

Smart Cities, Artificial Intelligence, and Territorial Justice

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Abstract. In the era of digital transformation, deploying artificial intelligence (AI) within urban environments significantly reconfigures regional planning and territorial governance. While smart technologies promise enhanced operational efficiency, evaluating their systemic impact on spatial equity and social sustainability indicators remains a crucial academic challenge. This study delivers a comprehensive scientometric review of global scientific production intersecting smart cities, AI, and territorial justice from 2000 to 2026. A corpus of 3,011 peer-reviewed documents extracted from the Scopus database (restricted to Social Sciences, Economics, and Management) was analyzed using computational science-mapping techniques. The findings reveal a critical paradigm shift in contemporary literature, transitioning from technical infrastructure metrics toward human-centric indicators of social equity, urban inclusion, and the mitigation of socio-spatial inequalities. Thematic clustering further highlights how automated decision-making and digital transformation can either foster inclusion or exacerbate territorial fractures. Conclusively, this paper synthesizes global research trajectories to provide policymakers with a strategic framework that effectively reconciles technological innovation with territorial justice and social sustainability.

Keywords: *Smart Cities, Artificial Intelligence, Territorial Justice, Socio-spatial Equity, Urban Governance, Scientometric Analysis.*

1. Introduction

The contemporary paradigm of urban governance is undergoing an unprecedented structural mutation driven by digital transformation and the systemic deployment of Artificial Intelligence (AI). Within the fabric of modern "smart cities," algorithmic architectures, predictive modeling, and automated decision-making systems are no longer merely peripheral tools for computational optimization; they have become core mechanisms of territorial governance. However, as metropolitan and national spaces accelerate their integration of these technologies, an acute academic and empirical tension emerges between technological efficiency and territorial justice. In the globalized knowledge economy, ensuring that smart infrastructures do not worsen socio-spatial fragmentation requires a profound reassessment of social sustainability indicators.

While the foundational literature on smart cities heavily prioritized technical infrastructure metrics—such as IoT sensor density, broadband connectivity, and data processing speeds—it systematically obscured the socio-distributive consequences of algorithmic planning. This

technical determinism introduces a severe risk of "digital redlining" and automated exclusion, where AI-driven resource allocation may inadvertently exacerbate territorial fractures, marginalizing vulnerable socio-economic areas. This study addresses this critical gap by conducting a rigorous scientometric mapping of the intellectual landscape.

This chapter systematically answers the following research questions:

- **RQ1:** What is the macro-structural evolutionary trajectory of global scientific production intersecting smart cities, AI, and territorial justice between 2000 and 2026?
- **RQ2:** Who are the leading scientific actors (countries, institutions, and core journals) driving the intellectual discourse on social sustainability indicators within algorithmic governance?
- **RQ3:** What is the conceptual and thematic architecture of this domain, and how has the literature transitioned from techno-centric metrics to human-centric indicators of spatial equity?

The primary objective of this chapter is to map, quantify, and synthesize the intellectual trajectories of global research dedicated to reconciling technological innovation with spatial equity. To achieve this, the chapter is structured as follows: Section 2 establishes the theoretical foundations of territorial justice and social sustainability in the digital era. Section 3 delineates the scientometric methodology, including the Scopus query string and R-Bibliometrix software parameters. Section 4 presents the empirical results (production trends, conceptual structures, and thematic maps). Finally, Section 5 discusses the policy implications and proposes a strategic framework for smart governance.

2. Theoretical Foundations: Reconciling Algorithmic Efficiency with Spatial Equity

a. The Evolution of the Smart City Paradigm: From Techno-Centric to Human-Centric

The conceptualization of the "smart city" has evolved through distinct generational paradigms. The earliest iterations, frequently conceptualized as *Smart Cities 1.0 and 2.0*, were characterized by high degrees of corporate-led technological determinism (Wirtz et al., 2019). Under this early framework, urban centers were viewed primarily as complex technical systems that could be optimized via internet-of-things (IoT) architectures, ubiquitous sensing, and big data analytics (Allam et al., 2022). The primary indicators of success within this paradigm were strictly technical and economic: data latency, energy efficiency, transaction speeds, and infrastructure cost reduction.

