francesco Di Nocera, Alessandro Dall'Olio, Cristina Pellegrini, Marco Mordacci, Enzo Bertolotti	Italy	IoT-Enabled Smart Sustainable Cities: Challenges and Approaches (2020)	<i>Smart Cities</i>	Original research	68	[4]
14	Tim Heinrich Son, Zack Weedon, Tan Yigitcanlar, Thomas Sanchez, Juan M. Corchado, Rashid Mehmood	Australia, USA, Spain, Saudi Arabia	Algorithmic urban planning for smart and sustainable development: Systematic review of the literature (2023)	<i>Sustainable Cities and Society</i>	Review	59	[22]
15	Simon Elias Bibri	Norway	Data-driven smart sustainable cities of the future: An evidence synthesis approach to a comprehensive state-of-the-art literature review (2021)	<i>Sustainable Futures</i>	Review	56	[23]
16	Armin Razmjoo, Poul Alberg Østergaard, Mouloud Denai, Meysam Majidi Nezhad, Seyedali Mirjalili	Spain, Denmark, UK, Italy, Australia	Effective policies to overcome barriers in the development of smart cities (2021)	<i>Energy Research & Social Science</i>	Original research	45	[24]
17	Jayden Khakurel, Birgit Penzenstadler, Jari Porras, Antti Knutas, Wenlu Zhang	Finland, USA	The Rise of Artificial Intelligence under the Lens of Sustainability (2018)	<i>Technologies</i>	Original research	42	[25]
18	Tahereh Saheb, Mohamad Dehghani, Tayebbeh Saheb	Iran	Artificial intelligence for sustainable energy: A contextual topic modeling and content analysis (2022)	<i>Sustainable Computing: Informatics and Systems</i>	Original research	35	[26]
19	Tarana Singh, Arun Solanki, Sanjay Kumar Sharma, Anand Nayyar, Anand Paul	India, Vietnam, South Korea	A Decade Review on Smart Cities: Paradigms, Challenges and Opportunities (2022)	<i>IEEE Access</i>	Review	33	[27]
20	Jose Sanchez Gracias, Gregory S. Parnell, Eric Specking, Edward A. Pohl, Randy Buchanan	USA	Smart Cities—A Structured Literature Review (2023)	<i>Smart Cities</i>	Review	32	[5]

3. Source Correlation Analysis

The co-authorship correlations (Figure 2) show that sustainable AI in smart grids and renewable energy management can mitigate air pollution and climate change. IoT technology [28] can optimize sustainable building design, energy consumption and sources, and water and waste management in smart cities. Blockchain, AI, and IoT technologies can enable environmentally sustainable practices and decision-making processes [1] with

regard to smart city eco-planning through coherent data collection and analysis, resulting in optimized resource management. The use of smart city technologies can enable the development of the potential of urban green spaces [26] to enhance environmental sustainability. Urban big data and computing systems, through connected IoT devices, can enhance the environmental performance, operational management, decision-making processes, and self-adaptive behavior [10] of sustainable smart cities. Machine and deep reinforcement learning algorithms develop on big data analysis [29] to facilitate sustainable growth, renewable energy, responsible digitization and societal implications, decision-making and public service optimization, and environmental management in smart cities and in resilient urban environments. Big-data-driven IoT, AI, and cloud computing technologies can be deployed in urban environmental sustainability digital transformation [30] mapping and decision-making processes, and can optimize organizational practices, capabilities, and performance with regard to waste management and pollution control, driving a competitive advantage.

