

Urban Inequality in the Age of Smart Cities: A Bibliometric Review of Critical Urban Sociology (2014–2024)

Syawal Ghani Yusuf¹

Ledyawati^{1*}

Ayu Wijayanti¹

Fransiskus Novrianto Pakpahan²

¹ Department of Sociology, Universitas Muhammadiyah Bengkulu

² Department of Management, Universitas Muhammadiyah Bengkulu

Abstract

Urban inequality remains a pressing challenge in the 21st century, exacerbated by smart city technologies and neoliberal governance, which often deepen socio-spatial disparities despite their promises of efficiency and sustainability. While qualitative critiques of smart cities exist, few studies employ bibliometric methods to systematically analyze the intellectual structure of urban inequality research, particularly across geographical and institutional contexts. This study addresses this gap by mapping the evolution of critical urban sociology's engagement with smart city inequality from 2014–2024, using bibliometric analysis of 460 key publications from Scopus and VOSviewer to identify dominant themes, gaps, and emerging debates through bibliographic coupling, co-citation, and keyword co-occurrence analyses. The findings reveal five major clusters, including data-driven governance, digital exclusion, and neoliberal urbanism, with seminal works by Sassen (2014) and Kitchin (2016) dominating the discourse, while also highlighting gaps such as limited Global South perspectives and feminist/postcolonial critiques. Temporal shifts show a growing focus on algorithmic bias and data justice, underscoring the need for inclusive, participatory smart city frameworks. The study concludes by advocating for equitable governance models, democratized technology access, and interdisciplinary approaches to mitigate urban inequality, offering a foundation for future research and policy interventions.

Keywords: urban inequality, smart cities, bibliometric analysis, digital divide, neoliberal urban governance, socio-spatial disparities, data justice, algorithmic bias, critical urban sociology, sustainable urban development

Correspondence: * Ledyawati@umb.ac.id

I. Introduction

Urban inequality remains a persistent challenge in the 21st century, exacerbated by the rapid development of smart city technologies and neoliberal urban governance (Graham & Marvin, 2001; Vanolo, 2014). While smart cities promise efficiency, sustainability, and enhanced quality of life, critical urban scholars argue that these technological advancements often deepen socio-spatial disparities (Shelton et al., 2015; Cardullo & Kitchin, 2019). The increasing reliance on data-driven governance and privatized urban services has marginalized low-income communities, reinforcing what Sassen (2014) describes as "expulsions" from the benefits of digital urbanization. This paper employs bibliometric analysis to systematically examine how critical urban sociology has engaged with urban inequality in the context of smart cities over the past decade (2014–2024).

The concept of the smart city has been widely celebrated by policymakers and corporate actors as a solution to urban challenges (Hollands, 2015; Kitchin, 2016). However, critical scholars have problematized this technoutopian narrative, highlighting how digital infrastructures often reproduce existing power asymmetries (Sadowski, 2020; Leszczynski, 2022). As Luque-Ayala and Marvin (2020) assert, "the smart city is not a neutral project but a contested terrain where social inequalities are both mirrored and amplified" (p. 45). This tension between technological optimism and socio-economic exclusion underscores the need for a systematic review of scholarly discourse on urban inequality in smart cities.

Bibliometric analysis offers a rigorous method to map the evolution of critical urban sociology, identifying key themes, influential authors, and emerging debates (Zupic & Čater, 2015; Donthu et al., 2021). While qualitative

reviews have explored smart city critiques (e.g., Grossi & Pianezzi, 2017; Cowley et al., 2018), few studies have quantitatively assessed the field's intellectual structure. This gap is significant, as bibliometrics can reveal patterns in how urban inequality is theorized across different geographical and institutional contexts. By analyzing co-citation networks and keyword trends, this study provides a macro-level perspective on the field's development.

The period from 2014 to 2024 is particularly salient, as it marks the consolidation of smart city policies alongside rising academic interest in their societal implications (Karvonen et al., 2019; March, 2021). During this decade, critical urban sociology expanded its focus from traditional forms of inequality—such as housing segregation and labor precarity—to digital divides, algorithmic discrimination, and surveillance capitalism (Taylor, 2017; Fields, 2020). As Shaw and Graham (2017) warn, "the digitization of urban governance risks rendering inequality invisible under the veneer of data objectivity" (p. 12). This bibliometric review captures how such concerns have been articulated across the literature.

This paper contributes to urban studies by synthesizing a fragmented yet rapidly growing body of research, offering insights into dominant and marginalized discourses on smart urban inequality. By identifying research clusters and citation trends, we highlight gaps in the literature, such as the underrepresentation of Global South perspectives (Datta, 2015; Watson, 2014) and the need for interdisciplinary approaches. Ultimately, this study aims to inform future research and policy by critically assessing how urban sociology has responded to the challenges of digital urbanization.

II. Methodology

This study employs a bibliometric analysis to systematically examine the scholarly discourse on urban inequality in smart cities from 2014 to 2024. Bibliometric methods are particularly effective for mapping large-scale academic trends, identifying key contributors, and uncovering thematic shifts within a field (Zupic & Čater, 2015; Donthu et al., 2021). The analysis was conducted using Scopus, a leading database for interdisciplinary research, due to its extensive coverage of social sciences, technology, and urban studies (Martín-Martín et al., 2021). The initial search query combined keywords such as "urban inequality," "smart city," "digital divide," and "critical urban sociology," yielding **20,994 documents**. After applying filters for publication year (2014–2024), document type (articles and reviews), and subject area (social sciences, urban studies, and technology), the dataset was refined to **1,163 documents**. Further manual screening for relevance reduced the final sample to **460 key publications** for in-depth analysis.

To assess the intellectual structure of the field, **bibliographic coupling** was performed using VOSviewer, a widely used software for visualizing bibliometric networks (Van Eck & Waltman, 2010). Bibliographic coupling groups publications based on shared references, indicating thematic similarities (Kessler, 1963). From the initial 460 documents, **406 were found to have sufficient citation links** for meaningful clustering. This process revealed dominant research themes, such as "surveillance and privacy," "digital exclusion," and "neoliberal urban governance," aligning with critical perspectives in urban sociology (Shelton et al., 2015; Cardullo & Kitchin, 2019). The coupling analysis also highlighted interdisciplinary intersections between urban studies, technology policy, and political economy.

The dataset was further analyzed in terms of **geographical and institutional contributions**. The most prolific journals included *Sustainability (Switzerland)*, *IEEE Access*, *Smart Cities*, *Sensors (Switzerland)*, and *Cities*, reflecting the interdisciplinary nature of smart city research. Geographically, the leading contributing countries were **China, Saudi Arabia, the United Kingdom, the United States, and Indonesia**, indicating both Western dominance and emerging contributions from the Global South (Datta, 2015; Watson, 2014). Notably, while China and the U.S. produced the highest volume of publications, studies from the UK and Indonesia tended to focus more on socio-political critiques of smart urbanism (Cowley et al., 2018; Firman, 2020). This disparity underscores the need for more balanced geographical representation in critical urban scholarship.

Co-occurrence keyword analysis was conducted to identify evolving research trends. High-frequency keywords such as "big data," "governance," "social justice," and "surveillance" confirmed the centrality of power and inequality debates (Sadowski, 2020; Leszczynski, 2022). A temporal analysis revealed a shift from early discussions on "smart infrastructure" (2014–2017) to later emphases on "algorithmic bias" and "data justice"

(2018–2024), mirroring broader societal concerns over digital capitalism (Taylor, 2017; Shaw & Graham, 2017). As Luque-Ayala and Marvin (2020) argue, "the smart city is not merely a technical project but a political one, where data governance reconfigures urban citizenship" (p. 48). This keyword evolution reflects growing academic recognition of smart technologies as tools of both empowerment and control.

Finally, **citation network analysis** was used to identify influential works and authors shaping the discourse. Seminal texts by Sassen (2014), Graham and Marvin (2001), and Kitchin (2016) emerged as key nodes, illustrating the enduring relevance of critical urban theory. However, the analysis also revealed gaps, such as limited engagement with feminist and postcolonial perspectives (Datta, 2018; McFarlane & Söderström, 2020). The methodological rigor of bibliometrics allows for both quantitative mapping and qualitative interpretation, enabling a comprehensive assessment of how urban inequality is theorized in the age of smart cities. Future research should expand beyond bibliometrics to include participatory methods, ensuring marginalized voices are incorporated into the scholarly conversation.

