

The Evolution of Smart Green Cities Research: A Global Bibliometric Analysis of Knowledge Structures, Emerging Themes, and Future Directions

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Abstract

The growing convergence of digital transformation and sustainability agendas has accelerated scholarly interest in smart green cities as a strategic model for sustainable urban development. However, a comprehensive understanding of the intellectual structure, thematic evolution, and global research trends in this field remains limited. This study aims to map the development of smart green cities research through a bibliometric analysis of 672 Scopus-indexed publications published between 2003 and 2025. Using the Bibliometrix package in R, the study examines publication trends, leading sources, country contributions, collaboration patterns, and thematic structures. The findings reveal a substantial increase in research output since 2016, with rapid growth after 2020, reflecting the increasing importance of sustainability-driven urban transformation. Sustainable development, smart city, and urban planning emerge as dominant foundational themes, while digital technologies, including artificial intelligence, the Internet of Things, and big data, represent emerging research frontiers. This study provides a comprehensive knowledge map that supports future research and evidence-based policymaking for smart and sustainable urban development.

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1. Introduction

Rapid urbanization, climate change, environmental degradation, and increasing energy demand have intensified the need for more sustainable and intelligent urban development models. In response to these challenges, the concept of the smart city has emerged as a strategic approach that integrates information and communication technologies (ICTs) into urban governance to improve service efficiency, resource management, and citizens' quality of life while promoting environmental sustainability (Caragliu et al., 2011). Over the last decade, smart city research has evolved beyond a

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technology-centered perspective and increasingly incorporates social, economic, environmental, and governance dimensions. Albino et al. (2015) emphasize that smart cities should be viewed as multidimensional systems that integrate interconnected social, economic, and ecological components. Similarly, Neirotti et al. (2014) argue that the global implementation of smart city initiatives has expanded significantly in areas such as mobility, governance, and environmental management, although challenges remain in aligning technological innovation with sustainability objectives.

Chen et al. (2024) emphasis on sustainability has led to the emergence of the smart green city paradigm, which combines digital innovation with environmental stewardship and sustainable urban development. Previous studies have highlighted the importance of integrating smart city and sustainable city concepts to achieve long-term urban resilience and environmental performance. Ahvenniemi et al. (2017) identified significant conceptual differences between smart cities and sustainable cities, arguing that technological advancement alone does not automatically result in sustainable urban outcomes. In contrast, Bibri and Krogstie (2020) and Shao and Min (2025) suggest that the successful realization of smart sustainable cities requires the integration of digital technologies, sustainability principles, and data-driven governance systems.

Recent empirical evidence further demonstrates the contribution of smart city initiatives to sustainable urban transformation. Cui et al. (2025) found that smart city development significantly promotes green development, while Yang and Yang (2025) reported that smart city policies contribute to carbon emission reduction and low-carbon regional growth. Likewise, Jiang and Sun (2025) show that smart city construction positively influences urban green development through improvements in environmental quality, economic growth, and resource efficiency. These findings indicate that smart cities function not only as digital transformation projects but also as strategic mechanisms for achieving broader sustainability goals.

Technological innovations such as the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and intelligent monitoring systems have become essential enablers of smart green city development. He et al. (2022), Ball et al. (2024), Kasem et al. (2025), and Kozar et al. (2025) demonstrate that these technologies enhance energy efficiency, environmental monitoring, waste management optimization, and sustainable resource allocation. Furthermore, Filiou et al. (2023) show that the interaction between environmental policies and digital technologies stimulates green innovation and eco-friendly urban transformation. Consequently, the convergence of sustainability and digitalization has become a central theme within contemporary urban development research.

Given the rapid expansion of this research field, bibliometric analysis has become an increasingly valuable method for systematically mapping scientific knowledge and identifying emerging research trends. Donthu et al. (2020; 2021) argue that bibliometric techniques provide robust tools for examining publication patterns, intellectual structures, collaboration networks, and thematic developments within a research domain. The use of the Scopus database further strengthens the reliability of bibliometric investigations due to its comprehensive multidisciplinary coverage and rigorous indexing standards (Ram, 2020; Majid et al., 2015; Borgohain et al., 2022).

Although studies examining smart cities, sustainability, and green urban development continue to increase, a comprehensive bibliometric assessment focusing specifically on smart green cities remains limited. Existing studies generally focus on technological applications, sustainable urban development, or smart city governance independently, while integrated analyses of publication dynamics, thematic evolution, international collaboration, and intellectual structures remain scarce. This gap (see Table 1) highlights the need for a comprehensive scientific mapping of smart green city research.