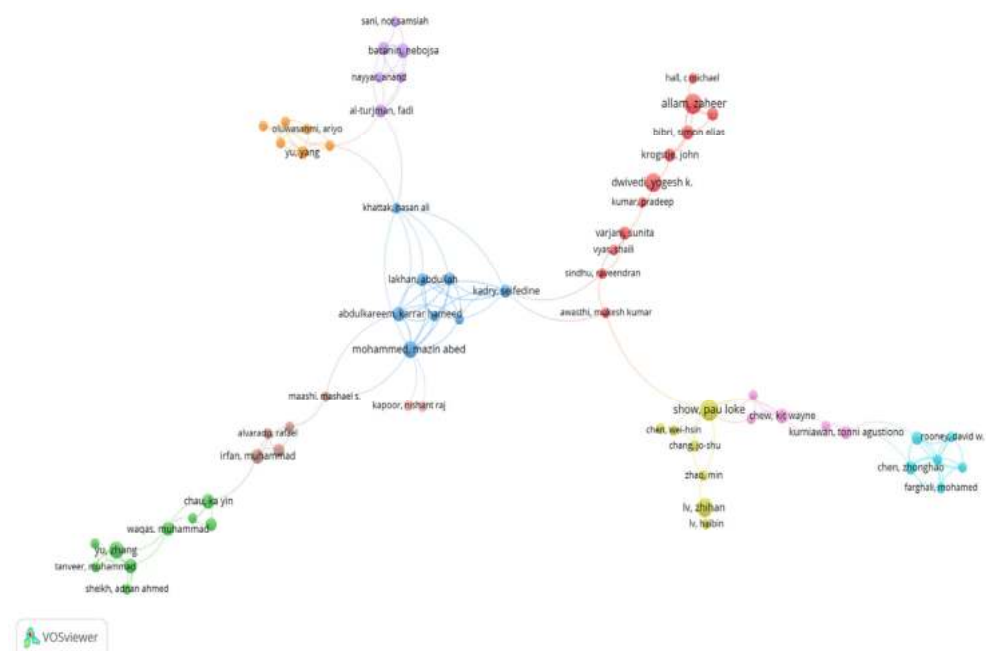


Figure 2. VOSviewer mapping of artificial intelligence technologies in sustainable smart city administration: Internet of Things big data analytics, sensor-based digital twin urban computing vision algorithms, and blockchain cloud networks regarding co-authorship. (see Table 2 for VOSviewer clusters).

Citation correlations (Figure 3) show that smart eco-cities develop on AI and AIoT technology-based management, design, and planning practices to become environmentally friendly communities [1], impacting the sustainable urban development. The integrated use of cognitive computing, blockchain, and IoT can determine sustainable smart city design [13], meaning they are subject to significant attention from stakeholders. Predictive analytics, data modeling, and digital twin techniques [31] can be deployed in smart city dynamic environments for sustainable urban development. Green resources shape urban economic growth and environmentally sustainable development [32] across eco-city construction. Sensor wireless networks, urban intelligence functions, and data processing tools [33] optimize operational modeling, simulation, analysis, functioning, monitoring, planning, evaluation, and development of big data analytics-based intelligent decision support, control, design, automation, and management across cloud and fog computing governance infrastructures in smart sustainable cities. Emerging technologies help the development of smart and integrated cities by creating [14] sustainable ecosystems with the role of improving economic performance. By harnessing the value of AI and AIoT technologies, smart eco-cities can achieve their goals of ecological sustainability, inclusivity,

resilience, and quality of life for citizens, while paving the way for a more sustainable urban future. IoT, energy efficiency technologies, and big data analytics [34] can optimize urban operational management, environmental monitoring systems, and development planning for sustainable smart cities. Big data analytics, the IoT, and citizen engagement [23] can bring about sustainable eco-city development.

Table 2. VOSviewer clusters.

Main topics addressed by the authors in each group	violet (smart city management), orange (smart urbanism operational management), blue (sustainable smart city planning), crimson (urban ecosystem sustainable development), brown (urban system development), emerald (smart city environmentally responsible governance), olive (environmentally sustainable city design), magenta (urban environmental sustainability digital transformation), cyan (smart city planning and designing)
The reasons behind their research focus	violet (urban operation decision-making), orange (urban sustainability), blue (urban ecosystem sustainability), crimson (urban infrastructures and systems), brown (resilient urban system functionalities), emerald (sustainable smart cities), olive (smart city technologies), magenta (urban big data and computing systems), cyan (resilient urban environments)
The number of research groups with common interests	violet (6), orange (6), blue (8), crimson (11), brown (5), emerald (9), olive (7), magenta (5), cyan (6)

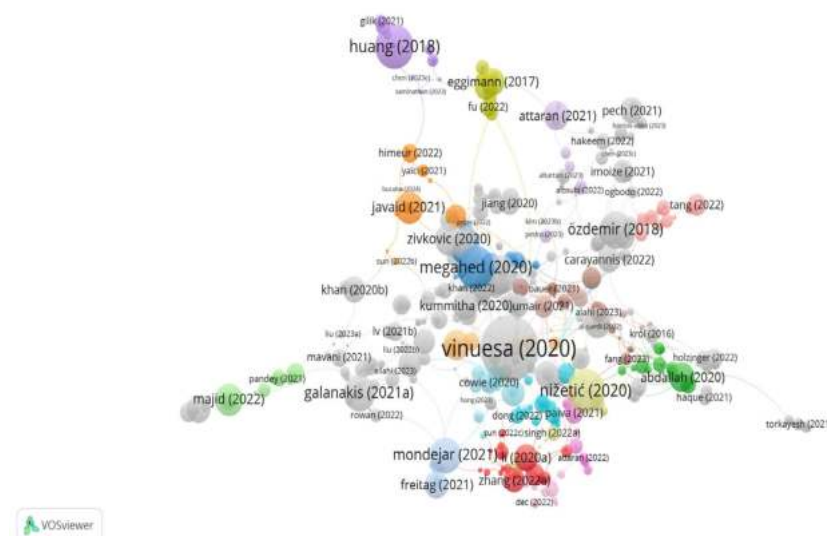


Figure 3. VOSviewer mapping of artificial intelligence technologies in sustainable smart city administration: Internet of Things big data analytics, sensor-based digital twin urban computing vision algorithms, and blockchain cloud networks regarding citation. (see Table 3 for VOSviewer clusters).

