



# Artificial Intelligence Research in Smart Cities: A Bibliometric Analysis

## Akıllı Şehirlerde Yapay Zeka Araştırmaları: Bibliyometrik Bir İnceleme

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### ABSTRACT

This study presents a comprehensive bibliometric analysis examining the applications of artificial intelligence (AI) in smart cities in terms of global research trends, thematic evolution, and future directions. Based on the analysis of 810 publications from the Web of Science (WoS) database covering the period 2004-2025, the study maps the intellectual structure of the field through co-citation, co-authorship, and keyword co-occurrence networks using VOSviewer software, and conducts thematic content analysis of the most influential publications. The findings reveal the application areas of AI in smart cities under six main headings: smart cities, AI and machine learning, internet of things, management, data security and blockchain, environmental sustainability, and digital twins for urban planning. Publication trends indicate a rapid increase in research outputs between 2019 and 2024, while data for 2025 reflect only partial-year publication activity and are therefore interpreted cautiously. "Smart city", "AI", "machine learning", and "internet of things" are among the most frequently encountered keywords. The study identifies critical challenges such as the need for standard data protocols, ethical AI governance, and interdisciplinary collaboration for scalable and equitable urban solutions. The results highlight the transformative potential of AI in smart city development, while highlighting the importance of balanced approaches that integrate technological innovation with societal and environmental elements. This research serves as an essential reference for policymakers, local governments, urban planners, and researchers working at the intersection of AI and smart urban systems.

**Keywords:** Smart cities, Artificial intelligence, Machine learning, Internet of things, Bibliometric analysis

### ÖZ

Bu çalışma, yapay zekanın (YZ) akıllı şehirlerdeki uygulamalarını küresel araştırma eğilimleri, tematik evrim ve gelecek yönelimler açısından inceleyen kapsamlı bir bibliyometrik analiz sunmaktadır. Web of Science (WoS) veri tabanından 2004-2025 dönemini kapsayan 810 yayının analizine dayanan çalışmada, VOSviewer yazılımı kullanılarak ortak atıf, ortak yazarlık ve anahtar kelime eş-oluşum ağlarıyla alanın entelektüel yapısı haritalanmış ve en etkili yayınların tematik içerik analizi yapılmıştır. Bulgular, YZ'nin akıllı şehirlerdeki uygulama alanlarını altı ana başlıkta ortaya koymaktadır: akıllı şehirler, YZ ve makine öğrenmesi, nesnelerin interneti, yönetimi, veri güvenliği ve blockchain, çevresel sürdürülebilirlik ile kentsel planlama için dijital ikizler. Yayın eğilimleri, 2019 ile 2024 yılları arasında araştırma çıktılarında hızlı bir artış olduğunu gösterirken, 2025 verileri yalnızca kısmi yıl yayın faaliyetini yansıtmaktadır ve bu nedenle ihtiyatlı bir şekilde yorumlanmalıdır. "Akıllı şehir", "yapay zeka", "makine öğrenmesi" ve "nesnelerin interneti" en sık karşılaşılan anahtar kelimeler arasındadır. Çalışma, ölçeklenebilir ve adil kentsel çözümler için standart veri protokolleri, etik YZ yönetimi ve disiplinlerarası iş birliği ihtiyacı gibi kritik zorlukları tanımlamaktadır. Sonuçlar, YZ'nin akıllı şehir gelişimindeki dönüştürücü potansiyelini vurgularken, teknolojik yeniliği toplumsal ve çevresel unsurlarla bütünleştiren dengeli yaklaşımların önemine dikkat çekmektedir. Bu araştırma, YZ ve akıllı kentsel sistemler kesiminde çalışan politikacılar, yerel yönetimler, şehir plancıları ve araştırmacılar için temel bir referans niteliği taşımaktadır.

**Anahtar Kelimeler:** Akıllı şehirler, Yapay zeka, Nesnelerin interneti, Makine öğrenimi, Bibliyometrik analiz

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## INTRODUCTION

Smart cities are technology-driven urban transformation projects that have emerged to provide solutions to the global challenges of the 21st century, such as rapid urbanization, population growth, and resource scarcity (Kumar et al., 2018). These cities aim to increase resource efficiency, strengthen citizen participation, and improve quality of life by integrating Fourth Industrial Revolution technologies such as the Internet of Things (IoT), AI, and big data analytics (Allam & Dhunny, 2019). AI plays a transformative role in the planning, management, and operational processes of smart cities (Yigitcanlar et al., 2019).

The technological infrastructure that forms the basis of smart cities optimizes urban services with real-time data collection and analysis capabilities. IoT-based sensor networks increase efficiency in systems such as traffic management, energy distribution, and waste management (Zanella et al., 2014). For example, machine learning algorithms can reduce traffic congestion by 30% using historical and real-time data (Bibri & Krogstie, 2021), and AI-supported smart grids provide savings of up to 15-20% by analysing energy consumption patterns (Avci, 2024). These technologies play a critical role in cities achieving their sustainable development goals.

From a sustainability perspective, smart cities aim to reduce carbon footprint and build inclusive societies in line with the United Nations Sustainable Development Goals (SDGs) (United Nations Human Settlements Programme [UN-Habitat], 2020). Smart water management systems can reduce water losses by 25% (Rathore et al., 2016), while digital participation platforms increase transparency and accountability by involving citizens in decision-making processes (Angelidou et al., 2018). However, with the proliferation of these technologies, new problems such as data security and the digital divide also emerge (Kitchin, 2019).

As the theoretical background suggests, the role of AI in smart cities needs to be supported by bibliometric data. For this purpose, studies conducted in recent years in the literature will be analysed and some of the studies that have made significant contributions to the field are as follows:

The comprehensive study by Szpilko et al. (2023) covering 3101 publications was a significant milestone in the field. The study systematically classified seven main application areas of AI (security, life, energy, mobility, health, pollution and industry). Innovative applications—such as autonomous vehicles (AVs), electric vehicles (EVs), and unmanned aerial vehicles (UAVs)—have emerged as prominent features in the field of urban mobility.