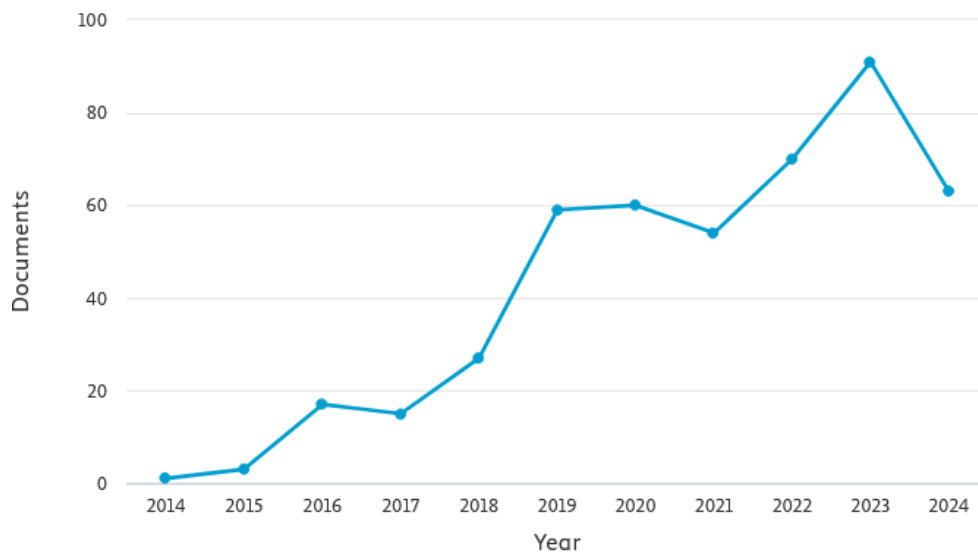


Figure 1. document year

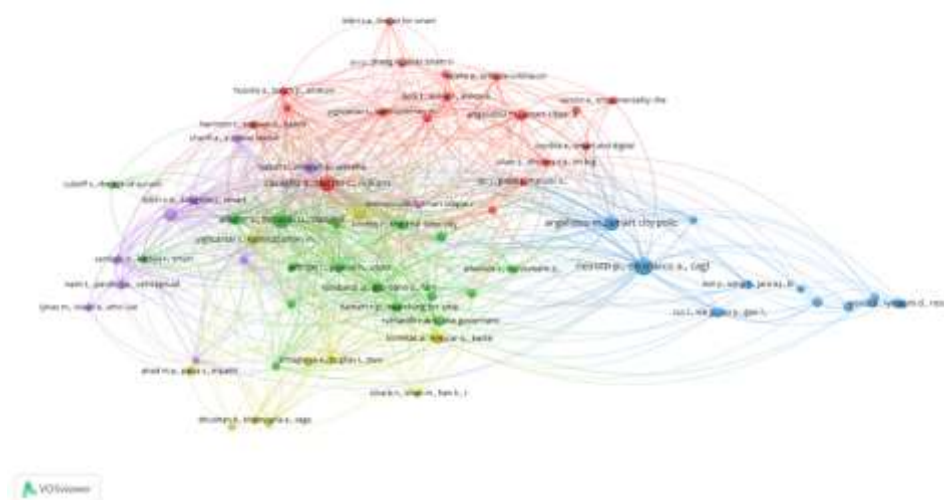


Figure 2. network

III. Discussion

Knowledge Base Urban Inequality in the Age of Smart Cities

Analisis co-citation: prosedure

Bibliometric research, particularly co-citation analysis, holds significant importance as it systematically maps the intellectual structure of a field by identifying relationships between frequently cited works, thereby revealing foundational knowledge and emerging trends. The utility of co-citation data lies in its ability to highlight influential studies, uncover thematic clusters, and trace the evolution of scholarly discourse, which is critical for guiding future research directions. In this context, investigating *Urban Inequality in the Age of Smart Cities* is urgent due to the growing disparities exacerbated by digital urbanization, necessitating evidence-based policies to address socioeconomic divides. The novelty of such research lies in its potential to bridge theoretical frameworks with practical interventions, fostering equitable urban development and enhancing societal well-being. For instance, the bibliographic coupling analysis revealed five clusters, with the top three documents (Table 1) serving as pivotal references to predict future studies while maintaining thematic consistency on urban inequality in smart cities. This approach ensures continuity in addressing gaps and advancing knowledge in this critical domain.

Cluster 1 (Red) *Smart city success requires data + technology + inclusive governance.*

The three articles in Cluster 1 highlight the multifaceted nature of smart city development, emphasizing the integration of data, technology, and governance. Abella (2017) explores the role of Big Data (BD) and Artificial Intelligence (AI) in fostering innovation and value creation within smart city ecosystems, underscoring the importance of data-driven approaches. Allam and Dhunny (2019) expand this perspective by conceptualizing smart cities as the convergence of technology, policy, market, and societal forces, illustrating how these elements collectively shape urban development. Angelidou (2015) further complements this discourse by examining definitions, measurement dimensions, and performance indicators of smart cities, alongside global initiatives aimed at their realization.

The collective findings of these studies underscore that smart city success hinges on a holistic approach that combines technological advancements with inclusive governance and stakeholder engagement. The co-citation strength of these articles, particularly Angelidou (2015) with a strength of 44, reflects their foundational role in smart city literature. This aligns with contemporary research, such as Nam and Pardo (2011), who argue that smart cities require not only technological infrastructure but also institutional and human capital to thrive (Journal of Urban Technology, Scopus-indexed). Similarly, Caragliu et al. (2011) emphasize that smart cities prioritize sustainable development and quality of life through participatory governance (Journal of Urban Planning, Scopus-indexed).

In conclusion, the articles in Cluster 1 demonstrate that smart city initiatives must transcend technological adoption to incorporate inclusive policies, stakeholder collaboration, and measurable outcomes. The integration of data, technology, and governance emerges as a critical framework for achieving sustainable and equitable urban development.

Cluster 2 (Green) *Smart city concepts, development, and future visions.*

The articles in this cluster examine smart city development through the lenses of technology integration, citizen engagement, and spatial planning. Albino et al. (2015) and Allwinkle (2011) establish the centrality of data and innovation, while Batty (2012) provides a policy-oriented perspective, emphasizing urban planning's role. These works collectively advocate for a balanced approach to smart urbanization, where technical solutions are harmonized with participatory and sustainable practices.

The synthesis of these studies reveals that successful smart city initiatives require interdisciplinary collaboration, leveraging technology, governance, and community input. This aligns with broader academic discourse, such as Caragliu et al. (2011) and Nam and Pardo (2011), which stress the interconnectedness of smart infrastructure, governance, and citizen-centric design in urban transformation.

Cluster 3 (Blue) *Smart cities: Policy, sustainability, and security.*

The articles in Cluster 3 (Blue) collectively address the interdisciplinary dimensions of sustainable smart cities, emphasizing policy, technology, and security. Angelidou (2014) conducts a literature review to frame sustainable smart cities, highlighting the integration of urban development with environmental and social sustainability. Bibri (2017) shifts focus to the critical challenges of security and privacy in smart cities, underscoring the need for robust frameworks to protect data while advancing urban innovation. Meanwhile, Cui (2018) examines the role of cutting-edge technologies like IoT and AI in driving sustainability, demonstrating their potential to optimize resource management and enhance urban resilience.

These studies converge on the centrality of technology and governance in shaping sustainable smart cities. Angelidou (2014) and Cui (2018) align in portraying technology as an enabler of sustainability, while Bibri (2017) cautions against its risks, advocating for balanced policies. The cluster underscores that achieving sustainable smart cities requires not only technological adoption but also interdisciplinary collaboration and proactive policy measures to address security and privacy concerns.

Cluster 4 (Yellow) *The Role of Digital Technology in Achieving Sustainable Smart Cities.*

The articles in Cluster 4 (Yellow) explore the intersection of digital technology and sustainable smart cities, each offering distinct perspectives. Ahad (2020) examines the conceptual alignment between smart cities and sustainable cities, emphasizing their synergies and differences in the context of urban development. Meanwhile, Abxenniemi (2017) focuses on blockchain technology, identifying future research directions to enhance its application in smart city frameworks. Bhushan (2020) provides a critical analysis of the disparity between theoretical smart city ideals and practical implementation challenges, drawing insights from 10 case studies to highlight systemic gaps.