Accordingly, this study aims to analyze the evolution of smart green city research through a comprehensive bibliometric analysis of 672 Scopus-indexed documents published between 2003 and 2025. Specifically, the study investigates publication trends, leading sources, country contributions, collaboration patterns, thematic structures, and emerging research themes. By providing a systematic

knowledge map of the field, this research contributes to the growing literature on smart green cities and offers valuable insights for academics, policymakers, and urban planners seeking to advance sustainable and technology-driven urban development.

Table 1. Research Gap and Contribution of the Study

Previous Studies	Focus	Limitation
Ahvenniemi et al. (2017)	Smart vs Sustainable Cities	Conceptual comparison only
He et al. (2022)	IoT and Green Smart Cities	Technology-oriented review
Santoso et al. (2024)	Smart City Research in Indonesia	National scope
Kaiser & Deb (2025)	Smart Cities and SDGs	Narrative review
Current Study	Smart Green Cities Research Landscape	Global bibliometric mapping, thematic evolution, collaboration patterns, and knowledge structure

Source: Developed by the authors

2. Literature Review

Smart Cities and Sustainable Urban Development

The concept of the smart city has emerged as one of the most influential paradigms in contemporary urban studies, driven by the increasing complexity of urbanization, environmental degradation, resource scarcity, and growing demands for efficient public services. Initially, smart cities were primarily associated with the application of information and communication technologies (ICTs) to improve urban management and service delivery. However, the concept has evolved substantially over the last decade, extending beyond technological infrastructure to encompass social, economic, environmental, and governance dimensions.

Caragliu et al. (2011) define a smart city as an urban area that strategically utilizes investments in human capital, social capital, and information technology to achieve sustainable economic growth and improve quality of life. This perspective emphasizes that technological advancement alone is insufficient to create a truly smart city. Instead, smart urban development requires the integration of innovation, governance, environmental sustainability, and citizen participation.

Albino et al. (2015) further argue that smart cities should be understood as multidimensional systems that integrate economic competitiveness, environmental quality, social inclusion, and technological innovation. Similarly, Neirotti et al. (2014) identify six major dimensions of smart city implementation, including smart governance, smart mobility, smart environment, smart economy, smart living, and smart people. These dimensions highlight the interconnected nature of urban sustainability challenges and demonstrate the need for integrated urban management approaches.

As sustainability concerns became increasingly prominent, scholars began questioning whether technologically advanced cities automatically contribute to sustainable development outcomes. Ahvenniemi et al. (2017) found significant conceptual differences between smart cities and sustainable cities, arguing that many smart city initiatives remain heavily focused on technological efficiency while paying insufficient attention to environmental and social sustainability objectives. Consequently, the integration of smart city principles and sustainability frameworks has become a major research agenda within urban studies.

The relationship between smart city development and sustainable urban transformation has gained considerable attention in recent years. Bibri and Krogstie (2020) emphasize that future urban development requires the convergence of digital technologies, environmental sustainability, and data-

driven governance. Likewise, Shao and Min (2025) propose that sustainable smart cities should be built upon integrated frameworks that combine technological innovation, ecological protection, economic resilience, and social well-being.

Recent empirical evidence supports the argument that smart city initiatives can significantly contribute to sustainable urban development. Cui et al. (2025) demonstrate that smart city development promotes green growth through improvements in resource allocation efficiency and environmental management. Similarly, Yang and Yang (2025) show that smart city pilot policies contribute to regional low-carbon development and carbon emission reduction. Jiang and Sun (2025) further reveal that smart city construction positively influences urban green development by enhancing environmental quality and supporting sustainable economic growth. These findings collectively suggest that smart cities increasingly function as strategic instruments for achieving long-term sustainability objectives rather than merely serving as digital modernization projects.

Smart Green Cities: Integrating Technology and Sustainability

The growing convergence between digital transformation and sustainability agendas has led to the emergence of the smart green city concept. Smart green cities represent an advanced urban development model that integrates smart technologies with environmental sustainability strategies to improve ecological performance, resource efficiency, and urban resilience.

Unlike traditional smart city approaches that often prioritize technological innovation, smart green cities explicitly emphasize environmental objectives, including climate change mitigation, energy efficiency, green infrastructure development, waste reduction, and sustainable resource management. This integrated approach reflects the increasing recognition that urban sustainability challenges cannot be addressed through technology alone but require the simultaneous consideration of environmental and social dimensions.