The systematic literature review conducted by Haque et al. (2023) examined the theoretical foundations of the smart city-AI symbiosis and presented an interdisciplinary perspective. This study has made significant contributions to urban AI development processes.

Camocho et al. (2024) have examined in detail the impact of AI on energy systems in smart cities. The study has revealed the critical role of AI applications, especially in areas such as renewable energy resource allocation, predictive maintenance processes, anomaly detection, and grid stabilization.

Alsabt et al. (2024) examined the effects of AI on urban quality of life with a multidisciplinary approach. The study analysed in detail five main impact areas (public services and connectivity, accessibility and efficiency, health services, education and public safety).

Fan et al.'s (2025) analysis of 745 articles focused on the balance between technology integration and privacy protection. The study highlighted the importance of ethical standards and robust governance frameworks in urban security systems.

A comprehensive analysis of 2758 articles by Regalado-Pezua and Christofle (2025) revealed trends in the sustainable smart city's literature. The study particularly highlighted the research leadership of China and India in this field and the importance of sustainability.

Mongo and Daidj (2025) examined the role of digital twin technologies in sustainable smart cities along four key dimensions: key features, sustainability definitions, engineering challenges, societal impacts.

Sharifi et al. (2025) analysed the alignment of metaverse technologies with the Sustainable Development Goals (SDGs). The study highlighted potential benefits, particularly in the areas of health and education, while noting the need for further research on issues such as climate change and inequalities.

Kumari et al. (2025) conducted a comprehensive thematic mapping study to identify leading researchers, institutions, and countries in the field. The study highlighted the leadership of institutions such as King Abdulaziz University, Queensland University of Technology, and San Jose State University, and contributions from countries such as Saudi Arabia, the United States, China, the United Kingdom, and India.

Recent studies have increasingly examined the role of artificial intelligence and machine learning in smart city development, employing both empirical and bibliometric approaches (Srihith et al., 2022; Alahakoon et al., 2023; Karger et al., 2025; Alaeddini et al., 2023).

## 1. METHODOLOGY

### 1.1. Purpose of the Research

In this study, a bibliometric analysis was conducted on March 31, 2024, in the WoS database to understand the impact of AI in smart cities between 2004 and 2025. The study is expected to contribute to the field and provide a conceptual basis for future research. Given the exploratory and descriptive nature of bibliometric analysis, this study is guided by research questions rather than hypothesis testing.

The study seeks answers to the questions below.

1. What is the distribution of articles on AI in smart city design in WoS by year and their types of publications?
2. What is the distribution of citations to articles in WoS on AI studies in smart cities by year?
3. Who are the authors who published Co-Author Analysis on AI studies in smart cities?
4. What is the Citation Analysis of Authors who publish on AI studies in smart cities?
5. What is the Citation Analysis of Countries that publish on AI studies in smart cities?
6. What is the Keyword Analysis of publications in AI studies in smart cities?
7. How is the Bibliographic Matching Analysis of Texts in AI studies in smart cities?
8. What is the Bibliographic Matching Analysis of Authors publishing on AI studies in smart cities?
9. What is the Co-Citation Analysis of Authors who publish on AI studies in smart cities?

10. What themes were obtained because of the content analysis of the 50 most cited articles?

## 2. Methodology

### 2.2. Research Method

This research uses bibliometric analysis and content analysis methods in an integrated manner to reveal scientific trends regarding AI applications in smart cities. The data source of the study consists of academic publications indexed in WoS database. Bibliometric analysis is a method that enables the quantitative evaluation of scientific publications (Pritchard, 1969). In this study, basic analyses were performed using VOSviewer software (Van Eck & Waltman, 2010) in the bibliometric analysis process: co-citation analysis (Small, 1973), co-authorship analysis (Glänzel & Schubert, 2003) and keyword co-occurrence analysis (Callon, Courtial & Laville, 1991).

Content analysis refers to the process of systematically categorizing and interpreting qualitative data (Krippendorff, 2013). In this study, content analysis was conducted in two stages: thematic coding (Braun & Clarke, 2006) and conceptual mapping (Novak & Cañas, 2008). A qualitative content analysis was conducted to identify the main research themes. Author keywords and abstracts were manually coded using Microsoft Excel. The coding process followed three stages: (1) initial open coding of keywords, (2) grouping similar codes into conceptual categories, and (3) abstraction of higher-level themes. The coding was performed by a single researcher; therefore, inter-coder reliability analysis was not applicable. To mitigate potential subjectivity, the coding process involved multiple iterative rounds, constant comparison across themes, and cross-checking with keyword co-occurrence results obtained from VOSviewer, thereby enhancing internal consistency and analytical rigor. To enhance consistency, iterative recoding was applied.

In the research, bibliometric analysis method was used for studies on AI in smart cities. For this purpose, the WoS database was found on 31.04.2025. The search was made with the words ("smart cities" or "urban cities" or "smart city") (Title) AND ("ChatGPT", or "LLM" or "Genai" or "ai" or "AI") (Topic) (LIMIT-TO (LANGUAGE,"English")) " and 810 results were obtained. The keywords "ChatGPT", "LLM" and "Genai" were added to the search to understand the effects of generative AI. The data set was checked for repetitive studies. The data were retrieved from the Web of Science database on March 31, 2025. As a result, publications indexed for the year 2025 represent a partial dataset rather than a complete publication year. Therefore, records from 2025 were included to reflect emerging trends; however, they were not treated as a full-year indicator in longitudinal trend interpretations. The oldest study was 2004, while the newest was determined as 2025. The results obtained were downloaded to the computer in a format that could be processed with the analysis program, and the determined analyzes were applied with the VOSviewer 1.6.20 analysis program and graphics were obtained. For co-authorship, co-citation, bibliographic coupling, and keyword co-occurrence networks, the association strength normalization method was applied. Clustering was performed using the VOS clustering technique, with the resolution parameter set to 1.00. Minimum thresholds were defined as follows: at least one publications and one citations for author-based analyses, and at least three occurrences for keyword co-occurrence analysis. These threshold values were deliberately set at low levels to ensure the inclusion of emerging authors and newly developing research themes, while still maintaining network readability. Higher thresholds were tested during preliminary analyses; however, they resulted in fragmented networks and the exclusion of recent but influential studies. Therefore, the selected thresholds represent a balance between inclusiveness and interpretability. These parameters were selected to ensure network interpretability, reduce noise, and enhance the clarity of thematic structures.