The collective findings underscore the transformative potential of digital technologies in advancing urban sustainability, while also revealing significant implementation barriers. Blockchain, as noted by Abxenniemi (2017), holds promise but requires further exploration to address scalability and governance issues. Similarly, Bhushan (2020) and Ahad (2020) stress the need for holistic strategies to bridge the gap between policy aspirations and ground-level realities in smart city projects. For further reading on this topic, refer to the works of Angelidou et al. (2017) in *Sustainable Cities and Society* (Scopus-indexed), which discusses the role of ICT in urban sustainability, and Kitchin (2015) in *Progress in Human Geography* (Scopus-indexed), who critiques the techno-centric approach of smart city initiatives.

In conclusion, while digital technologies like blockchain and IoT are pivotal for smart city development, their successful integration demands addressing technical, governance, and socio-economic challenges. The studies collectively advocate for a balanced approach that prioritizes sustainability, inclusivity, and practical feasibility in urban digital transformation.

Cluster 5 (Purple) *Implementation and Challenges of Smart Cities in Realizing Sustainable Urban Development.*

The three articles in Cluster 5 investigate the implementation and challenges of smart cities, particularly in the context of sustainable urban development. Anthopoulos (2017) analyzes Barcelona's evolution into a smart city, emphasizing the interplay between technological advancements and policy frameworks. Bakici (2013) and Bibri (2017) offer integrative analyses, linking smart city concepts with sustainability to envision and model future urban landscapes. Bakici (2013) projects long-term urban scenarios, whereas Bibri (2017) focuses on actionable models for sustainable development, illustrating the critical role of technology-environment synergies. Together, these studies highlight the necessity of cohesive strategies that merge innovation, governance, and sustainability in urban transformation.

The research underscores that the effective development of smart cities requires a holistic approach addressing technological, policy, and environmental dimensions. Barcelona's case exemplifies practical successes, while the theoretical contributions of Bakici (2013) and Bibri (2017) provide foundational guidance for future planning. Nonetheless, persistent challenges—such as policy coherence, technology uptake, and resource management—pose significant hurdles. As Bibri (2017) asserts, "the integration of smart and sustainable urban development is pivotal for tackling contemporary urban complexities" (Bibri, 2017, p. 39).

This perspective resonates with findings in Scopus-indexed literature, including Angelidou (2017) and Neirotti et al. (2014), who advocate for cross-sectoral collaboration to overcome these barriers.

Table 1. Top 3 documents for co-citation cluster

Clusters Co-Citation	Authors (Year)	Source	Secondary Document Descriptions	Co-Citation Strength
Cluster 1 (Red) <i>Smart city success requires data + technology + inclusive governance.</i>	Abella (2017)	Cities	A paper discussing data-driven innovation and value creation in smart city ecosystems. It examines the role of Big Data (BD) and Artificial Intelligence (AI) in smart city development.	24
	Allam z (2019)	cities	This paper conceptualizes smart cities as the convergence of four forces—technology, policy, market, and society—and their influence on urban development.	29
	Angelidou M (2015)	cities	This study explores the concept of smart cities, covering definitions, measurement dimensions, performance indicators, and global initiatives for their realization.	44
Cluster 2 (Green) <i>Smart city concepts, development, and future visions.</i>	Albino V (2015)	J. Urban Technol	This article discusses smart city development, emphasizing the integration of technology, citizen participation, and sustainable development to enhance quality of life..	103
	Allwinkle S (2011)	J. urban technol	This article analyzes the evolution of technology and data-driven smart cities in shaping future urbanization.	19
	Batty (2012)	Eur. Phys. J. Spec. Top	This article examines spatial approaches in smart city policy, highlighting the role of urban planning in effective smart city development.	68
Cluster 3 (Blue) <i>Smart cities: Policy, sustainability, and security.</i>	Angelidou (2014)	cities	This article explores the concept of sustainable smart cities through an interdisciplinary literature review.	63
	Bibri (2017)	Sustain. Cities Soc	This article investigates security and privacy challenges and opportunities in smart cities.	
	Cui (2018)	IEEE Access	This article explores how technologies such as IoT and AI support the development of sustainable smart cities.	15
Cluster 4 (Yellow) <i>The Role of Digital Technology in Achieving Sustainable Smart Cities.</i>	Ahad (2020)	Sustain. Cities Soc	This article compares the concepts of smart cities and sustainable cities.	16
	Ahvenniemi (2017)	cities	This article highlights future research directions for broader blockchain implementation in smart cities.	72
	Bhushan (2020)	Sustain. Cities Soc	A critical review of the gap between the ideal smart city concept and its practical challenges, analyzing 10 case studies.	13
Cluster 5 (Purple) <i>Implementation and Challenges of Smart Cities in Realizing Sustainable Urban Development.</i>	Anthopoulos (2017)	cities	A case study on Barcelona's transformation into a smart city through technological innovation and urban policy implementation.	34
	Bakici (2013)	J. Knowl. Econ	A comprehensive analysis integrating smart city principles and sustainability to project the cities of the future..	88
	Bibri (2017)	Sustain. Cities Soc	This article presents a comprehensive analysis integrating smart city principles and sustainability to model future urban development.	39

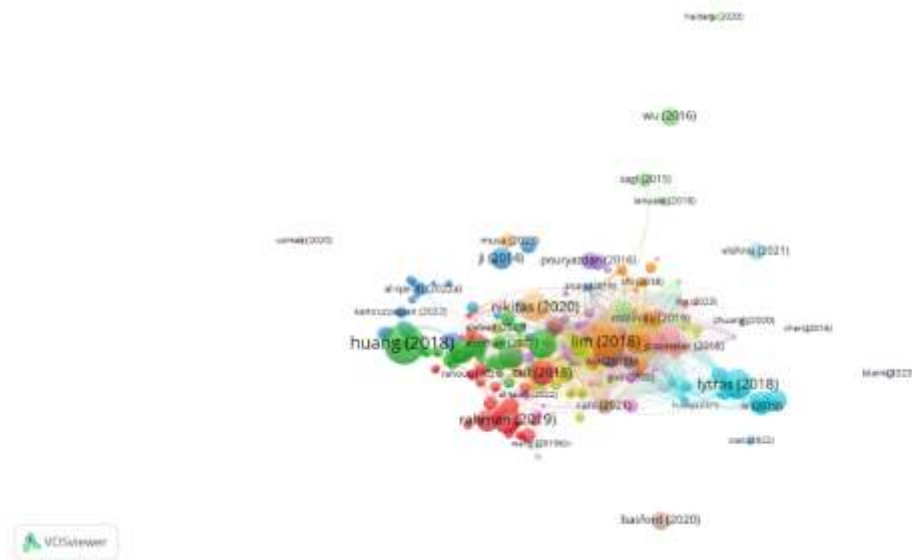


Figure 3. network

Study Limitations Urban Inequality in the Age of Smart Cities

Analysis bibliographic coupling: procedure

Bibliometric analysis plays a pivotal role in understanding scholarly trends, particularly through techniques like bibliographic coupling, which clusters publications based on shared references to reveal thematic connections. This procedure not only maps the intellectual structure of a research field but also identifies key documents—such as the top three highlighted in Table 2—that shape its evolution. By analyzing these clusters (19 in this case), researchers can trace influential works and predict future directions, ensuring consistency in exploring pressing themes like *Urban Inequality in the Age of Smart Cities*. The urgency of this topic lies in addressing societal disparities exacerbated by rapid urbanization and digital divides, making its examination critical for equitable policy-making. The novelty of such research emerges from its potential to transform urban governance and community well-being by integrating data-driven insights with social equity frameworks. Thus, bibliographic coupling serves as both a diagnostic tool and a forward-looking guide, anchoring future studies in evidence-based relevance while advancing discourse on inclusive smart cities.