A growing body of literature highlights the strategic role of digital technologies in facilitating sustainable urban transformation. He et al. (2022) demonstrate that the Internet of Things (IoT) plays a crucial role in improving environmental monitoring, optimizing resource utilization, and enhancing urban energy efficiency. Similarly, Ball et al. (2024) argue that IoT-based systems enable real-time environmental management and support sustainable energy transitions through intelligent monitoring and control mechanisms.

The importance of digital innovation is further emphasized by Filiou et al. (2023), who find that cities characterized by strong environmental regulations and advanced digital infrastructures exhibit higher levels of eco-innovation. Their findings suggest that technological innovation and environmental governance operate synergistically in supporting sustainable urban development.

Recent studies also highlight the transformative potential of artificial intelligence, big data analytics, and intelligent sensing technologies within smart green city ecosystems. Kasem et al. (2025) show that advanced technological systems contribute significantly to optimizing waste management processes, reducing environmental impacts, and accelerating progress toward the Sustainable Development Goals (SDGs). Similarly, Kozar et al. (2025) emphasize the growing role of Green Internet of Things technologies in supporting sustainable urban management and enhancing environmental performance.

The integration of multidimensional sensing networks further strengthens the smart green city framework. Lai (2025) demonstrates that intelligent sensing systems can improve green energy utilization, optimize energy allocation, and reduce urban carbon emissions. Supporting these findings, Wu et al. (2024) reveal that smart city policies significantly improve urban green energy efficiency through smart grids and IoT-based energy management systems.

In addition to improving energy efficiency, smart technologies contribute to broader ecological outcomes. Hui et al. (2023) find that integrating digital technologies with urban natural resources

enhances ecological resilience and environmental sustainability. Likewise, Wang (2023) demonstrates that smart city development contributes directly to urban greening and strengthens cities' carbon mitigation capacities. These findings reinforce the notion that smart green cities represent a holistic framework that integrates ecological sustainability with digital innovation.

Bibliometric Analysis in Smart Green City Research

As scientific knowledge expands rapidly, bibliometric analysis has become an increasingly important methodological approach for understanding research evolution, intellectual structures, and emerging scientific trends. Bibliometrics enables researchers to quantitatively examine publication outputs, citation relationships, collaboration networks, thematic developments, and knowledge diffusion patterns.

Donthu et al. (2020) emphasize that bibliometric techniques provide valuable insights into the intellectual foundations and development trajectories of scientific disciplines. Furthermore, Donthu et al. (2021) propose comprehensive methodological guidelines for conducting bibliometric studies, highlighting their usefulness in identifying influential authors, leading journals, collaboration networks, and emerging research themes.

The reliability of bibliometric analysis depends heavily on the quality and comprehensiveness of the underlying database. In this regard, the Scopus database is widely recognized as one of the most comprehensive and reliable sources for bibliometric research. Ram (2020) argues that Scopus offers extensive multidisciplinary coverage and provides robust citation indexing capabilities. Similarly, Majid et al. (2015) and Borgohain et al. (2022) highlight the advantages of Scopus in supporting large-scale scientific mapping and trend analysis across diverse research domains.

Within the smart city literature, bibliometric studies have become increasingly common. Santoso et al. (2024) conducted a bibliometric analysis of smart city research in Indonesia and found that existing studies remain concentrated on information technology, governance, and sustainability themes. However, their analysis was limited to the Indonesian context and did not comprehensively examine the global evolution of smart green city research.

Similarly, He et al. (2022) reviewed research related to IoT and green smart cities but primarily focused on technological applications rather than broader intellectual structures and thematic evolution. Kaiser and Deb (2025) examined the relationship between smart cities and the Sustainable Development Goals (SDGs), yet their study employed a narrative review approach rather than a systematic bibliometric methodology.

These limitations indicate that a comprehensive bibliometric investigation specifically focused on smart green cities remains limited. Existing studies often examine individual dimensions such as technology adoption, sustainability outcomes, or urban governance independently. Relatively few studies provide an integrated assessment of publication dynamics, collaboration networks, thematic evolution, and intellectual structures within the smart green city research domain.

3. Methodology

Research Design

This study employs a bibliometric analysis approach to systematically examine the development, intellectual structure, and thematic evolution of smart green city research. Bibliometric analysis has become an increasingly important methodological tool for mapping scientific knowledge because it enables researchers to quantitatively evaluate publication patterns, citation structures, research collaborations, and thematic developments within a specific field of study. According to Donthu et al.