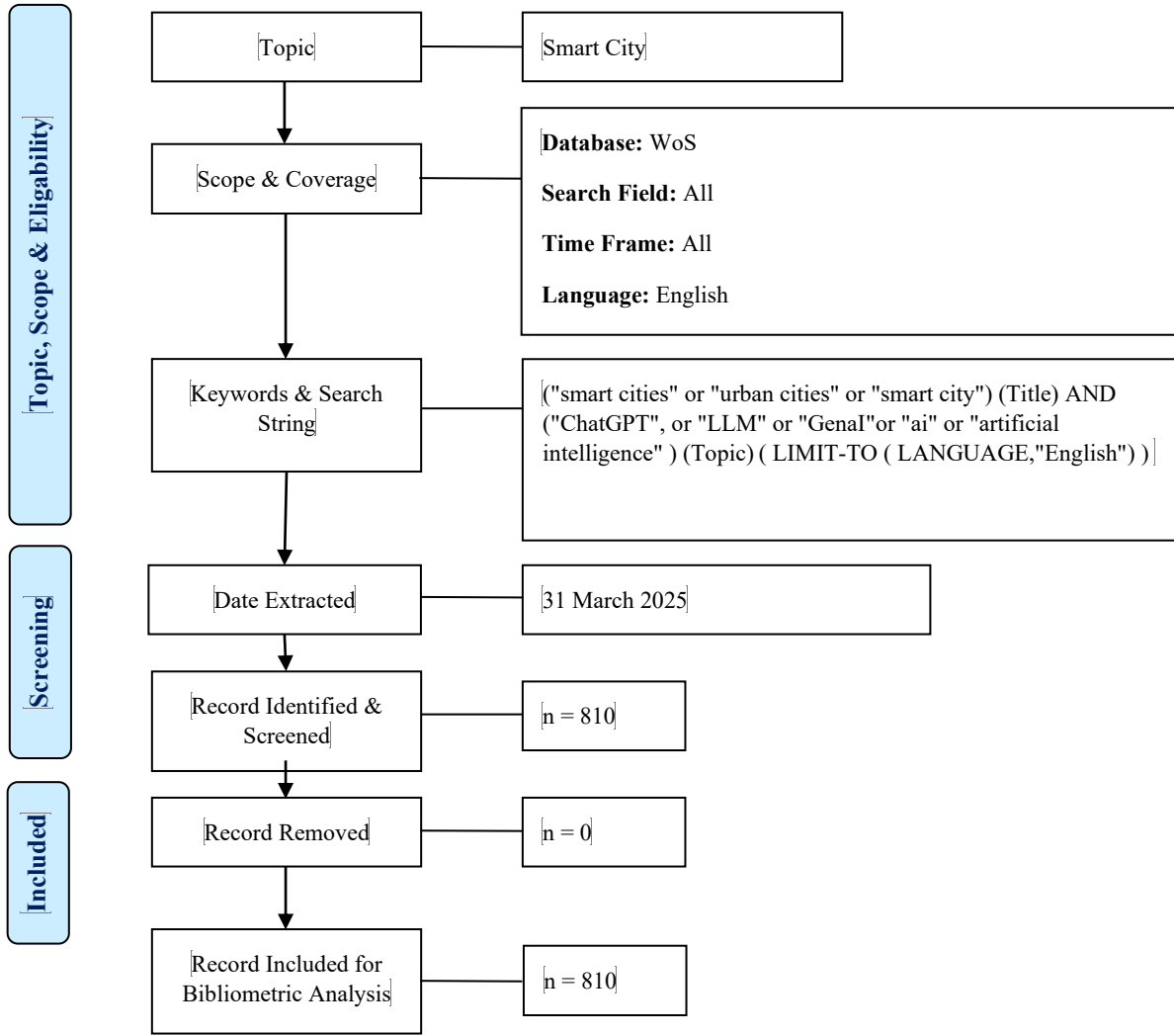


Figure 1: Flow diagram of the search strategy

Figure 1 shows the stages of the bibliometric analysis conducted for this study. In the first stage, data was extracted from the WoS database using the given keywords, and in the second stage, it was loaded into the analysis program VOSviewer and predetermined analyses were performed. Subsequently, content analysis was performed using the Excel program to determine the themes. In the last stage, trends and themes were determined and discussion and conclusion sections were created.

### 3. Findings

All network-based analyses presented in this section were conducted using VOSviewer, applying consistent normalization, clustering, and threshold parameters as described in the Methodology section to ensure analytical coherence across results.

#### 3.1. Distribution by year and types of publications

In the WoS database, there are 810 published studies on AI in smart cities spanning from 2004 to 2025. It was determined that these publications were written by 2815 authors. In AI studies in smart cities There are 1405 institutions and 92 countries. Smart cities are the work of AI It was found that it was published in 87 different journals.