Bibliographic coupling correlations (Figure 4) show that the IoT, blockchain, digital twins, AI, and computing technologies shape smart city green governance, management, and infrastructure [15] in relation to energy, tourism, mobility, and transport through social and environmental planning, design, and monitoring of sustainable urban forms, resulting in economic growth and living standard optimization. Sensor wireless networks, urban intelligence functions, and data processing tools optimize operational modeling, simulation, analysis, functioning, monitoring, planning, evaluation, and development of big data analytics-based intelligent decision support, control, design, automation, and management across [33] cloud and fog computing governance infrastructures in smart sustainable cities. Urban planning processes based on AI technologies contribute to the management of smart cities [35] and improve the quality of citizens' lives, ensuring sustainable growth.

AI algorithms can analyze vast amounts of data collected from sensors, satellites, social media, etc., to identify patterns and trends, helping planners understand current urban dynamics and predict future needs. Big data technologies and AI-driven integrated models of urbanism [22] can optimize sustainable transportation, pollution control, renewable energy, and smart grid systems. Blockchain-based improvement of recycling and circularity practices can generate sustainability benefits, optimizing natural resource management [26] and determining the construction of sustainable energy systems.

Table 3. VOSviewer clusters.

Main topics addressed by the authors in each group	violet (smart city dynamic environments for sustainable urban development), olive (smart and integrated city development), orange (urban operational management), blue (sustainable smart city development planning), salmon (interconnected smart sustainable city development), spring green (smart sustainable city development planning and operational management performance), brown (sustainable smart city planning), jade (sustainable smart urban development performance), cyan (smart sustainable city operational functioning), crimson (sustainable urban planning)
The reasons behind their research focus	violet (smart context-aware sustainable urban planning development systems), olive (resilient smart cities), orange (sustainable smart city connected networks), blue (technological solution-based sustainable urban strategies), salmon (sustainable urban environments), spring green (sustainable smart city design), brown (environmentally conscious sustainable smart cities), jade (urban planning and sustainable development efficiency), cyan (resilient urban environments), crimson (environmentally smart sustainable urbanism)
The number of research groups with common interests	violet (6), olive (5), orange (4), blue (5), salmon (6), spring green (4), brown (7), jade (9), cyan (14), crimson (7)

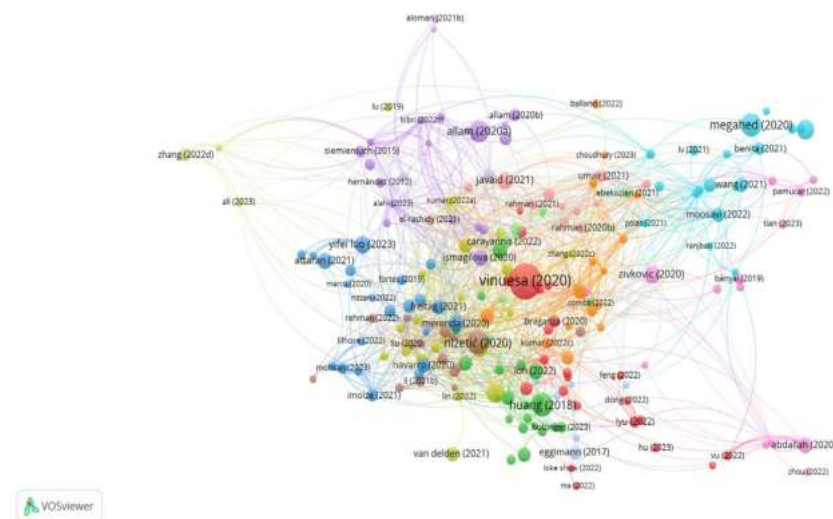


Figure 4. VOSviewer mapping of artificial intelligence technologies in sustainable smart city administration: Internet of Things big data analytics, sensor-based digital twin urban computing vision algorithms, and blockchain cloud networks regarding bibliographic coupling. (see Table 4 for VOSviewer clusters).

Co-citation correlations (Figure 5) show that big data technologies in sustainable urbanism [34] can influence the operational management of sustainable cities, generating an integrated process of change, promoting the consumption of renewable energy, reducing pollution, and preserving ecosystems within communities. Smart city waste management technology-based urban green space and natural resource integration [26] can improve

Table 5. VOSviewer clusters.