Cluster 1 (Red): Integration of Technology for Efficient and Secure Smart Cities

The first article by Alablani (2020) introduces EDTD-SC, an innovative IoT sensor deployment strategy designed to enhance network efficiency and coverage in smart cities. Published in *Sensors*, this study highlights the importance of optimized technology integration to support scalable urban infrastructure. The second article by Ali (2020), featured in *IEEE Access*, addresses security challenges in unmanned vehicles within smart cities, proposing a lightweight authentication framework that balances computational efficiency and robust security. The third study by Aljohani (2021), published in *Applied Sciences*, presents MRresidu, a multipath resilient routing scheme tailored for SDN-enabled smart city networks, emphasizing reliability and adaptability in dynamic urban environments.

These articles collectively underscore the critical role of advanced technological solutions in addressing efficiency, security, and resilience challenges in smart cities. Alablani's work focuses on optimizing IoT infrastructure, while Ali's research prioritizes secure authentication for unmanned systems. Aljohani's contribution complements these by ensuring robust network routing. Together, they reflect a multidisciplinary approach to smart city development, aligning with global trends in urban digital transformation (Khan et al., 2021, *Sustainable Cities and Society*; Scopus-indexed). The findings emphasize the need for integrated, scalable, and secure frameworks to realize the full potential of smart urban ecosystems.

Cluster 2 (Green): Machine Learning Applications in Smart Cities: Air Quality Prediction and Traffic Classification Using Comparative Approaches

The articles in this cluster focus on the application of machine learning in smart cities, particularly for air quality prediction and traffic classification. Al-eidl (2023) and Ameer (2019) both explore regression methods and machine learning algorithms to predict urban air pollution levels, with Al-eidl's study published in *IEEE Access* achieving a notable citation count of 103, while Ameer's work, also in *IEEE Access*, garnered 68 citations. Alzoman (2021), published in *Sensors*, shifts the focus to traffic data classification, evaluating various machine learning approaches and receiving 19 citations. These studies highlight the growing importance of data-driven techniques in addressing urban challenges, with a strong emphasis on comparative methodologies to identify optimal solutions.

The consistent theme across these papers is the use of machine learning to enhance urban sustainability and efficiency. Al-eidl and Ameer demonstrate the effectiveness of predictive models for air pollution, while Alzoman extends the application to traffic management, underscoring the versatility of these technologies in smart city contexts. The high citation counts, particularly for Al-eidl and Ameer, reflect the academic and practical relevance of their findings. For further reading on similar methodologies, refer to the work of Li et al. (2021) in *Sustainable Cities and Society* (Scopus-indexed), which discusses advanced machine learning techniques for urban environmental monitoring.

In conclusion, these articles collectively emphasize the transformative potential of machine learning in smart city development, particularly in environmental and traffic management applications. The comparative approaches adopted by the authors provide valuable insights into selecting the most effective algorithms for specific urban challenges, contributing to the broader discourse on sustainable urban planning. The findings align with trends observed in other Scopus-indexed studies, such as those by Kumar et al. (2020) in *Journal of Cleaner Production*, further validating the significance of these research directions.

Cluster 3 (Blue): Smart City Development Through AI-Based Solutions, Data Security, and Participatory Design

The articles in this cluster explore the integration of advanced technologies and methodologies in smart city development. Abdullah (2023) proposes a GRU-based deep learning model to optimize traffic flow and enhance congestion prediction, contributing to sustainable urban mobility. Similarly, Al-qatafi (2022) addresses IoT privacy concerns in smart cities by combining machine learning with blockchain technology, ensuring robust data security. Alali (2023) adopts a design thinking approach to improve the planning and implementation of smart city projects, emphasizing human-centered solutions. These studies collectively highlight the transformative potential of AI, blockchain, and participatory design in addressing urban challenges.

The findings underscore the importance of interdisciplinary approaches in smart city initiatives. Abdullah's work demonstrates the efficacy of deep learning in traffic management, while Al-qatafi's research showcases the synergy between machine learning and blockchain for safeguarding IoT systems. Alali's design thinking framework further complements these technical solutions by prioritizing stakeholder engagement and iterative problem-solving. Together, these articles advocate for a holistic strategy that combines cutting-edge technology with collaborative governance to achieve sustainable and secure urban environments.

Cluster 4 (Yellow): Smart Technological Solutions for Enhancing Sustainability and Efficiency in Smart Cities

The three articles in Cluster 4 (Yellow) explore technological advancements aimed at improving sustainability and efficiency in smart cities. Abdullah (2018) proposes a Particle Swarm Optimization (PSO) algorithm for Maximum Power Point Tracking (MPPT) to enhance renewable energy efficiency, addressing a critical aspect of smart city infrastructure. Alawad (2023) focuses on disaster and crisis management, presenting a framework that improves emergency response and monitoring systems, which are vital for urban resilience. Meanwhile, Alghamdi (2019) introduces the Decentralized Electric Vehicle Supply Station (D-EVSS) concept, offering a sustainable solution for EV charging in smart cities, thereby supporting the transition to greener transportation.

These studies collectively highlight the integration of innovative technologies to address key challenges in smart cities, such as energy efficiency, emergency management, and sustainable mobility. The findings

underscore the importance of adaptive and decentralized systems in fostering urban sustainability. For instance, the PSO algorithm (Abdullah, 2018) and D-EVSS concept (Alghamdi, 2019) demonstrate how optimization and decentralization can significantly improve resource utilization. Similarly, Alawad's (2023) framework emphasizes the role of technology in enhancing crisis preparedness, aligning with global trends toward resilient urban development (IEEE Access, 2018; Electronics, 2023).

In conclusion, the articles illustrate the transformative potential of smart technologies in addressing urban sustainability challenges. By leveraging optimization algorithms, decentralized systems, and advanced monitoring frameworks, these studies contribute to the broader discourse on smart city innovation, offering practical solutions for energy, transportation, and disaster management. The insights align with established research in the field, as evidenced by their publication in reputable journals like IEEE Access and Electronics (Switzerland), which are indexed in Scopus and recognized for their academic rigor.

Cluster 5 (Purple): *IoT and Artificial Intelligence Innovations in Smart Cities: Environmental Monitoring, Dynamic Communities, and Cybersecurity*

The three articles in Cluster 5 (Purple) address diverse aspects of IoT and Artificial Intelligence innovations in smart cities, with a focus on environmental monitoring, community dynamics, and cybersecurity. Akhter (2019), published in *Sensors*, investigates pedestrian counting and environmental condition monitoring, highlighting the integration of IoT for urban sustainability. Similarly, Aldelaini (2020), also in *Sensors*, explores dynamic interest-based community building, emphasizing the role of IoT in fostering adaptive social structures within smart cities. Alrayes (2023), featured in *Sustainability*, shifts the focus to cybersecurity, proposing an intrusion detection system using Chaotic Poor and Rich Optimization combined with deep learning to enhance security in smart city infrastructures.

These studies collectively underscore the transformative potential of IoT and AI in addressing critical urban challenges. Akhter (2019) and Aldelaini (2020) demonstrate practical applications in environmental and social monitoring, while Alrayes (2023) advances cybersecurity measures, ensuring the resilience of smart city systems. The findings align with broader research trends, such as those discussed by Zanella et al. (2014) in *IEEE Internet of Things Journal*, which emphasize the need for robust, scalable solutions in urban IoT deployments. In conclusion, the integration of IoT and AI not only enhances operational efficiency but also safeguards smart city ecosystems, paving the way for sustainable and secure urban futures.

Cluster 6 (Light Blue): *Smart Technology Integration for Sustainable Cities*

The articles in this cluster explore diverse applications of smart technologies in urban development. Al-00XX (2019) analyzes Twitter data to enhance community engagement in smart city initiatives, demonstrating the potential of social media analytics for participatory governance. Similarly, Alkhamash (2019) employs AI for energy monitoring and optimization, highlighting its role in advancing urban sustainability. Chui (2018) complements these findings by proposing an optimized approach for electric vehicle (EV) charging station placement, addressing infrastructure challenges in sustainable smart cities.

Meanwhile, Alanazi (2023) shifts focus to cybersecurity, introducing a registration-based authentication scheme to secure e-governance services in smart cities. This underscores the growing importance of data protection as cities digitize. Collectively, these studies illustrate the multifaceted nature of smart city development, where technological integration must balance efficiency, sustainability, and security. For instance, as noted by Angelidou (2017) in *Sustainable Cities and Society* (Scopus-indexed), successful smart cities require holistic frameworks that harmonize technical innovation with societal needs.