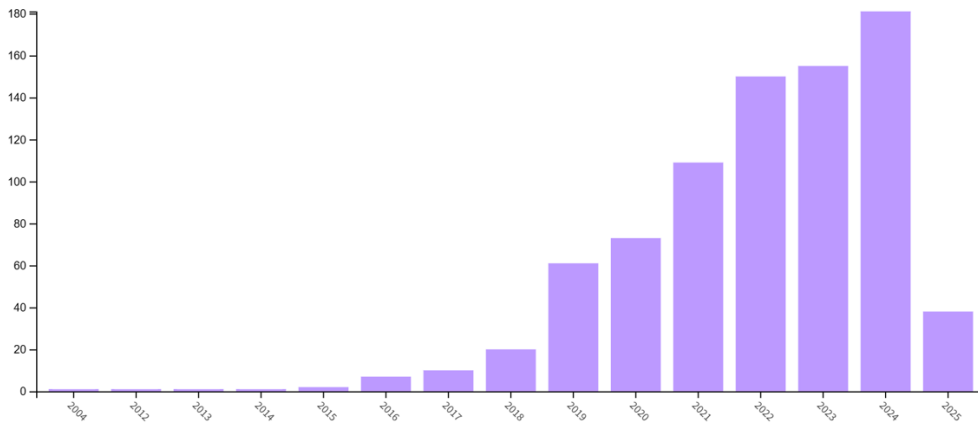


Figure 2. Number of publications by year (WoS, 2025)

When Figure 2 is examined, a significant increase is seen in the number of publications as of 2019, compared to the few publications as of 2004. This increase indicates that research on AI in smart cities experienced emerging pattern particularly between 2019 and 2024. It is seen that the number of publications increased in the following years and reached the highest value of 181 in 2024. Although Figure 2 shows up to 2024 increase in the number of publications for 2025, it should be noted that the data for this year are incomplete, as they cover only the first quarter of the year. Therefore, the observed values for 2025 should be interpreted cautiously and should not be considered indicative of the full annual publication output. Although publication records for 2025 are included to capture emerging research directions, they represent only the first quarter of the year and should not be interpreted as evidence of a full-year trend.

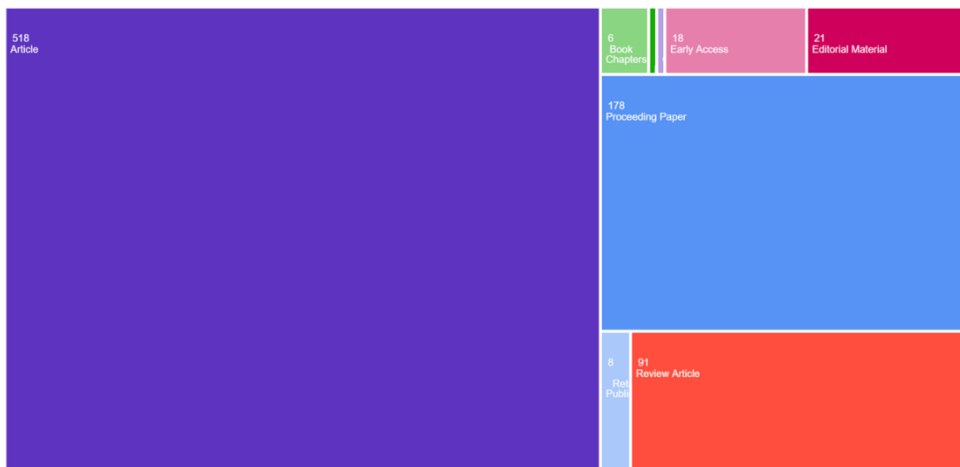


Figure 3. Publication types (WoS, 2025)

When we examine the publication types in Figure 3, it was determined that there were 518 articles, 144 papers, 91 compilation articles, 18 early appearances, 8 retracted publications, 6 book chapters, and 1 book review. We see that these were SCI-Expanded 421, conference proceedings CPCI-S 178, ESCI 165, SSCI 123, CPCI-SSH 16, A&HCI 3, and BKCI-SSH 3. When we look at the top five countries in which the authors published in Figure 4; China comes in with 192, India with 121, USA with 98 publications, Saudi Arabia with 94, and Australia with 58 publications.

Select All <input type="checkbox"/>	Field: Countries/Regions	Record Count	% of 810
<input type="checkbox"/>	PEOPLES R CHINA	192	23.704%
<input type="checkbox"/>	INDIA	121	14.938%
<input type="checkbox"/>	USA	98	12.099%
<input type="checkbox"/>	SAUDI ARABIA	94	11.605%
<input type="checkbox"/>	AUSTRALIA	58	7.160%
<input type="checkbox"/>	SOUTH KOREA	53	6.543%
<input type="checkbox"/>	ENGLAND	52	6.420%
<input type="checkbox"/>	ITALY	40	4.938%
<input type="checkbox"/>	CANADA	37	4.568%
<input type="checkbox"/>	SPAIN	32	3.951%

Figure 4. Number of publications by country (WoS, 2025)

When we examine the WoS category fields of the publications; Engineering Electrical Electronic 244, Computer science information systems 220, Telecommunications 152, Computer science AI 117, computer science theory methods 109, green sustainable science technology 100, computer science interdisciplinary applications 85, environmental studies 75, urban studies 74 and environmental sciences 71 studies are seen. It has been revealed that the majority are in the fields of engineering and computer science.