Main topics addressed by the authors in each group	olive (sustainable urban development practices), orange (smart city decision-making, planning, and management processes), red (development planning, design scalability, and operational management-based sustainable urbanism), blue (urban ecosystem sustainable development and resilience), green (data-driven smart city planning, design, processes, and practices), violet (smart sustainable city planning and design), cyan (urban intelligence and smart sustainable city planning)
The reasons behind their research focus	olive (smart city environmental sustainability practices), orange (smart city environmentally responsible governance), red (distribution planning and logistic decisions in smart cities), blue (connected and resilient urban system functionalities), green (sustainable city redesigning and restructuring), violet (urban operation decision-making), cyan (smart sustainable city urban planning, design, and management)
The number of research groups with common interests	olive (9), orange (6), red (19), blue (13), green (18), violet (9), cyan (8)

4. IoT Green Governance, AI Data-Based Mobile Communication Systems, and Urban Digital Twin Technologies for Sustainable Smart City Planning

Sustainability and green-governance-based smart city management [15] can develop energy production, environmental monitoring, and transport interaction applications. Urban big data analytics enable data-driven decision-making in governance by providing insights into citizens' needs, service delivery, and policy effectiveness, thus promoting transparency, accountability, and citizen engagement in urban governance processes. Smart-city decision-makers can integrate IoT technologies [38] to promote sustainability of health, mobility, and daily living activities. AI and AIoT technologies, algorithms, and data analysis can optimize sustainable urban development practices and address climate change and ecological degradation issues through environmental consciousness [1]. IoT sensors collect real-time data on factors like traffic flow, structural integrity, water quality, and energy usage, enabling maintenance schedule optimization, early problem detection, and efficient operations across urban infrastructures. Urban big data analytics and context-aware computational systems [33] support infrastructural and operational decision-making processing and data sharing, together with planning and development practices, across smart sustainable cities.

Smart city governance develops on economic competitiveness and civic engagement [4] in terms of renewable energy sources, waste and environmental footprint decreases, green buildings, and ecological transportation systems. Urban digital twin technologies [10] can transform the infrastructural development, management, and planning of sustainable smart cities by AIoT-driven decision support systems. By providing a digital image of the city, digital twins enable data-driven decision-making, citizen engagement, and proactive management of urban challenges. Monitoring operations in an eco-smart city using IoT and big data technologies drive policy adoption [1] favoring an increase in the standard of living of citizens and a higher degree of innovation of communities.

Smart city technologies [39] can enhance sustainable development, energy urbanization performance, and the environmentally friendly infrastructure. Algorithmization and datafication [8] through cloud and fog computing, IoT, and urban sensor-based big data technologies contribute to smart urbanism planning. Fog-based IoT systems [21] can cut down delays and improve energy efficiency in sustainable smart cities through machine learning techniques. Energy-efficient buildings and infrastructure contribute to lower carbon emissions and reduced resource consumption. IoT-based decision support systems and green technologies can be pivotal in sustainable urban infrastructures [22] since they allow for evaluating renewable energy consumption and conservation, traffic congestion, resource depletion, waste management, disaster resilience, and environmental risks.

Deploying AI and IoT, eco-innovation-based digital and environmental policies [19] can facilitate smart city long-term sustainable development and economic competitiveness. Citizen engagement, green infrastructure, connected technologies, and big data analytics [23] enable urban sustainable development and resilience. AI data-driven mobile communication systems [40] can mitigate climate change, waste, and emissions in Internet of Energy-based 5G sustainable smart cities through management techniques, clean processes, and renewable sources. Collaborative networks and platforms facilitate the exchange of ideas, resources, and expertise to accelerate progress towards sustainability goals. Also, big data technology-driven energy and waste management systems [41] can develop liveable and efficient urban environments.

Based on AI and the IoT, traditional cities are transforming into smart cities, using practical knowledge, skills, and tools to solve various issues [42] such as an aging transport infrastructure, environmental pollution, struggling healthcare provision, and high energy consumption. Sustainable knowledge, awareness, consumption, and production, and a sustainable resource base [2], underpin AI-based connectivities and technological innovations across the urban environment. IoT technologies empower organizations and communities to make data-driven decisions, optimize resource usage, and achieve sustainability goals. Smart eco-cities integrate IoT technologies and big data analytics, enhancing resource efficiency and coherent waste management practices [1] with the aim of creating and preserving environmentally sustainable urban settings. Digital twin technologies can build resilient production process systems [43] in sustainable urban environments.

Based on these analyses, we clarified that IoT green governance, AI data-based mobile communication systems, and urban digital twin technologies can assist in sustainable smart city planning (RQ1). Moreover, urban digital twin and AIoT technologies, context-aware computational and AI data-driven mobile communication systems, and urban big data analytics can be harnessed for green-governance-based smart city management and long-term sustainable development.