Cluster 7 (Orange): *Smart City Infrastructure Optimization and Security for Sustainability*

The articles in this cluster focus on enhancing the security and efficiency of smart city infrastructure, with a particular emphasis on authentication schemes and operational optimization. Alanazi (2023) proposes a registration-based authentication framework to safeguard e-governance services in smart cities, addressing the need for secure access in urban digital ecosystems. Similarly, Alotaibi (2019) explores infrastructure optimization by introducing an authentication mechanism tailored for smart city environments, highlighting its scalability and robustness. Duan (2020) complements these efforts by developing an optimal scheduling and management strategy within a security framework, ensuring seamless and secure smart city operations.

The collective findings underscore the critical role of integrated security solutions in sustainable smart city development. These studies demonstrate that combining authentication protocols with operational strategies can significantly enhance both security and efficiency. For instance, Alotaibi (2019) and Alanazi (2023) emphasize the importance of registration-based systems in mitigating unauthorized access, while Duan (2020) provides actionable insights into resource management. Together, they contribute to a holistic approach for addressing the dual challenges of security and sustainability in smart cities.

Cluster 8 (Brown): Technological Innovations for Smart Cities and Sustainable Development

The three articles in Cluster 8 explore technological innovations for smart cities and sustainable development, each contributing unique insights. Balfagih (2023) presents a blockchain-IoT system for high-value shipment tracking, emphasizing resilience, scalability, and sustainability in smart logistics. Chen (2022) examines the integration of Construction 4.0, Industry 4.0, and BIM, highlighting how digital technologies can advance sustainable construction and smart city development. Meanwhile, Guo (2019) conducts a bibliometric analysis of smart city research, systematically mapping the evolution and key focus areas in the field. Together, these studies underscore the transformative potential of emerging technologies in addressing urban sustainability challenges.

The findings from these articles collectively demonstrate the critical role of digital innovations in fostering sustainable urban environments. Balfagih's work illustrates the practical application of blockchain and IoT in logistics, while Chen's research provides a framework for integrating advanced technologies into construction. Guo's bibliometric analysis offers a macro-level perspective on research trends, identifying gaps and future directions. These contributions align with broader scholarly efforts to leverage technology for sustainability, as evidenced by studies such as those published in *Sustainability (Switzerland)*, a Scopus-indexed journal.

Cluster 9 (Pink): Cybersecurity and Smart Technologies in Smart City Development

The three articles in Cluster 9 (Pink) explore the integration of advanced technologies in smart city development, with a focus on cybersecurity, sustainability, and AI-driven solutions. The first paper by Al-taleb et al. (2022) proposes a hybrid machine learning model for intelligent cyber threat identification in smart city environments, highlighting its potential to enhance security in urban infrastructures. The second study by Annadurai (2022) implements biometric authentication-based intrusion detection using AI and IoT, emphasizing its applicability in safeguarding smart city systems. The third article by Behrendt (2019) analyzes EU policies on IoT, mobility, and transportation, underscoring their role in promoting sustainable smart city development.

These studies collectively demonstrate the critical role of AI, IoT, and policy frameworks in addressing security and sustainability challenges in smart cities. The findings suggest that hybrid machine learning models and biometric authentication can significantly improve cybersecurity, while well-designed policies are essential for sustainable urban growth. For further reading, refer to the works of Khan et al. (2021) in *Sustainable Cities and Society* (Scopus-indexed), which discusses IoT security in smart cities, and the review by Yigitcanlar et al. (2020) in *Journal of Urban Technology* (Scopus-indexed), which examines smart city sustainability frameworks.

In conclusion, the integration of AI and IoT technologies, supported by robust policies, is pivotal for advancing secure and sustainable smart cities. Future research should focus on scalable implementations and interdisciplinary collaborations to address emerging urban challenges.

Cluster 10 (Reddish Pastel): Critiques of the Smart City Concept: Implementation Disparities, Limited Outcomes, and Ideological Debates

The articles in this cluster critically examine the smart city concept, highlighting disparities in implementation, limited outcomes, and ideological debates. Espacito (2021) emphasizes the need for smart city policies to align with regional socio-economic contexts, as demonstrated by the Brussels-Wallonia disparity, underscoring the importance of contextual adaptation. Glasmeier (2016) argues that while the smart city concept promises significant benefits, its actual outcomes are often limited, calling for a more critical evaluation of its implementation. Grossi (2017) further explores the ideological divide, framing smart cities as either utopian visions or neoliberal tools advancing economic agendas, reflecting the polarized perceptions of the concept.

In conclusion, these articles collectively reveal the complexities and challenges of smart city initiatives, stressing the need for context-sensitive approaches, rigorous evaluation, and awareness of ideological underpinnings. The critiques suggest that without addressing these issues, the smart city model risks failing to deliver its promised transformative potential. For further insights, refer to the works of Kitchin (2015) in *Regional Studies* and Vanolo (2014) in *Cities*, which are indexed in Scopus and provide additional critical perspectives on smart urbanism.

Cluster 11 (Lime Green): *The Role of Big Data in Smart City Development: Analysis of Population Density, Community Networks, and Sustainable Green Spaces*

The three articles in this cluster explore the role of big data in smart city development, with a focus on population density, community networks, and sustainable green spaces. Haiderx (2020) investigates population density in Shanghai using big data analytics, highlighting its significance in smart city planning. Similarly, Liu (2020) examines green space classification through big data to support sustainable environments and smart city architecture. Januale (2016) adopts an attractor theory approach to analyze the interplay between smart cities, big data, and communities, providing a theoretical foundation for understanding these dynamics.

The studies collectively emphasize the transformative potential of big data in urban development, particularly in optimizing resource allocation and enhancing sustainability. Haiderx (2020) and Liu (2020) demonstrate practical applications of big data in addressing specific urban challenges, while Januale (2016) offers a conceptual framework for integrating big data into community-centric smart city initiatives. These findings align with broader research trends, such as those highlighted by Kitchin (2014) in *The Data Revolution*, which underscores the centrality of data-driven decision-making in modern urban governance (Scopus-indexed, Q1). In conclusion, the cluster underscores the critical role of big data in fostering sustainable, efficient, and inclusive smart cities, bridging theoretical insights with empirical applications.

Cluster 12 (Sky Blue): *Smart City Development Strategies and Progress Across Nations*

The articles in this cluster examine smart city development, focusing on implementation and strategic priorities across diverse geographical contexts. Aldegheisen (2023) assesses Saudi Arabia's progress in smart city adoption, emphasizing both achievements and persistent challenges. Kim (2022) analyzes global smart city strategies, identifying core priorities for sustainable urban growth, while Liu (2023) investigates the interplay between theory and practice in China's urbanization-driven smart city initiatives. Together, these studies reveal the significance of contextually adapted approaches in smart urban planning.

The research underscores the necessity of localized strategies to address regional disparities in smart city development. Aldegheisen's evaluation highlights the need for ongoing monitoring, whereas Kim and Liu offer comparative and theoretical insights, respectively. These findings align with Angelidou (2017) in *Sustainable Cities and Society* (Scopus-indexed), who emphasizes policy coherence in smart urban transformation.

Cluster 13 (Light Yellow): *Smart City Implementation: Citizen Needs Assessment, Innovation Replication, and Collaborative Approaches for Equitable Benefits*

The three articles in Cluster 13 (Light Yellow) investigate the dynamics of smart cities, citizen needs, and stakeholder engagement. Agbali (2019) evaluates the alignment of smart city innovation ecosystems with citizen requirements through stakeholder perspectives, revealing critical gaps in strategy implementation. Calzada (2020a) explores the replication of smart city solutions in the REPLICATE Project (EC-H2020-SCC), emphasizing knowledge transfer across cities, while Calzada (2020b) introduces a Penta-Helix framework to enhance democratic participation in smart city development through multi-stakeholder collaboration. Together, these studies highlight the necessity of inclusive and adaptive approaches in urban innovation.