### 3.2. Number of citations by year

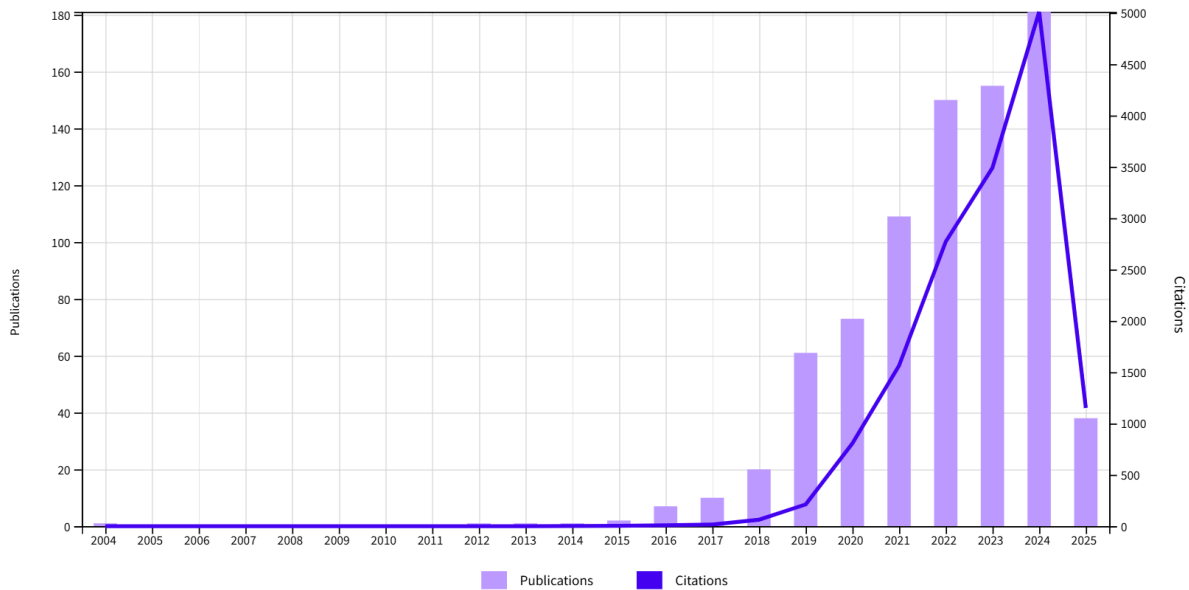


Figure 6. Number of citations by year (WoS, 2025)

When the number of citations is examined by year in Figure 6, the number of citations, which was 212 in 2019, reached 805, almost four times in 2020. The number of citations reached 1563 in 2021, 2771 in 2022, 3490 in 2023, and 5009 in 2024. Citation momentum observed up to 2024 indicates a rapid increase in scholarly attention, while citation data for 2025 remain preliminary due to partial-year coverage. This situation is more clearly demonstrated with the graph obtained from the analysis. Similarly, citation counts for 2025 are based on partial-year data and may not fully reflect the cumulative citation impact for the entire year.

Table 1 shows the ten most cited publications. The article titled *“On Big Data, AI, and Smart Cities”* by Z. Allam & Z.A. Dhunny has received a total of 479 citations, making it the most cited work in this field. Following this, *“Applications of AI and Machine Learning in Smart Cities”* has garnered 319 citations, while *“Enabling Technologies and Sustainable Smart Cities”* has received 277 citations, ranking them among the top three most cited articles.

Table 1. Most cited publications (WoS, 2025)

No	Publication year	Name of the Study	Authors	Total number of citations
1	2019	On big data, AI and smart cities	Allam & Dhunny, 2019	479
2	2020	Applications of AI and Machine learning in smart cities	Ullah et al.,2020	319
3	2020	Enabling technologies and sustainable smart cities	Ahad et al.,2020	277
4	2020	Convergence of blockchain and AI in IoT network for the sustainable smart city	Singh et al.,2020	257
5	2021	A systematic review of a digital twin city: A new pattern of urban governance toward smart cities	Deng et al.,2021	242
6	2022	Future smart cities requirements, emerging technologies, applications, challenges, and future aspects	Javed at al.,2022	237
7	2019	A Comparative Study of PSO-ANN, GA-ANN, ICA-ANN, and ABC-ANN in Estimating the Heating Load of Buildings' Energy Efficiency for Smart City Planning	Le et al.,2019	232
8	2020	On the Coronavirus (COVID-19) Outbreak and the Smart City Network: Universal Data Sharing Standards Coupled with AI (AI) to Benefit Urban Health Monitoring and Management	Allam & Jones, 2020	223
9	2022	The Metaverse as a Virtual Form of Smart Cities: Opportunities and Challenges for Environmental, Economic, and Social Sustainability in Urban Futures	Allam et al.,2022	208

10	2019	Survey on Collaborative Smart Drones and Internet of Things for Improving Smartness of Smart Cities	Alsamhi et al.,2019	206
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### 3.3. Co-authorship of Authors

By applying the criteria of at least one publication and one citation, a network map was constructed to identify the most interconnected and collaborative authors. The analysis revealed that the network consists of nine clusters, with a total of 293 connections and an overall connection length of 310.

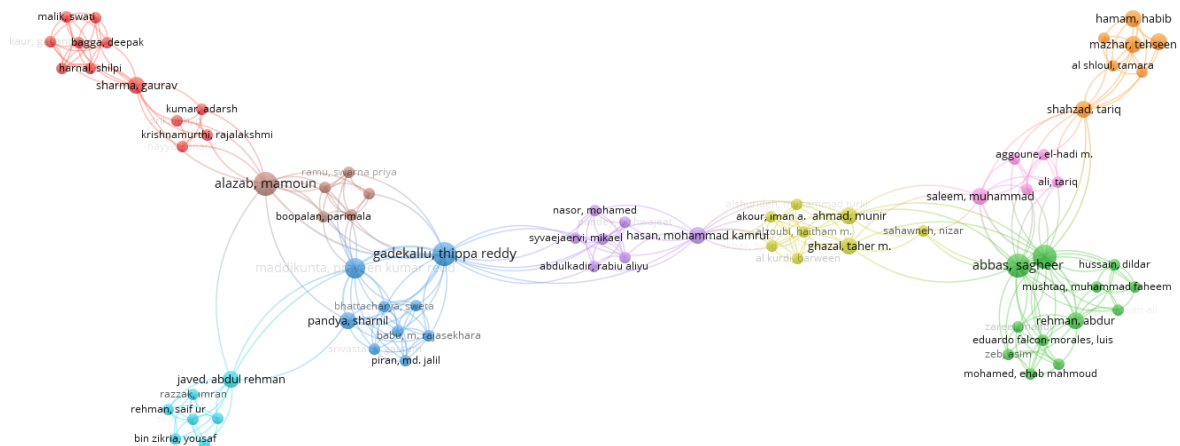


Figure 7. Co-authorship of Authors (VOSviewer, 2025)

Using co-authorship analysis conducted in VOSviewer, a network map was generated to identify collaborative structures among authors. According to Figure 7, the most cited name in the given clusters is Zaher Allam, who has 9 publications and 1158 citations. Fadi Al-Turjman is in second place with 4 publications and 453 citations. Simon Elias Bibri also has 9 publications and 450 citations. However, when we look at the connection strength, Thippa Reddy Gadekallu is the strongest author in the blue cluster with 4 publications and 293 citations. Then comes Sagher Abbas with 4 publications, 136 citations, Muhammad Adnan Khan with 4 publications and 136 citations in the green cluster. However, it is seen that the person with the most publications is not the most connected person.