(2020), bibliometric methods provide a rigorous framework for identifying influential publications, emerging themes, and knowledge structures across scientific disciplines. Furthermore, Donthu et al. (2021) emphasize that bibliometric analysis offers a transparent and reproducible approach for synthesizing large volumes of scientific literature and uncovering research trends that may not be apparent through traditional literature reviews.

The present study adopts a descriptive and exploratory bibliometric design to investigate the evolution of smart green city research. Specifically, the analysis focuses on publication growth, source productivity, geographical distribution, collaboration networks, and thematic structures within the scientific literature. The objective is to provide a comprehensive overview of the intellectual landscape of smart green cities and identify emerging directions for future research.

Data Source and Search Strategy

The bibliographic data used in this study were retrieved from the Scopus database, which is widely recognized as one of the most comprehensive and reliable sources for bibliometric investigations. Scopus offers extensive multidisciplinary coverage, rigorous indexing standards, and robust citation tracking capabilities, making it particularly suitable for large-scale scientific mapping studies (Ram, 2020; Majid et al., 2015; Borgohain et al., 2022).

Data collection was conducted in November 2025 using the search query employed in the original study: TITLE-ABS-KEY ("Smart Green City") AND TITLE-ABS-KEY ("Sustainability")

The search was limited to documents indexed in Scopus between 2003 and 2025 and included all document types relevant to the research topic. The initial search yielded 672 documents, which constituted the final dataset analyzed in this study. The selected documents represent the global scientific literature addressing the intersection of smart green city development and sustainability.

Data Screening and Selection Procedure

To ensure transparency and reproducibility, the study follows a structured document selection process adapted from bibliometric review procedures commonly applied in sustainability and urban studies research. After the retrieval process, documents were screened based on their relevance to the smart green city and sustainability domains.

Figure 1. Research Selection Procedure

Identification

Records retrieved from Scopus
(n = 672)

Screening

Documents examined based on
title, abstract, and keywords
Eligibility

Relevant publications related
to smart green cities and
sustainability
Included

Final dataset
(n = 672)

Source: Developed by the authors

The resulting dataset was subsequently exported in BibTeX format for further processing and analysis using bibliometric software tools. This procedure ensures consistency and facilitates the generation of reproducible analytical outputs.

Data Analysis Tools

The study utilizes the Bibliometrix package in R as the primary analytical tool. Bibliometrix is a widely adopted open-source software package designed for quantitative bibliometric analysis and scientific mapping. According to Donthu et al. (2021), Bibliometrix provides comprehensive functionalities for examining publication trends, author productivity, source impact, thematic structures, collaboration networks, and conceptual evolution.

The analytical procedures were conducted using the Biblioshiny interface, which facilitates visual exploration and interpretation of bibliometric indicators. The software enables the generation of publication trend analyses, country productivity maps, thematic maps, word clouds, treemaps, and collaboration networks. These visualizations provide a comprehensive understanding of the development and structure of smart green city research.

Bibliometric Indicators and Analytical Framework

To achieve the objectives of the study, several bibliometric indicators were employed (see Table 2). These indicators are commonly used in bibliometric investigations to evaluate scientific performance and knowledge development.

Table 2. Bibliometric Indicators Applied in the Study

Indicator	Purpose
Annual Scientific Production	Examines publication growth over time
Most Relevant Sources	Identifies leading journals in the field
Country Scientific Production	Maps geographical distribution of research
Collaboration Analysis	Evaluates international research partnerships
Keyword Analysis	Identifies dominant research themes
Thematic Map	Examines thematic maturity and development
Word Cloud Analysis	Visualizes frequently occurring concepts
Treemap Analysis	Illustrates thematic concentration patterns

Source: Developed by the authors

The annual scientific production analysis was conducted to examine publication growth patterns and identify periods of accelerated scholarly interest. Source analysis was used to determine the most influential journals contributing to smart green city research. Country productivity analysis was performed to evaluate global research participation and geographical distribution patterns.

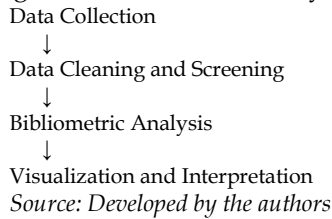
Furthermore, keyword-based analyses were conducted to identify dominant research themes and emerging topics. Thematic mapping techniques were employed to classify themes according to their centrality and density, thereby providing insights into thematic maturity and development trajectories. Word cloud and treemap visualizations were also generated to support the interpretation of conceptual structures within the field.