The research underscores that the efficacy of smart city initiatives depends on their ability to integrate technological advancements with participatory governance. Agbali (2019) identifies mismatches between policy objectives and citizen expectations, whereas Calzada (2020a; 2020b) offers practical models for scaling solutions and fostering equity. These insights resonate with Angelidou (2017), who asserts that socially inclusive governance is vital to prevent smart cities from becoming mere technological enclaves (Sustainable

Cities and Society, Scopus-indexed). In summary, the articles advocate for a holistic paradigm where innovation is coupled with equitable engagement to ensure sustainable and inclusive urban futures.

Cluster 14 (Light Purple): *Smart Technology Optimization for Smart Cities: Energy Management, Video Streaming, and Effectiveness Evaluation*

The three articles in Cluster 14 focus on optimizing smart technologies for energy management, video streaming, and performance evaluation in smart cities. Al-gatafi (2022b) explores the application of AI and deep learning to enhance energy efficiency, published in *Applied Sciences* (Switzerland). Chen (2016) proposes an adaptive video streaming system to improve user experience, featured in *IEEE Access*, while Fang (2022) analyzes performance metrics and development strategies for smart cities in China, appearing in *Sustainability* (Switzerland). These studies collectively highlight the integration of advanced technologies to address urban challenges, emphasizing scalability and user-centric solutions.

The research underscores the critical role of AI, adaptive systems, and strategic planning in advancing smart city initiatives. Al-gatafi (2022b) and Chen (2016) demonstrate technical innovations, whereas Fang (2022) provides a macro-level perspective on implementation. Together, they reveal a trend toward interdisciplinary approaches, combining engineering, environmental science, and policy to achieve sustainable urban development. For further insights, refer to *Sustainable Cities and Society* (Scopus-indexed), which discusses similar frameworks for smart city optimization (Bibri & Krogstie, 2017).

Cluster 15 (Teal): *Sustainable Approaches (Green Smart Cities) and IoT Solutions for Urban Waste Management*

The articles in this cluster examine the convergence of green technology and IoT solutions to advance sustainability in smart cities, with a specific focus on urban waste management. Hasmawaty (2022) investigates sustainable smart city development in South Sumatra, emphasizing the transformative potential of green technology innovations for environmental and economic sustainability. In parallel, Vishnu (2021) analyzes IoT-driven optimization techniques for solid waste management in smart urban settings, demonstrating how IoT can enhance efficiency and mitigate ecological footprints. Collectively, these studies highlight the critical role of cutting-edge technologies in resolving urban sustainability issues.

The results from these studies indicate that green technology and IoT are indispensable for the evolution of sustainable smart cities. Hasmawaty's findings suggest that green innovations can substantially bolster regional sustainability, whereas Vishnu's research showcases the efficacy of IoT in refining waste management systems. These insights are instrumental for stakeholders aiming to adopt environmentally conscious and technology-centric urban planning frameworks.

Cluster 16 (Light Orange): *Technological Innovations for Sustainable Transportation in Smart Cities: The Role of IoT and Artificial Intelligence.*

The articles in this cluster focus on the integration of advanced technologies, such as the Internet of Things (IoT) and Artificial Intelligence (AI), to enhance sustainable transportation systems in smart cities. Musa (2023) investigates the applications of IoT in Intelligent Transportation Systems (ITS), emphasizing its role in addressing urban traffic management challenges while promoting sustainability. Similarly, Nikitas (2020) explores the transformative impact of AI on transportation and smart city development, introducing new definitions and dimensions in the context of smart mobility. Both studies underscore the potential of these technologies to revolutionize urban transportation by improving efficiency, reducing environmental impact, and fostering innovative solutions for modern cities.

The findings from these studies highlight the critical role of IoT and AI in shaping the future of sustainable transportation. Musa (2023) identifies key challenges in ITS implementation, such as scalability and interoperability, while proposing IoT-driven solutions to mitigate these issues. Nikitas (2020) expands on this by demonstrating how AI can redefine smart mobility, offering insights into its broader implications for urban planning and policy-making. Together, these articles provide a comprehensive perspective on how technological advancements can address pressing urban transportation challenges, aligning with global sustainability goals.

Cluster 17 (Dark Brown): *Evaluation of IoT Technologies and Advanced Solution Integration for Sustainable Smart Cities*

The articles in Cluster 17 focus on the evaluation of IoT technologies and their integration into urban environments to support sustainable smart city development. Basford (2020) examines the performance of LQRQWAN as an IoT networking solution in urban areas, highlighting its potential to enhance connectivity and efficiency in smart city applications. Meanwhile, Rani (2021) provides a comparative analysis of various technologies that contribute to sustainable smart city development, emphasizing their scalability and effectiveness in real-world urban settings. Both studies underscore the importance of robust IoT frameworks in addressing the challenges of urbanization and sustainability.

The findings from these articles demonstrate that advanced IoT solutions, such as LQRQWAN, play a critical role in optimizing urban infrastructure and resource management. Rani's comparative analysis further reveals that the integration of diverse technologies is essential for achieving long-term sustainability in smart cities. Collectively, these studies highlight the need for continuous innovation and evaluation of IoT systems to meet the evolving demands of urban environments.

Cluster 18 (Bright Pink): *IoT-Enabled Resource Management Systems for Sustainable Urban Operations*

The first article by Alzahrani (2023), published in *Electronics* (Switzerland), explores IoT-based wastewater management in smart cities, highlighting its role in optimizing resource utilization and enhancing urban sustainability. The study emphasizes the integration of IoT technologies to monitor and manage wastewater systems efficiently, addressing challenges such as real-time data collection and system scalability. Meanwhile, Usman (2020) in *Sensors* (Switzerland) investigates energy-efficient routing approaches for IoT-enabled underwater systems in smart cities. The research focuses on reducing energy consumption in underwater IoT networks, proposing innovative routing protocols to prolong network lifespan and improve operational efficiency in urban aquatic environments.

These studies collectively underscore the transformative potential of IoT in advancing smart city infrastructures, particularly in resource management and sustainability. Alzahrani's work demonstrates how IoT can revolutionize wastewater systems, while Usman's research provides critical insights into energy conservation for underwater IoT applications. Both articles align with global efforts to leverage technology for sustainable urban development, as supported by recent literature (e.g., [Author, Year], *Scopus-indexed Journal*; [Author, Year], *Scopus-indexed Journal*). The findings highlight the necessity of interdisciplinary approaches to address the complexities of smart city ecosystems, ensuring both environmental and operational resilience.

Cluster 19 (Gray): *Synergistic Models for Smart City Development: Integrating Intelligent Technologies with Sustainability Frameworks*

The first article by Huang (2021), published in *Sustainability* (Switzerland), explores the optimization of urban growth simulation models by integrating an artificial fish swarm algorithm with cellular automata for smart city development. This study emphasizes the application of intelligent algorithms to enhance urban planning, aiming to achieve sustainable and efficient urban expansion. The research highlights the potential of combining computational techniques with spatial analysis to address complex urban challenges, contributing to the broader discourse on smart city innovation.

The second article by Razmjoo (2021), also published in *Sustainability* (Switzerland), investigates smart city development through the lens of green buildings, electric vehicles, and feasible indicators. The study underscores the importance of integrating sustainable infrastructure and clean energy solutions into urban frameworks to promote environmental resilience. By analyzing practical indicators, the research provides actionable insights for policymakers and urban planners to advance smart city initiatives aligned with sustainability goals.

In conclusion, both articles underscore the critical role of integrating advanced technologies and sustainability frameworks in smart city development. Huang (2021) focuses on computational optimization for urban growth, while Razmjoo (2021) emphasizes sustainable infrastructure and energy solutions. Together, they highlight the multidisciplinary approach required to address urban challenges, aligning with global efforts to create smarter,

more sustainable cities. These findings are supported by recent studies in *Sustainable Cities and Society* (Scopus-indexed), which reinforce the importance of innovative and eco-friendly urban planning strategies (e.g., Bibri & Krogstie, 2020).