### 3.4. Citation Analysis of Authors

To identify citation networks, a network map was constructed for author citation analysis using the criteria of at least one publication and one citation. Analysis of 980 interconnected units revealed a total of 35 clusters, 6,685 connections, and an overall connection strength of 6,967.



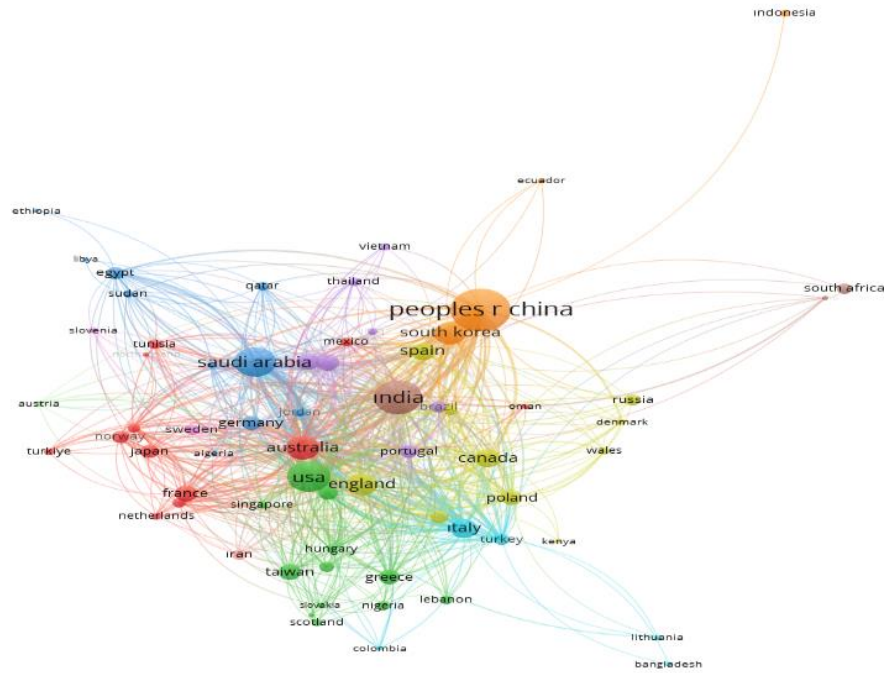


Figure 9. Citation Analysis of Countries (VOSviewer, 2025)

A country-level citation analysis was performed using VOSviewer to identify geographically distributed patterns of scholarly influence in the field. According to Figure 9, the countries with the most citations are China (3353 citations), Australia (2679 citations), USA (2606 citations) and India (2421 citations). These countries are in the top four in terms of total link strength. However, the total link strength rankings are Australia (341), China (301), USA (298) and Saudi Arabia (276). In terms of the number of works, the top five countries are China (192 publications), India (121 publications), USA (98 publications), Australia (58 publications), Saudi Arabia (94 publications) and England (27 publications). These patterns indicate citation concentration rather than national research superiority and may be influenced by publication volume and database coverage.

### 3.6. Keyword Analysis (Co-occurrence of Author Keywords)

Based on the analysis of 209 observation units that appeared at least three times and exhibited interrelationships, a total of 16 clusters, 1,905 connections, and an overall connection strength of 3,665 were identified.



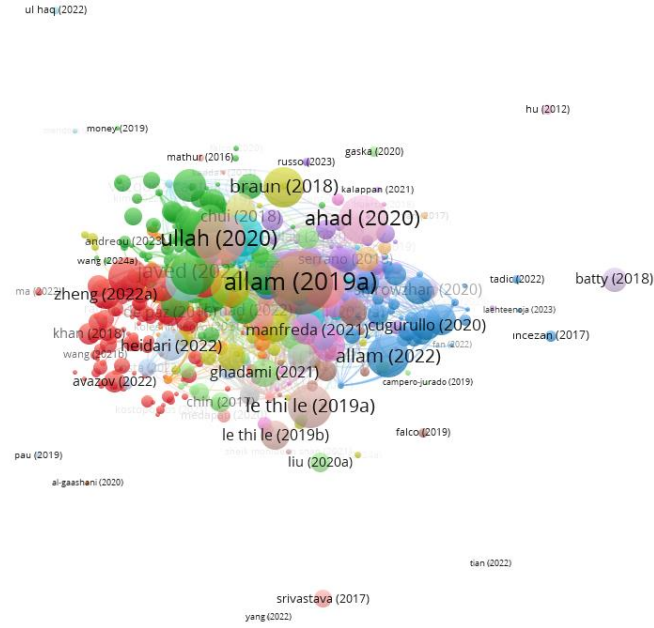


Figure 11. Bibliographic Coupling Analysis of Documents (VOSviewer, 2025)

Bibliographic coupling analysis was applied to identify documents that share common references, thereby revealing structural similarities among recent publications. According to Figure 11, the publications with the highest number of bibliographic matches are Allam (2019a) with 476 citations, Ullah et al. (2020) with 319 citations, Ahad (2020) with 277 citations, Singh et al. (2020) with 257 citations, and Deng et al. (2021) with 242 citations. When we examine in terms of total link strength, Rani (2021) with 37 citations, Sharifi et al. (2025) with 54 citations, Talebkah et al. (2023) with 6 citations, and Zhao (2019) with 63 citations. Here, the high number of citations does not mean that the link strength will be high. Since bibliographic coupling is particularly sensitive to contemporary research, this analysis highlights emerging thematic alignments in the literature.