5. Deep Learning Forecasting and Prediction Tools, Sensing and Big Data Technologies, and Self-Organizing Spatial–Social Network and Decision Support Systems in Environmentally Responsible Governance of Smart Cities and Sustainable Urbanism

E-administration determines the adoption of flexible and sustainable bureaucratic procedures that improve mobility and economic competitiveness in smart cities [2]. Algorithmic urban planning-based smart sustainable development [35] integrates evidence-based decision-making mechanisms. Decision-making processes regarding the development of the urban system can be improved [10] by using prediction tools and urban digital twins. Data-driven smart city planning, design, processes, and practices develop on urban computing [8] and intelligence tools, sustainable economic development and natural resource management, and self-organizing social–spatial networks and infrastructures. Urban natural resources, green spaces, and smart city technologies can further environmental sustainability [26] through the use of big-data-driven grids and renewable energy-efficient buildings. Moreover, urban intelligence function-based simulation, monitoring, and planning systems [33] support decision-making processes in smart sustainable cities.

AI and AIoT technologies, algorithms, and data analysis [1] can optimize sustainable urban development practices and address climate change and ecological degradation issues through environmental consciousness. AIoT and blockchain technology can further sustainable urban mobility [44] by cutting polluting gas emissions and vehicular traffic congestion, while ensuring data security and immutability. Big-data-based sustainable urbanism can optimize innovative ways [34] of planning, monitoring, and analyzing to improve the performance of smart cities. AI-based energy-efficient buildings, climate resilience planning practices, operations, and decision-making, green infrastructure, and water resource management [45] underpin the environmentally responsible governance of smart cities and sustainable urbanism.

Deep learning forecasting and prediction tools can be harnessed for efficient sustainable energy consumption management systems across resilient building [46] and public

space urban designs, architectural configurations, and transport infrastructures. AI-driven urban creative strategies integrate smart city management [47] and green technologies to develop environmentally friendly buildings and ensure sustainable growth. Sensing and big data technologies, cloud and fog computing and visual analytics tools, and self-organizing spatial–social network and decision support systems [8] underpin smart sustainable city planning and design. Urban ecosystem sustainability [9] and resilience planning support land-use policymaking and informed decision-making, for harmonious and balanced environmental management decisions; the urban ecosystem’s sustainable development and resilience; and environmental awareness and ecological conservation.

Smart sustainable city planning, simulation, and monitoring require decision support systems [33] for urban intelligence functions, structures, and forms supported by big data analytics-based operations, designs, and practices. Advanced optimization techniques [48] enable sustainable urban pattern management, distribution planning, and logistic decisions in smart cities. Meanwhile, data-driven technologies enable real-time analysis [8] that can be used in the decision-making, planning, and management processes of smart cities. Beyond this, the long-term resource sustainability of smart buildings [36] and mobility and transportation systems can be achieved through energy modeling, planning, and efficiency. Additionally, orienting citizens towards sustainability-based behaviors [5] and encouraging their involvement in solving public administration issues may shape the development of circular economy in a smart city. Furthermore, IoT-enabled urban computing technologies can assess automatically [49] sensed data in sustainable smart cities.

IoT, big data, and cloud-computing-based digital transformation strategies [30] can optimize the stakeholders’ decision-making process, developing environmental sustainability practices in smart cities. Here, deep learning algorithms can forecast and improve the IoT communication system and heterogeneous network performance [50] across sustainable smart cities with regard to the large-scale quality of service, for fault avoidance. Urban infrastructural digitization for sustainable informed decision-making [51] can configure carbon emission reductions, environmental protection processes, and lower resource consumption in smart cities. IoT technologies and big data analytics can monitor urban operation decision-making [1] through AI design and planning functions, optimizing environmental sustainability and citizen’s quality of life across smart eco-cities.

Based on these analyses, we clarified that deep learning forecasting and prediction tools, sensing and big data technologies, and self-organizing spatial–social network and decision support systems can assist in the environmentally responsible governance of smart cities and sustainable urbanism (RQ2). AIoT and blockchain technologies, urban intelligence function-based simulation, monitoring, and planning systems, and deep learning forecasting and prediction tools can be leveraged for algorithmic urban planning-based smart sustainable development, data-driven smart city planning, design, processes, and practices, the environmentally responsible governance of smart cities and sustainable urbanism, and self-organizing social–spatial networks and infrastructures.

6. Cloud Computing Technologies, Blockchain and AI-Driven Sustainable Urban Mobility, and Computer Simulation Network Performance Algorithms for Cost-Effective Smart City Management and Resource Optimization

AI technologies and data analytics can enhance citizens’ quality of life [4] through an optimized infrastructure and service performance in environmentally sustainable smart cities, driving economic growth and competitiveness. Urban intelligence and smart sustainable city planning and design systems [8] integrate data-driven operational management, performance, and decision-making. Blockchain-based energy management with cloud integration [17] develops sustainable and efficient cities and societies. Smart city technologies can reduce the environmental impact [26] through sustainable urban water conservation and waste management, renewable energy source usage, green infrastructure and transportation, and natural filtration systems. Fog computing can enable green production and sharing while optimizing energy grid resilience [40] and reliability by integrated power network technologies in sustainable smart urban environments.