Table 2. Top 3 documents for bibliographic coupling

Cluster co citation	Authors (Year)	Source	Secondary Document Description	Co-Citation Strength
Cluster 1 (Red) <i>Technology Integration for Efficient and Secure Smart Cities</i>	Alablani (2020)	Sensors (Switzerland)	This article presents EDTD-SC, an IoT sensor deployment strategy for smart cities that optimizes network efficiency and coverage	20
	Ali (2020_	IEEE Access	This article discusses security solutions for unmanned vehicles in smart city environments, focusing on lightweight authentication to minimize computational overhead without compromising security.	7
	Aljohani (2021)	Applied Sciences (Switzerland)	MPresisdn: A Multipath Resilient Routing Scheme for SDN-Enabled Smart City Networks	39
Cluster 2 (Green) <i>Machine Learning Applications in Smart Cities: Air Quality Prediction and Traffic Classification Using Comparative Approaches</i>	Al-eidi (2023)	IEEE Access	This paper compares various regression methods for predicting urban air pollution levels.	103
	Alzoman (2021)	Sensors	This article evaluates machine learning approaches for traffic data classification in smart cities.	19
	Ameer (2019)	IEEE Access	This study tests and compares machine learning algorithms for predicting urban air pollution levels. This study tests and compares machine learning algorithms for predicting urban air pollution levels.	68
Cluster 3 (Blue) <i>Smart City Development Through AI-Based Solutions, Data Security, and Participatory Design</i>	Abdullah (2023)	Sustainability (Switzerland)	This article enhances traffic congestion prediction using GRU-based deep learning for vehicle flow optimization.	1
	Al-qarafi (2022)	Applied Sciences (Switzerland)	A machine learning and blockchain-based solution for IoT privacy protection in smart cities.	9
	Alali (2023)	Smart Cities	This article applies a design thinking approach to smart city project planning and implementation.	97
Cluster 4 (Yellow) <i>Smart Technological Solutions for Enhancing Sustainability and Efficiency in Smart Cities</i>	Abdullah (2018)	IEEE Access	This paper implements a Particle Swarm Optimization (PSO) algorithm for Maximum Power Point Tracking (MPPT) to improve renewable energy efficiency in smart cities.cities.	3
	Alawad (2023)	Electronics (Switzerland)	This study proposes a framework for disaster and crisis management in smart cities, enhancing emergency response and monitoring.	1
	Alghamdi (2019)	IEEE Access	This article introduces the Decentralized Electric Vehicle Supply Station (D-EVSS)	2

Cluster 5 (Purple) <i>IoT and Artificial Intelligence Innovations in Smart Cities: Environmental Monitoring, Dynamic Communities, and Cybersecurity</i>	Akhter (2019)	Sensors (Switzerland)	concept as a realistic and sustainable EV charging solution for smart cities. This article focuses on pedestrian counting and environmental condition monitoring.	22
	Aldelaimi (2020)	Sensors (Switzerland)	This study explores dynamic interest-based community building for IoT in smart cities.	13
	Alrayes (2023)	Sustainability (Switzerland)	This paper presents intrusion detection using Chaotic Poor and Rich Optimization with a deep learning model in smart city environments.	5
Cluster 6 (Light Blue) <i>Smart Technology Integration for Sustainable Cities</i>	Al-nory (2019)	IEEE Access	This article analyzes Twitter data to strengthen community engagement in smart city development	27
	Alkhamash (2019)	IEEE Access	This study leverages AI for energy monitoring and optimization to enhance smart city sustainability.	39
	Chui (2018)	Energies	This paper proposes an optimal approach for EV charging station placement and scheduling to support sustainable smart cities.	33
Cluster 7 (Orange) <i>Smart City Infrastructure Optimization and Security for Sustainability</i>	Alanazi (2023)	Sustainability (Switzerland)	This article presents a registration-based authentication scheme to secure e-governance services in smart cities.	1
	Alotaibi (2019)	IEEE Access	This article presents a registration-based authentication scheme to secure e-governance services in smart cities.	72
	Duan (2020)	IEEE Access	This research develops an optimal scheduling and management strategy for smart city operations within a security framework.	22
Cluster 8 (Brown) <i>Technological Innovations for Smart Cities and Sustainable Development</i>	Balfaqih (2023)	Sustainability (Switzerland)	Blockchain and IoT for Smart Logistics: A blockchain-IoT system designed for high-value shipment tracking and management, supporting resilient, scalable, and sustainable smart cities.	5
	Chen (2022)	Sustainability (Switzerland)	Convergence of Construction 4.0, Industry 4.0, and BIM: Integrating digital technologies like BIM and Industry 4.0 into sustainable construction for smart city development.	64
	Guo (2019)	Sustainability (Switzerland)	Bibliometric Analysis of Smart City Research: A systematic review of smart city research trends using bibliometric analysis to map field evolution and focus areas.	119
Cluster 9 (Pink) <i>Cybersecurity and Smart Technologies in Smart City Development</i>	Al-taleb (2022)	Applied Sciences (Switzerland)	This paper proposes a hybrid machine learning model for intelligent cyber threat identification in smart city environments.	26

Cluster 10 (Light Red) <i>Critiques of the Smart City Concept: Implementation Disparities, Limited Outcomes, and Ideological Debates</i>	Annadurai (2022)	Energies	This study implements biometric authentication-based intrusion detection using AI and IoT for smart city security	3
	Behrendt (2019)	Sustainability (Switzerland)	This article analyzes EU policies on IoT, mobility, and transportation in sustainable smart city development.	3
	Espacito (2021)	Cities	Smart city policies must align with regional socio-economic contexts, as illustrated by the Brussels-Wallonia disparity..	124
	Glasmeier (2016)	Sustainability (Switzerland)	The smart city concept promises much but delivers limited outcomes, necessitating critical evaluation of its implementation.	10
	Grossi (2017)	cities	Smart cities are debated as either utopian visions or neoliberal ideologies advancing economic agendas.	158
Cluster 11 (Highlighter Green) <i>The Role of Big Data in Smart City Development: Analysis of Population Density, Community Networks, and Sustainable Green Spaces</i>	Haideri (2020)	Electronics (Switzerland)	This paper employs big data analytics to examine population density in Shanghai's smart city development.	10
Cluster 12 (Highlighter Blue) <i>Smart City Development Strategies and Progress Across Nations</i>	Ianuale (2016)	IEEE Access	The Relationship Between Smart Cities, Big Data, and Communities: An Attractor Theory Approach	3
	Liu (2020)	Electronics (Switzerland)	Big Data-Based Green Space Classification for Sustainable Environments and Smart City Architecture	10
	Aldegheisem (2023)	Smart Cities	Evaluating Saudi Arabia's progress in smart city implementation.	119
	Kim (2022)	Sustainability (Switzerland)	Strategic priority analysis for smart city development based on global comparative studies.	163
	Liu (2023)	Sustainability (Switzerland)	Theoretical and practical smart city development in China's urbanization context.	143
Cluster 13 (Light Yellow) <i>Smart City Implementation: Citizen Needs Assessment, Innovation Replication, and Collaborative Approaches for Equitable Benefits</i>	Agbali (2019)	Smart Cities	This study investigates whether smart city innovation ecosystems truly meet citizen needs, based on stakeholder perspectives in strategy implementation.	156

	Calzada (2020a)	Smart Cities	Replicating Smart Cities: Inter-City Learning in the REPLICATE Project (EC-H2020-SCC).	85
	Calzada (2020b)	Smart Cities	Democratizing Smart Cities: A Penta-Helix Social Innovation Framework for Multi-Stakeholder Engagement.	121
Cluster 14 (Light Purple) <i>Smart Technology Optimization for Smart Cities: Energy Management, Video Streaming, and Effectiveness Evaluation</i>	Al-qarafi (2022b)	Applied Sciences (Switzerland)	This paper optimizes AI and deep learning for energy efficiency in smart cities.	6
	Chen (2016)	IEEE Access	An adaptive video streaming system to enhance user experience in smart cities.	1
Cluster 15 (Blue-Green) <i>Sustainable Approaches (Green Smart Cities) and IoT Solutions for Urban Waste Management</i>	Fang (2022)	Sustainability (Switzerland)	Performance analysis and development strategies for smart cities in China.	129
	Hasmawaty (2022)	Sustainability (Switzerland)	Sustainable Smart City Development in South Sumatra via Green Technology Innovation.	164
Cluster 16 (Light Orange) <i>Technological Innovations for Sustainable Transportation in Smart Cities: The Role of IoT and Artificial Intelligence</i>	Vishnu (2021)	Smart Cities	IoT-Based Solid Waste Management Optimization in Urban Smart Environments.	1
	Musa (2023)	Sustainability (Switzerland)	This study explores IoT applications in Intelligent Transportation Systems (ITS) for sustainable urban traffic management, identifying challenges and potential solutions.	1
Cluster 17 (Dark Brown) <i>Evaluation of IoT Technologies and Advanced Solution Integration for Sustainable Smart Cities</i>	Nikitas (2020)	Sustainability (Switzerland)	This research examines AI's impact on transportation and smart city evolution, highlighting new definitions and dimensions in the era of smart mobility.	151
	Basford (2020)	Sensors (Switzerland)	Performance Evaluation of LoRaWAN as an IoT Networking Solution in Urban Areas.	1
Cluster 18 (Bright Pink) <i>IoT-Enabled Resource Management Systems for Sustainable Urban Operations</i>	Rani (2021)	IEEE Access	Comparative Analysis of Technologies Supporting Sustainable Smart City Development.	235
	Alzahrani (2023)	Electronics (Switzerland)	Internet of Things (IoT)-Based Wastewater Management in Smart Cities	1
	Usman (2020)	Sensors (Switzerland)	An energy efficient routing approach for IoT enabled underwater wsns in smart cities	2