### 3.8. Co-citation of Cited authors

Different sources cited within a publication are referred to as co-citations. Based on an analysis of 382 units with a minimum of 10 citations, a total of 7 clusters, 27,536 connections, and an overall connection strength of 71,788 were identified.

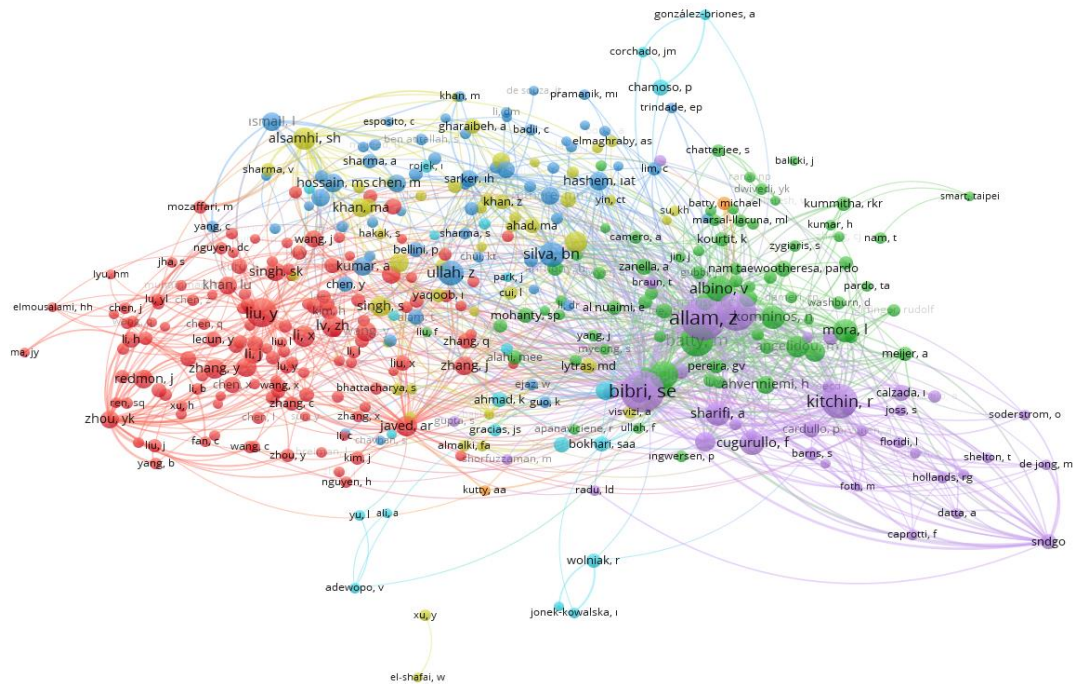


Figure 12. Co-citation Analysis of Co-authors (VOSviewer, 2025)

Co-citation analysis was conducted to examine how frequently pairs of documents are cited together, thereby revealing the intellectual structure of the field. According to Figure 12, the most cited authors were identified as Z. Allam (173), S. Bibri (169), and T. Yigitcanlar (136). The identification of the most cited authors is based on an author-level citation analysis, in which citations are assigned to all contributing authors regardless of their position in the author list (e.g., first author or corresponding author). When the ranking is examined in terms of total link strength, a similar ordering is observed, with Bibri, Allam, and Yigitcanlar occupying the top positions. This finding indicates that these authors play a central role in the research network and are both highly influential and frequently referenced within the literature. Highly co-cited publications can be interpreted as influential within the intellectual network; however, co-citation does not necessarily imply methodological or theoretical superiority.

The graph visualizes subgroups within research areas and the interactions between these groups using clusters shown in different colors. These differently colored clusters represent groups of authors who focus on specific topics or research areas in the literature. Stronger connections indicate stronger citation relationships among authors and greater collaboration within a particular academic field.

### 3.9. Content analysis

Content analysis was conducted for the 50 most cited articles. Each article was manually coded into Excel and thematic analysis was performed. It was seen that the studies consisted of literature reviews, experimental studies and case studies. The themes and keywords frequently mentioned in these academic articles on smart cities reflect the focal points and future trends of the research field. As a result of the analysis, i) smart cities, ii) AI and machine learning (ML), iii) internet of things (IOT), iv) sustainability, v) blockchain and security, vi) digital twins (DT) themes were reached.



### iii) Internet of Things (IoT) and Sensor Networks

Keywords: Wireless sensor networks, edge computing, smart grids, real-time monitoring, 5G and B5G communication.

IoT forms the data collection and automation foundation of smart cities:

- Smart buildings: IoT sensors that optimize energy consumption.
- Waste management: Optimization of garbage collection according to occupancy rate.
- Air quality monitoring: Pollution control with PM2.5, CO<sub>2</sub> sensors (Alsamhi et al., 2019; Sharma et al., 2021).

### iv) Sustainability and Green Technologies

Keywords: Renewable energy, carbon footprint, smart mobility, circular economy, climate resilience.

Smart cities provide solutions to climate change and resource efficiency problems through the following methods:

- Electric vehicles and charging stations
- Energy production with solar energy and wind turbines
- Smart irrigation systems for water saving (Ghadami et al., 2021; Serban et al., 2020).

### v) Blockchain and Data Security

Keywords: Decentralized systems, smart contracts, data privacy, cybersecurity, trustless transactions.

Blockchain is used for transparent and secure data sharing in smart cities:

- Energy trading: Citizens selling excess solar energy via blockchain.
- Identity management: Secure storage of digital identities.
- Voting systems: Transparent and manipulation-proof elections (Rahman et al., 2019; Ahmad et al., 2022).

### vi) Digital Twins and Simulation

Keywords: Virtual city models, urban simulation, real-time data integration, predictive modelling.

The success of Singapore's Digital Twin (Li et al., 2021) initiative has been widely reported in the literature. However, it should be noted that the present study does not empirically evaluate such implementations but rather maps the research themes addressing digital twin applications.