AI-based urbanism and IoT [8] enable a smart sustainable infrastructure and an increase in citizens' quality of life. Blockchain, computer vision, and vehicle communication technologies [44] can improve road safety, travel times, and energy efficiency, and decrease traffic congestion and emissions, leading to sustainable urban mobility in smart cities. Machine and deep learning technologies [52] can be pivotal in cost-effective smart city management and resource optimization by delivering sustainable urban traffic flow surveillance and monitoring. Cloud computing technologies and big data analytics [18] can optimize IoT-enabled sensor device development and monitoring in sustainable smart cities. Inclusive urban planning, intelligent transportation systems, and disaster risk management [16] can facilitate the transition to sustainable urban development. Artificially intelligent transport systems developed on green energy [53] ensure optimization across a distributed IoT-blockchain cloud infrastructure in sustainable smart cities.

Big data technologies can enhance self-organizing social networks, infrastructures, and environments that can forge sustainable urbanism through development planning, design scalability, and operational management, thus [34] optimizing renewable energy production and use, reducing waste generation and pollution, preserving green areas, and providing solutions for carbon neutrality. Smart city AI and IoT can enable long-term digital and environmental systemic sustainable development [19] and transformations, resulting in eco-innovation investment-based economic competitiveness. Connected and resilient urban system functionalities require heterogeneous integrated technologies [14] for economic and social performance optimization in sustainable AI, edge computing, and blockchain-based smart city networks. Computer simulation network performance algorithms and big data analytics enable urban planning, design, and management of smart sustainable cities with regard to the technological system scale, behavioral patterns, and connectivity. AIoT technologies [1] can decrease energy consumption, resource use, and the carbon footprint, leading to climate change mitigation and the optimization of citizens' behaviors and participation in environmentally smart sustainable urbanism through process and practice automation.

IoT-based smart sustainable cities [3] deliver a decreased urban environmental impact, optimized energy resource management, and innovative mobility functionalities and service design across networked architectures and infrastructures. Urban environment and sustainable city redesigning and restructuring can be achieved through IoT big data computing technologies [12] with regard to operational management, governance network, and development planning mechanisms and practices shaping social norms and decision-making processes. IoT sensor technology and intelligent engineering system design [38] can bring about energy efficiency, carbon footprint reduction, and technological sustainability across smart architectures. Sustainable 5G/6G networks [37] contribute to developing green communication systems, enhancing the urban infrastructure, and reducing the carbon footprint and pollution.

Based on these analyses, we clarified that cloud computing technologies, blockchain and AI-driven sustainable urban mobility, and computer simulation network performance algorithms can assist in cost-effective smart city management and resource optimization (RQ3). Urban intelligence and smart sustainable city planning and design systems, machine and deep learning technologies, and computer simulation network performance algorithms can be deployed for sustainable AI, edge computing, and blockchain-based smart city networks, connected and resilient urban system functionalities, and the urban planning, design, and management of smart sustainable cities.

7. Discussion

Smart sustainable technological innovations can enhance entrepreneurial urban governance. Urban infrastructural digitization [51] increases the decision-making process efficiency and thus drives smart city sustainable development. Multidimensional, integrative and inclusive, multilayered, co-governed, network-centric, organized, and interconnected smart sustainable city development [54] requires socio-cognitive system-based engaged

citizenship, explicit design transformation-driven shared responsibility, dynamic community co-creation and participation, and flexible urban structures. Big data technologies can monitor and assess [34] smart sustainable cities with regard to development planning and operational management performance. Smart city services integrate monitoring and controlling processes [6] for climate-change-driven urban resilient behaviors and economic sustainable development. Smart cities require urban planning and sustainable development efficiency [55] to increase productivity and reduce the task achievement time.

Green AI technologies can ensure environmentally friendly sustainable growth [47] through streamlined building, energy, and waste management, design, and planning, conservation systems, and land, resource, water, and material efficiency, while reducing greenhouse gases. Cloud integration for computational offloading [17] is pivotal in blockchain-based energy trading systems for smart and sustainable cities, increasing user privacy and security. In order to develop efficient urban mobility and reduce gas emissions in smart cities, decision-makers [44] can integrate blockchain technologies and computer vision algorithms to provide convenience to citizens and increase the quality of urban life. Computerized urban planning, management, design, policymaking processes, and societal development practices [33] shape smart sustainable city operational functioning in terms of normative actions, automation, and control. Collective and collaborative low-carbon technology-based urban infrastructural network digitization [51] shapes the decision-making process efficiency in smart spatial and sustainable development.