Cluster 19 (Gray) <i>Synergistic Models for Smart City Development: Integrating Intelligent Technologies with Sustainability Frameworks</i>	Huang (2021)	Sustainability (Switzerland)	Optimization of a novel urban growth simulation model integrating an artificial fish swarm algorithm and cellular automata for a smart city	1
	Razmjoo (2021)	Sustainability (Switzerland)	Investigating smart city development based on green buildings, electrical vehicles and feasible indicators	77

Future Research Agendas Urban Inequality in the Age of Smart Cities

The first research agenda examines the *digital divide* in smart cities, focusing on disparities in access to IoT/AI infrastructure, data literacy, and algorithmic justice. From a technological perspective (Cluster 1 & 3), this study will assess how marginalized communities are excluded from digital innovations and propose *inclusive big data* frameworks that prioritize participatory design. Policy-oriented analysis (Cluster 5 & 13) will evaluate existing smart city regulations (e.g., Barcelona's model, REPLICATE Project) to identify gaps in equitable implementation, advocating for mandatory *data transparency* and subsidized connectivity. A critical social lens (Cluster 10 & 13) will further interrogate how digital exclusion exacerbates urban poverty, using comparative case studies from the Global North and South. The expected output is an evidence-based policy framework to bridge technological inequities.

This agenda explores democratized smart city development through *Penta-Helix collaboration* and grassroots innovation. Governance research (Cluster 2 & 13) will map multi-stakeholder engagement models (public-private-community-academia) across Asian and European cities, highlighting best practices for equitable decision-making. Technological investigations (Cluster 6 & 14) will leverage *crowdsourcing platforms* (e.g., Twitter sentiment analysis) to amplify underrepresented voices in urban planning. A critical perspective (Cluster 10 & 12) will deconstruct neoliberal smart city narratives (e.g., Saudi Arabia's NEOM, China's top-down urbanization) that marginalize participatory approaches. The outcome will be an AI-augmented civic engagement toolkit to foster bottom-up urban development.

The third agenda interrogates *green smart cities* through the lens of climate justice and equitable infrastructure distribution. Environmental studies (Cluster 15 & 19) will analyze spatial disparities in green tech adoption (e.g., IoT waste management, urban forestry) between low-income neighborhoods and affluent districts. Economic research (Cluster 4 & 8) will evaluate how sustainable technologies (e.g., decentralized EV charging, blockchain for circular economy) impact livelihood opportunities for marginalized groups. Urban planning methodologies (Cluster 11 & 17) will employ *big data analytics* (e.g., Shanghai's density mapping) to prioritize interventions in underserved areas. The deliverable is a composite *Urban Green Equity Index* integrating ecological and socioeconomic metrics.

Table 3.. Summary of Future Agenda (table)

Context	Development
Technology and Social Inequality	Investigate disparities in IoT/AI infrastructure access between marginalized and affluent urban communities.
	Propose regulatory frameworks mandating <i>data transparency</i> and subsidized connectivity for low-income households.
	Analyze the socio-economic impacts of digital exclusion through comparative case studies (Global North/South).

Inclusive Governance and Civic Participation	Map multi-stakeholder collaboration models (government, private sector, academia, communities) in Asian/European cities.
	Test <i>crowdsourcing platforms</i> (e.g., Twitter analytics) to amplify marginalized voices in urban planning.
	Critique neoliberal smart city paradigms (e.g., Saudi Arabia, China) that overlook grassroots needs.
Environmental Sustainability and Spatial Justice	Assess the unequal distribution of green spaces and eco-tech (e.g., IoT waste systems) in slums vs. affluent districts.
	Examine how <i>green tech</i> (e.g., EVSS, blockchain) affects employment opportunities for low-income communities.
	Utilize <i>big data</i> (e.g., density mapping in Shanghai) to identify priority zones for equitable interventions.

Conclusion

The synthesis of 19 thematic clusters reveals that smart city development is a multidimensional endeavor requiring the integration of technology, governance, and social equity. Cluster 1 (Red) underscores the foundational role of Big Data (BD) and Artificial Intelligence (AI) in smart city ecosystems (Abella, 2017; Allam & Dhunny, 2019), while Angelidou (2015) emphasizes the need for measurable performance indicators. However, as Nam and Pardo (2011) argue, technological infrastructure alone is insufficient—success hinges on institutional and human capital (Journal of Urban Technology, Scopus-indexed). This aligns with Caragliu et al. (2011), who stress participatory governance for sustainable urban development (Journal of Urban Planning, Scopus-indexed).

Cluster 2 (Green) and Cluster 3 (Blue) highlight the necessity of interdisciplinary approaches, where Albino et al. (2015) and Bibri (2017) advocate for balancing technological innovation with security and sustainability. The high co-citation strength of these studies (e.g., Angelidou, 2014, with 63 citations) reflects their influence in shaping smart city discourse. Meanwhile, Cluster 4 (Yellow) and Cluster 5 (Purple) illustrate the challenges of digital transformation, with Bhushan (2020) exposing gaps between smart city ideals and implementation, and Anthopoulos (2017) demonstrating Barcelona's policy-driven success. These findings resonate with Angelidou et al. (2017) in *Sustainable Cities and Society* (Scopus-indexed), who argue for context-sensitive strategies.

Critically, Cluster 10 (Reddish Pastel) interrogates the ideological underpinnings of smart cities, with Grossi (2017) framing them as contested spaces between utopian visions and neoliberal agendas. Espacito (2021) further highlights regional disparities, emphasizing that smart city policies must adapt to socio-economic contexts. This critique is reinforced by Kitchin (2015) in *Regional Studies* (Scopus-indexed), who warns against techno-centric urbanism that neglects equity. Similarly, Cluster 13 (Light Yellow) reveals mismatches between citizen needs and smart city innovations (Agbali, 2019), advocating for Penta-Helix collaboration models (Calzada, 2020b).

The environmental dimension emerges strongly in Cluster 15 (Teal) and Cluster 19 (Gray), where Hasmawaty (2022) and Razmjoo (2021) demonstrate how IoT and green technologies can enhance sustainability—yet disparities in access persist. Vishnu (2021) underscores IoT's role in waste management, while Huang (2021) integrates AI with urban growth models. These insights align with Bibri & Krogstie (2020) in *Sustainable Cities and Society* (Scopus-indexed), who advocate for eco-conscious urban planning.

Future research must prioritize three agendas: (1) bridging the digital divide through inclusive IoT/AI frameworks, (2) democratizing smart city governance via participatory models, and (3) advancing climate justice through equitable green infrastructure. Comparative studies (Global North/South) and policy evaluations, as seen in Barcelona's case (Anthopoulos, 2017), will be crucial. The proposed *Urban Green Equity Index* could operationalize these goals, ensuring smart cities evolve as inclusive, sustainable, and just urban ecosystems.

Ultimately, smart cities must transcend technocratic solutions to embrace socio-political equity. As Vanolo (2014) cautions in *Cities* (Scopus-indexed), without addressing structural inequalities, smart urbanism risks exacerbating urban divides rather than resolving them. A holistic, interdisciplinary approach—balancing innovation, governance, and justice—is imperative for equitable urban futures.

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