Analytical Workflow

During the first stage (see Figure 2), bibliographic records were retrieved from the Scopus database using the predefined search strategy. The second stage involved screening and organizing the retrieved documents. The third stage consisted of conducting bibliometric analyses using Bibliometrix and Biblioshiny. Finally, the results were visualized and interpreted to identify publication trends, thematic structures, collaboration patterns, and emerging research directions.

The analytical workflow adopted in this study consists of four sequential stages:

Figure 2. Bibliometric Analysis Workflow



Research Reliability and Validity

The reliability of this study is supported by three methodological considerations. First, the use of the Scopus database ensures high-quality bibliographic data due to its extensive coverage of peer-reviewed international publications. Second, the application of standardized search procedures enhances the reproducibility of the research process. Third, the utilization of Bibliometrix, which is widely recognized in bibliometric scholarship, strengthens the consistency and transparency of analytical outcomes (Donthu et al., 2020; Donthu et al., 2021).

By combining a comprehensive dataset, systematic analytical procedures, and established bibliometric techniques, this study provides a robust assessment of the evolution, intellectual structure, and emerging directions of smart green city research. The methodological framework offers a reliable foundation for understanding knowledge development within this rapidly expanding field and supports evidence-based recommendations for future research and policy formulation.

4. Results

Overview of Scientific Production

The bibliometric analysis was conducted using a dataset comprising 672 Scopus-indexed publications related to smart green cities and sustainability published between 2003 and 2025 (see Table 3). The dataset reflects the growing academic interest in the integration of digital technologies and sustainable urban development.

Table 3. Main Information About the Dataset

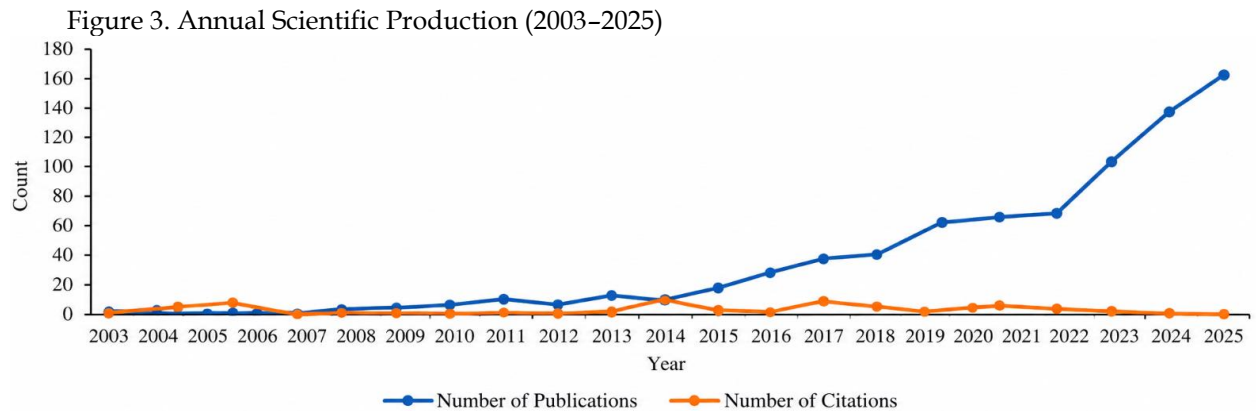
Description	Value
Database	Scopus
Study Period	2003–2025
Total Documents	672
Research Topic	Smart Green Cities and Sustainability
Analysis Tool	Bibliometrix (R)
Document Type	Scopus-indexed publications

Source: Developed by the authors

The dataset indicates that smart green city research has evolved into an increasingly important area of inquiry, particularly in response to global sustainability challenges and technological transformation in urban environments.

Annual Scientific Production

One of the most notable findings concerns the growth of scientific publications over time (see Figure 3). The annual production analysis reveals a relatively limited number of publications during the early years of the observation period, followed by a substantial increase after 2016 and accelerated growth after 2020.