Sustainable urban planning, the design infrastructural composition, and public decision-making processes can lead to a mitigation of environmental consequences, climate change, and fossil fuel reliance [46] through energy-efficient eco-conscious city texture planning. Moreover, data analytics can decrease energy consumption and costs, furthering environmental sustainability in efficient urban environments. Data analytics can monitor carbon emissions for sustainable, resilient energy production [41] and distribution management systems, and reduce waste and water usage. IoT-driven city operational management is pivotal in overseeing changes in the socio-economic needs of citizens [34] and development planning of sustainable smart cities. Smart-city-driven management and the integration of sustainable energy resources and technologies can be used to promote [26] sustainability through renewable energy and energy-efficient buildings. Cloud computing and big data should power IoT-enabled sensor devices [18] for green and sustainable smart cities.

8. Specific Contributions to the Literature

Our systematic review clarifies that big data analytics, integrated design and planning practices, and pervasive context-aware computing technologies can optimize operations and services [33] through automation and control in sustainable urban development. Policies on water resource management and sustainable agriculture should integrate strategies on urban ecosystem development [9] and resilience planning, enhancing citizens' quality of life. AI technologies can be deployed in smart cities to strengthen integrated sustainable [47,56] environmental forecasting, planning, and management practices for socio-economic stability. Industry 4.0-based automated sensors [56] assist citizens' social governance and engagement in sustainable smart cities. IoT sensor technology and intelligent engineering system design can bring about energy efficiency, carbon footprint reduction, and technological sustainability [38] across smart architectures. Green 5G/6G AI wireless communication networks enable smart sustainable cities [37] in terms of broad-spectrum energy efficiency and harvesting, the carbon footprint, and power consumption through infrastructure design optimization, connectivity, and scalability. Smart city development is based on the resizing and interconnection [54] of urban ecosystems, social change, and engaged citizenship. Environmentally smart sustainable eco-cities [1] deploy IoT and AI technologies, together with remote sensors and big data analytics, in real-time monitoring of the air and water quality and recycling and resource recovery. Cooperative communication across cognitive radio sensor networks [11] requires efficient energy consumption, sustainable data collection, cluster behaviors, and resource allocation in smart

cities. Smart cities can deploy AI and IoT technologies and green spaces [26] to enable environmental sustainability through natural resources' effective management. Sustainable, resilient, and reliable technological, data communication, and organizational processes, tools, automations, and infrastructures can optimize [24,57] citizens' quality of life in smart cities and urban environments. Moreover, artificial-neural-network-based sustainable smart urban development performance [58] can alleviate traffic congestion and optimize resource consumption.

9. Limitations and Further Directions of Research

This quantitative literature review was performed only across ProQuest, Scopus, and the Web of Science, and for published original and review research between 2018 and 2024 covering Internet of Things big data analytics, sensor-based digital twin urban computing vision algorithms, and blockchain cloud networks. Predictive analytics can anticipate future trends, enabling proactive decision-making in areas like infrastructure planning, resource allocation, and public service optimization. The economic and social needs of the community in a smart city [1] are solved with blockchain, AI, and IoT technologies with the aim of transparency and security of information, data, and transactions.

Future research should further investigate the potential for integrating sensor data with digital twin models, as urban planners and policymakers can gain real-time visibility of urban dynamics and can simulate various scenarios to test the impacts of different interventions. Digital twin technologies, data analytics, and predictive models [31] optimizing city environments shape sustainable urban development, and cloud computing and energy-efficient resource management technologies can shape environmentally conscious sustainable smart cities [40] and resilient urban environments. Computer simulation network performance algorithms and big data analytics enable urban planning, design, and the management of smart sustainable cities [33] with regard to the technological system scale, behavioral patterns, and connectivity. Advanced vision algorithms, including computer vision and image processing, enhance the capability of digital twins to interpret and analyze sensor data, enabling more accurate simulations and decision-making.

10. Practical Implications

Promoting the use of renewable energy sources [26] and green infrastructure can provide smart city solutions for sustainable e-waste management and environmental conservation. AI-based, sustainable socio-technical systems can build a resilient infrastructure [20] in terms of resource consumption and production, fostering innovation and reducing waste and pollution. Moreover, the development and use of blockchain in intelligent transportation systems for sustainable smart cities [53] drive the integration of a secure and efficient autonomous transportation system. AIoT-based transportation planning, decision-making, and management can enable sustainable mobility in smart eco-cities through robust data collection and analysis. Furthermore, AIoT technologies can decrease energy consumption, resource use, and the carbon footprint, leading to climate change mitigation and the optimization of citizen behavior [1] and participation in environmentally smart sustainable urbanism through process and practice automation. Energy use and greenhouse gas emission decreases can be attained in sustainable smart cities [25] through AI-based resource management and service provision. Computerized urban planning, management, design, policymaking processes, and societal development practices shape smart sustainable cities' operational functioning [33] in terms of normative actions, automation, and control. Finally, the use of smart and sustainable devices and new technologies in smart city governance policies [56] determines the development of human capital, the degree of social involvement of community residents, and the reduction of digital divides.