Digital twins create virtual copies of cities, which:

- Testing disaster scenarios (earthquake, flood simulations)
- Transportation planning (predicting the traffic impact of the new metro line)
- It can provide infrastructure maintenance (digital monitoring of bridges and roads) (Li et al., 2021; Weil et al., 2023).

## LIMITATIONS

This study has some methodological limitations. First, the scope of the research is limited to the WoS database only. The limitations of the scope and search algorithms of WoS may have led to the inability to include some studies in other important databases in the analysis (Mongeon & Paul-Hus, 2016). In particular, the omission of studies published in journals not indexed in WoS and regional studies is a factor that may affect the generalizability of the findings (Martín-Martín et al., 2021).

The second important limitation is that the analysis based on a single database may contain potential biases in terms of publication types and research areas. This may lead to overrepresentation of mainstream research trends and inadequate coverage of emerging or underrepresented topics (Zupic & Čater, 2015). In addition, the inclusion of both journal articles and conference proceedings in the analysis creates some difficulties in terms of data quality. Another factor that may affect the reliability of the results is that conference proceedings have shorter peer-review processes and tend to present preliminary findings (Glänzel & Schubert, 2003). Finally, the keyword-based search strategy and selection criteria applied in the study may have led to the exclusion of some new and pioneering studies. Terminological differences, especially in interdisciplinary fields, may cause some relevant studies not to be identified (Gusenbauer & Haddaway, 2020). To reduce the impact of these limitations, it is recommended that additional databases such as Scopus and Dimensions be used in future studies, publications outside of English be included, and more comprehensive search strategies be developed (Pranckutė, 2021). Additionally, publications indexed for 2025 represent a partial-year dataset, which limits the robustness of trend-based interpretations for that year.

## Results and Recommendations

This study examines the academic trends in AI (AI) applications in smart cities by examining the developments in the field using bibliometric and content analysis methods. The analysis of 810 publications obtained from the WoS database shows that AI plays an increasingly important role in the management and sustainability of smart cities. The findings of the study revealed that AI has a strong interaction with areas such as IoT, blockchain, digital twins, and sustainability. The increase in the literature observed after 2019—particularly between 2019 and 2024—indicates that the integration of AI-related technologies into urban systems has accelerated. (Allam & Dhunny, 2019; Yigitcanlar et al., 2020). Findings derived from 2025 publications should be regarded as preliminary, as the dataset represents only the early months of the year.

The content analysis conducted within the scope of the research shows that four critical areas stand out in the development smart cities : interdisciplinary studies, data standards, ethics and privacy, and pilot applications. Interdisciplinary collaborations can offer innovative solutions to the complex problems of smart cities through the integration of AI, IoT, and blockchain technologies (Rahman et al., 2019). However, the lack of data management and standards is one of the important factors that limit the scalability and efficiency of smart city projects (Sharma et al., 2021; Alsamhi et al., 2019). In this direction, the adoption of common data formats and open standards at the city scale can increase inter-system compatibility and enable smart city projects to be implemented more effectively. In addition, ethical and privacy issues emphasize the need to protect the privacy of individuals in large-scale data collection processes (Ahmad et al., 2022). The adoption of strong cybersecurity measures and transparent data policies plays a critical role in ensuring user trust. Finally, digital twins and simulation-based pilot projects can enable technologies to be tested in real city environments, increasing their applicability (Li et al., 2021; Weil et al., 2023).

The country-based analysis shows that China, India, and the USA are the countries that have made the most academic contributions to the field of smart cities and AI. The intense academic activities in these countries can be directly related to the investments in smart city projects and the increase in

research funds (Kumar & Singh, 2022; Rathore et al., 2016). Another important contribution of the study is to determine the most common areas of use of AI in smart cities. The results show that traffic management, energy optimization, and data security are among the most studied topics in this field (Ullah et al., 2020; Singh et al., 2020). In addition, a strong interaction has been observed between the fields of engineering, computer science, and urban planning (Bibri & Krogstie, 2021).

Moving forward, there are responsibilities that fall on different stakeholders for the successful implementation of AI-based applications in smart cities. Future research should extend beyond technical dimensions to address social challenges such as digital inequality and data privacy (Eren & Çay, 2025; Caragliu & Del Bo, 2023). Policy makers should develop standard data sharing protocols and ethical frameworks to increase the success of smart city projects (Kitchin, 2019). Local governments can increase resource efficiency through the integration of IoT and AI; for example, smart grids can save energy (Avci, 2024), while advanced traffic management systems can reduce carbon emissions (Bibri & Krogstie, 2020). For researchers, it is an important area of research that future studies should not only focus on technical aspects but also address social dimensions such as digital inequality and data privacy (Angelidou et al., 2018).

There are some limitations to this study. First, the analysis is based only on WoS database. In the future, the inclusion of different databases such as Scopus, Google Scholar and IEEE Xplore could expand the scope of the study. In addition, the literature reviews up to the first three months of 2025 (dataset was taken on March 31) should be updated to capture new developments in the field in the future. In terms of language, the evaluation of only English publications may cause a lack of a global perspective. The inclusion of academic studies in other languages would provide a more comprehensive analysis of developments in the field.

As a result, future global comparisons can reveal regional differences by examining smart city strategies of different countries. In addition, citizens' attitudes towards AI-based applications can be analyzed more deeply through qualitative studies. Finally, research on AI ethics can contribute to the development of recommendations for ethical and fair AI use by examining possible biases and injustices in automated decision-making systems (Fan et al., 2025). Interdisciplinary collaborations and innovative approaches will significantly contribute to smart cities becoming more inclusive and sustainable.

## Compliance with Ethical Standards

### 1. Conflict of Interest Declaration

The author(s) declare that there are no conflicts of interest involving themselves or any potential third parties, either prior to or following publication of this work.

### 2. Ethics Committee Approval

*This study does not require ethics committee approval. A signed declaration confirming this has been submitted with the manuscript.*

### 3. Generative Artificial Intelligence (GAI) Usage Statement

*Artificial intelligence was used during the translation of our study.*

### 4. Funding Statement

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