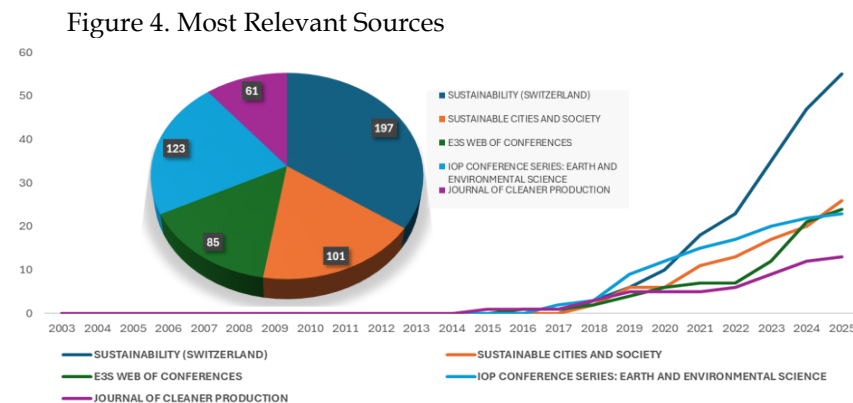


Source: Developed by the authors

The publication trend demonstrates three major phases. The first phase (2003–2010) was characterized by limited scholarly attention. The second phase (2011–2019) witnessed gradual growth associated with increasing interest in smart city development and sustainability transitions. The third phase (2020–2025) experienced rapid expansion, reflecting the growing importance of digital technologies, climate change mitigation, sustainable urban governance, and green innovation within urban studies.

Most Relevant Sources

The analysis of publication sources identifies the journals that have contributed most significantly to the development of smart green city research (see Figure 4).



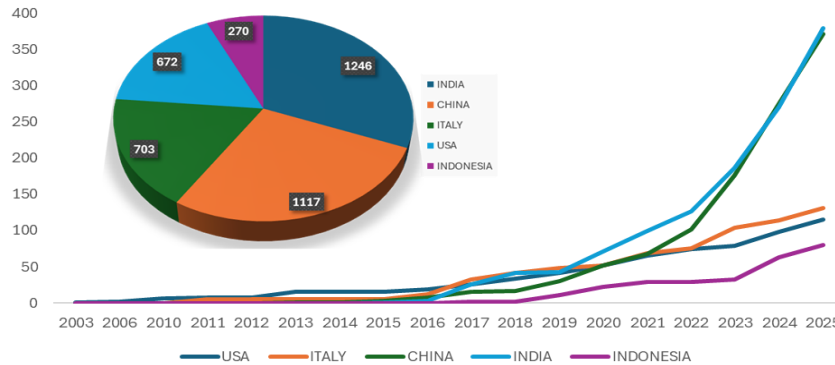
Source: Developed by the authors

The distribution of publications across journals demonstrates the interdisciplinary nature of smart green city research, encompassing sustainability science, urban studies, environmental management, and technological innovation.

Country Scientific Production

Country-level analysis reveals substantial differences in research productivity among nations (see Figure 5).

Figure 5. Country Scientific Production



Source: Developed by the authors

The results indicate that China emerges as the most productive country in the smart green city literature, followed by several countries with strong research capacities in sustainability and urban innovation. The geographical distribution highlights the global expansion of research activity while also revealing the concentration of scientific output within countries actively implementing smart city and sustainability policies.

Keyword Analysis

Keyword analysis provides insights into the conceptual structure of the research field and identifies the most frequently discussed topics (see Figure 6).

Figure 6. Word Cloud of Author Keywords



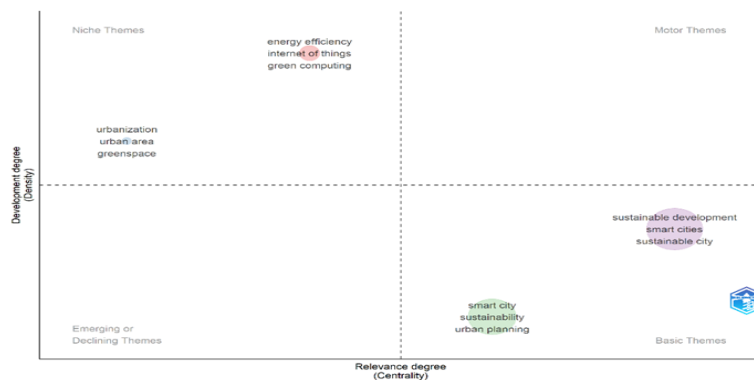
Source: Developed by the authors

The word cloud reveals the dominance of several recurring concepts, including Smart city, Sustainability, Sustainable development, Urban planning, green development, Digital transformation. These keywords illustrate the close relationship between technological innovation and sustainable urban development within the contemporary literature.