11. Opportunities, Challenges, and Gaps According to the Selected Literature

Public administration, through AI-based data processing [2], can optimize economic competitiveness and performance, bureaucratic procedures, and social mobility in sustain-

able smart cities. Policymakers benefiting from AI and AIoT opportunities for environmental sustainability [1] can articulate interconnections between smart cities and green cities, contributing to redefining urban infrastructures and systems. Industry 4.0 and digital twin technologies may be harnessed to meet local governments' [15] and citizens' requirements regarding smart city planning and designing. Blockchain-based smart cities [26] can effectively decrease waste volumes, carbon emissions, and environmental pollution, manage electricity resources and recycling and circularity practices, and encourage sustainable behaviors and supply chain tracking.

Different economies should improve their technological and financial resources [38] in order to develop a regional and transborder green infrastructure. Here, computational analytics and data mining techniques [33] can be deployed in the management, design, and organization of smart context-aware sustainable urban planning development systems. Moreover, green resources shape urban economic growth and environmentally sustainable development [32] across smart city construction. Beyond this, urban resilience improvements, by monitoring and controlling procedures [41], shape smart city strategic plans. Furthermore, smart city local authorities can use big-data-driven technologies [27] to achieve sustainable economic and social developments.

Sustainable information and communication technology infrastructures enable resilient smart cities to design and develop [24] public policies, recommendations, and certification processes for citizens' quality of life improvement. Edge computing and blockchain technologies [14] can allow for sustainable smart city connected networks and urban AI system development, enhancing the economic performance by reducing power consumption in device data communication. Integrated technological solution-based sustainable urban strategies [52] optimize traffic management and safety, monitoring the quality of life in smart cities. AI-driven environmental management and practices can improve the quality of life [29] and optimize public services in smart cities. Additionally, in the context of smart cities, blockchain and IoT offer solutions [44] for improved urban mobility, traffic optimization, and road safety, thus supporting sustainability goals. Moreover, digital twin technologies can build resilient production process systems [43,59] in sustainable urban environments. Sustainable urban mobility planning, management, and development [16] integrate intelligent transportation systems in smart cities. Policymakers benefiting from AI and AIoT opportunities for environmental sustainability [1,60] can articulate interconnections between smart cities and green cities, contributing to redefining urban infrastructures and systems. To become carbon-neutral areas, data-driven smart sustainable cities should develop on big-data-driven urban infrastructures [61], spectrum-sensing-based urban governance networks [62], renewable energy sustainable development and organization management [63–65], and civic and public engagement development [66,67], in circular economy practices, machine-learning-based IoT systems [68], cognitive-radio-based IoT networks [69], greenhouse gas environmental quality demand [70], green public procurement sustainability policy adoption [71], and renewable energy technology [72].

12. Conclusions

Geospatial mapping and urban planning tools, wireless visual sensor and mobile edge computing networks, location- and context-aware networked augmented reality systems, remote sensing and situational awareness algorithms, and image-based object recognition and machine vision technologies underpin big-data-driven urban digital governance and geopolitics in IoT-enabled smart and environmentally sustainable cities. Smart urban sensors, environment perception mechanisms, ambient sound recognition software, and spatial data analytics shape digital twin and sustainable smart cities. The creation of smart city strategies and the use of associated technologies can be made participatory, in favor of having citizens acting directly in defining the premises of sustainability and conscientious use of the resources provided, through transparent data use and collaborative decision-making, public institution activity traceability (e.g., by live streaming meetings with instant feedback availability), and professional algorithmic expertise (in terms of

automatic knowledge validation for positions in public institutions). To ensure that the use of smart city technologies is sustainable, solving social problems and generating inclusion, rather than bringing about new problems, public and private bodies should deploy digital twin, immersive metaverse, extended reality, and generative AI simulation and modeling algorithms to precisely and dynamically identify and quantify the impact of multi-sensor environment data fusion on networked urban environments. The main social repercussions associated with the investigated topics concern the blockchain-based digital twin management of real-time cognitive data visualization, enabling smart city governance and big-data-driven urban geopolitics, due to current interests in and concerns from both institutions and citizens about immersive interconnected 3D worlds and 6G hyper-connected networks. From this perspective, computationally networked urbanism, simulated 3D environments, and extended reality-powered immersive spaces integrate environment perception mechanisms, big urban cloud data, and object and image processing techniques, thus increasing social datafication, public surveillance, and mass control.

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