Thematic Structure of Smart Green City Research

To examine the conceptual organization of the field, thematic mapping was performed using keyword co-occurrence patterns (see Figure 7).

Figure 7. Thematic Map



Source: Developed by the authors

The thematic map identifies several dominant research clusters. Sustainability, smart cities, and urban planning appear as central themes within the knowledge structure. In addition, emerging themes are associated with digital technologies such as artificial intelligence, big data, and Internet of Things applications that support sustainable urban management.

The distribution of themes suggests that smart green city research increasingly incorporates multidisciplinary perspectives that combine technological innovation, environmental sustainability, and governance considerations.

Treemap Analysis

Treemap visualization was conducted to examine the relative prominence of thematic categories within the literature (see Figure 8). The treemap confirms that sustainability-related concepts occupy the largest thematic area within the field. Smart city development, sustainable urban planning, environmental management, and technological innovation also represent major components of the research landscape. The visualization further demonstrates the diversification of research interests and the increasing integration of environmental and technological dimensions.

Emerging Research Directions

The bibliometric findings reveal a gradual transition from conventional smart city discussions toward more integrated smart green city frameworks. Emerging research topics increasingly emphasize: Artificial intelligence for urban sustainability; Internet of Things applications in environmental management; Smart energy systems and renewable energy integration; Carbon reduction strategies and climate resilience; Data-driven urban governance. These themes indicate the

growing importance of digital technologies as enablers of sustainable urban transformation and suggest expanding opportunities for future interdisciplinary research.

Figure 8. Treemap of Research Themes



Source: Developed by the authors

5. Discussion

The findings reveal a substantial expansion of smart green city research over the period 2003–2025, reflecting the growing convergence between digital transformation and sustainability agendas in urban development. The sharp increase in publication output after 2020 indicates that smart green cities have evolved from a niche research topic into a prominent interdisciplinary field. This trend is closely associated with increasing global concerns regarding climate change, urban resilience, carbon neutrality, and sustainable urban governance. The results support the argument of Bibri and Krogstie (2020) that future urban development increasingly requires the integration of advanced digital technologies with sustainability objectives to address complex urban challenges.

The dominance of sustainability, smart city, and sustainable development keywords demonstrates that the intellectual foundation of the field is no longer centered solely on technological innovation. Instead, the literature increasingly conceptualizes smart green cities as integrated socio-technical systems designed to balance economic growth, environmental protection, and social well-being. This finding is consistent with Albino et al. (2015), who argue that smart cities should be understood as multidimensional systems encompassing technological, environmental, social, and governance dimensions. Similarly, Ahvenniemi et al. (2017) emphasize that sustainable urban outcomes cannot be achieved solely through digitalization but require explicit integration of sustainability principles into urban planning and management processes.

The thematic structure identified in the analysis further demonstrates an important shift in research orientation. However, Liu et al. (2023) found early studies largely focused on technological infrastructure, ICT implementation, and urban digitalization. However, recent themes increasingly emphasize environmental sustainability, green development, carbon reduction, renewable energy integration, and climate resilience. This evolution suggests a transition from a technology-oriented paradigm toward a sustainability-oriented paradigm and, more recently, toward an integrated smart green city paradigm. Such a transformation reflects the broader recognition that urban sustainability challenges require holistic solutions that combine technological innovation, environmental stewardship, and adaptive governance mechanisms.

The emergence of artificial intelligence, Internet of Things (IoT), big data analytics, and intelligent sensing systems as prominent research themes further illustrates the technological sophistication of contemporary smart green city initiatives. Previous studies have shown that these technologies enhance

urban environmental monitoring, energy efficiency, waste management, and resource allocation optimization (He et al., 2022; Ball et al., 2024; Kasem et al., 2025; Kozar et al., 2025). The present findings confirm that digital technologies increasingly function as enabling mechanisms for sustainable urban transformation rather than as isolated technological solutions. This observation supports the view of Filiou et al. (2023) that the interaction between environmental governance and digital innovation generates significant opportunities for green innovation and sustainable urban development.

Another notable finding concerns the geographical distribution of scientific production. The results identify China as the leading contributor to smart green city research. This dominance may be associated with the country's extensive investments in smart city initiatives, rapid urbanization processes, large-scale digital infrastructure development, and long-term sustainability commitments. China's leadership in the field reflects broader national strategies aimed at promoting green growth, carbon neutrality, and digital transformation. Similar patterns have been observed in previous studies examining smart city development and sustainable urban innovation. The concentration of research output within a limited number of countries also suggests disparities in research capacity and technological readiness among regions, highlighting opportunities for broader international collaboration and knowledge exchange.

The results also indicate that smart green city research is becoming increasingly interdisciplinary. Publications are distributed across journals specializing in sustainability, urban studies, environmental management, technological innovation, and public policy. This interdisciplinary character demonstrates that smart green city development cannot be adequately understood through a single disciplinary lens. Instead, effective urban transformation requires collaboration among urban planners, environmental scientists, engineers, policymakers, economists, and information technology specialists. The increasing integration of these disciplines contributes to the emergence of a more comprehensive knowledge structure capable of addressing complex urban sustainability challenges.

From a theoretical perspective, the findings suggest an evolutionary framework for understanding smart green city research. The literature appears to have progressed through three major stages. The first stage focused primarily on urban digitalization and ICT adoption. The second stage expanded toward sustainable urban development and environmental management. The third and current stage integrates digital technologies, sustainability objectives, and governance innovations within a unified smart green city framework. This evolution contributes to the growing body of knowledge by demonstrating how smart city research has matured from a technology-centric perspective into a broader socio-ecological-technological paradigm.

Overall, the findings reveal that smart green city research has developed into a dynamic and rapidly expanding field characterized by increasing thematic diversification, technological sophistication, and sustainability orientation. The identified trends provide valuable insights into the intellectual development of the field and highlight emerging research frontiers that are likely to shape future scholarly inquiry and urban policy agendas.

Policy Implications and Recommendations

The findings have important implications for policymakers, urban planners, and public administrators seeking to promote sustainable urban transformation. First, smart city initiatives should move beyond a narrow focus on technological modernization and incorporate broader sustainability objectives, including environmental protection, resource efficiency, climate resilience, and social inclusiveness. The strong association between smart city development and sustainability themes identified in this study suggests that integrated planning approaches are essential for achieving long-term urban sustainability.

Second, governments should strengthen investments in enabling digital technologies such as artificial intelligence, IoT, big data analytics, and intelligent monitoring systems. These technologies have emerged as important drivers of green urban development and can support evidence-based decision-making, efficient resource management, and environmental monitoring. Third, policymakers should encourage cross-sectoral collaboration among government agencies, academic institutions, private enterprises, and local communities to facilitate knowledge exchange and innovation diffusion. Finally, international cooperation should be expanded to reduce disparities in research capacity and accelerate the global adoption of smart green city practices. Such collaborative efforts can contribute to achieving broader sustainability targets, including the Sustainable Development Goals (SDGs) and long-term carbon neutrality commitments.

6. Conclusion

This study provides a comprehensive bibliometric assessment of smart green city research based on 672 Scopus-indexed publications published between 2003 and 2025. The findings reveal a significant increase in scientific output over the last two decades, particularly after 2020, indicating growing academic interest in the integration of digital technologies and sustainability within urban development. The bibliometric evidence demonstrates that smart green city research has evolved into a multidisciplinary field that encompasses sustainability, urban planning, environmental management, governance, and technological innovation.

The analysis identifies sustainability, smart city, and sustainable development as the dominant themes shaping the intellectual structure of the field. Furthermore, emerging topics such as artificial intelligence, Internet of Things (IoT), big data analytics, smart energy systems, and carbon reduction strategies indicate a gradual shift toward more integrated approaches to sustainable urban transformation. The results also highlight the significant contribution of China and other leading research nations in advancing knowledge production within the smart green city domain. These findings suggest that contemporary smart city initiatives increasingly function as mechanisms for achieving environmental sustainability and long-term urban resilience rather than solely promoting technological modernization.

From a theoretical perspective, the study demonstrates the evolution of smart green city research from a technology-oriented paradigm toward a broader socio-ecological-technological framework that integrates digital innovation, environmental sustainability, and urban governance. This contribution enriches the growing body of knowledge on sustainable urban development and provides a systematic understanding of the field's intellectual and thematic evolution.

Despite its contributions, this study is limited to publications indexed in the Scopus database and therefore may not capture relevant studies from other sources. Future research should expand data coverage by incorporating multiple databases, applying advanced bibliometric techniques such as co-citation and bibliographic coupling analyses, and examining the relationship between smart green city initiatives and emerging sustainability agendas, including climate neutrality, circular economy practices, and Sustainable Development Goals (SDGs).

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