However, a critical body of social science literature emerged to challenge this techno-centric focus, arguing that it ignored the human capital, civic agency, and socio-spatial realities of urban inhabitants (Aria & Cuccurullo, 2017). This critique catalyzed a paradigm shift toward *Smart Cities 3.0*, an approach that re-centers human-centric indicators, urban inclusion, and co-creation (Ozmen Garibay et al., 2023). Within this contemporary perspective, technological deployment is not an end in itself, but a socio-technical enabler designed to enhance collective well-being, maximize subjective and objective social indicators, and preserve environmental integrity. The integration of AI into this paradigm introduces complex challenges, as the opacity of machine learning models ("black boxes") often conflicts with the transparency required for democratic urban governance (Pasquale, 2015; Dignum, 2019).

b. Theoretical Frameworks of Territorial Justice in the Digital Era

To understand how artificial intelligence interacts with regional planning, this study synthesizes established theories of territorial and spatial justice, translating them into the digital context. Territorial justice, at its core, refers to the equitable distribution of public resources, opportunities, and burdens across geographic space, ensuring that an individual's geographical

location does not dictate their quality of life (Harvey, 1973). This study draws upon a tripartite conceptualization of justice to evaluate algorithmic governance:

i. Distributive Territorial Justice

Grounded in the egalitarian principles of John Rawls and the spatial critiques of David Harvey, distributive justice focuses on the outcomes of resource allocation (Harvey, 1973). In a smart city, AI algorithms are increasingly deployed to automate the distribution of public goods—such as smart grids, waste management systems, public health infrastructure, and optimized transport networks (Bullock et al., 2020). Distributive territorial justice requires that these algorithmic models do not concentrate premium smart infrastructures exclusively in high-income, highly connected urban cores while leaving peripheral or marginalized regions digitally under-resourced—a phenomenon known as spatial digital redlining (Eubanks, 2018).

ii. Procedural Territorial Justice

Procedural justice concerns the fairness, transparency, and inclusivity of the decision-making processes that shape territorial configurations (Sen, 1999). In the context of AI-driven governance, procedural justice demands that citizens are not merely passive data points to be harvested by urban algorithms, but active participants in the governance of data architectures (Taylor, 2017). This aligns with Amartya Sen's capabilities approach, which posits that public policies must expand individuals' substantive freedoms and capabilities to lead lives they value (Sen, 1999). Procedural justice in smart cities therefore requires algorithmic accountability, public data sovereignty, and participatory modeling, ensuring that regional algorithmic planning is co-designed with local communities (Janssen & Kuk, 2016; Veale & Brass, 2019).

iii. Recognitional Territorial Justice

Developed by Nancy Fraser, recognitional justice demands the explicit political and social acknowledgment of the distinct identities, historical disadvantages, and cultural specificities of marginalized groups. When translated to automated urban planning, recognitional justice highlights how standardized algorithms often fail to capture the informal economic networks, unique spatial practices, and specific vulnerabilities of diverse populations (Noble, 2018; Benjamin, 2019). For instance, optimizing urban mobility using smartphone data inherently biases algorithms in favor of affluent populations, misrepresenting or entirely erasing the spatial needs of lower-income groups, the elderly, or digitally excluded populations (Norris, 2001).

c. Operationalizing Social Sustainability Indicators

Social sustainability within regional planning requires that technological interventions foster long-term social cohesion, institutional trust, and equity (Esping-Andersen, 1990). In an AI-dominated urban landscape, traditional social sustainability indicators must be upgraded to address the digital dimensions of vulnerability. Key indicators documented in the recent literature include:

- **Socio-Spatial Digital Accessibility:** Measuring the geographical distribution of high-speed connectivity and AI-driven public service interfaces to prevent the deepening of the global and national digital divide (Norris, 2001).
- **Algorithmic Equity and Fairness:** Evaluating automated resource-allocation models for systemic statistical biases that disadvantage specific territorial or demographic socio-economic strata (O'Neil, 2016; Thiebes et al., 2021).
- **Territorial Well-Being and Social Welfare Metrics:** Leveraging objective and subjective social indicators to ensure that automated decisions directly correlate with improvements in collective citizen well-being rather than just fiscal optimization (Barrett, 2003).

By synthesizing these multi-dimensional theoretical frameworks, this chapter establishes a robust conceptual foundation. This baseline allows us to interpret the scientometric mappings generated from the corpus of 3,011 documents, tracing how global scholarship responds to these pressing socio-technical challenges.

3. Data and Methods

To map the intellectual architecture and structural shifts within the scientific discourse on smart ecosystems and spatial equity, this study employs a quantitative, data-driven approach known as scientometric analysis. Unlike traditional, subjective literature reviews, scientometric mapping leverages computational workflows to analyze large bibliographic corpuses, reducing author bias and uncovering latent intellectual structures, conceptual frameworks, and thematic networks (Aria & Cuccurullo, 2017; Zupic & Čater, 2015).

The methodological framework of this chapter is designed to process, filter, and synthesize global scientific production to operationalize social sustainability indicators within algorithmic territorial governance. By applying advanced bibliometric techniques—such as co-word analysis, scientific productivity distribution mapping, and structural network modeling—this section establishes a replicable and transparent empirical foundation for evaluating how public management and regional planning literature addresses spatial inequalities in the era of artificial intelligence.

4. Methodology

The research design follows a rigorous four-stage sequential pipeline: (1) identification and retrieval of bibliographic records, (2) application of formal inclusion and exclusion criteria, (3) data preprocessing and normalization, and (4) computational science mapping and network extraction.

a. Data Source and Search Strategy

The primary bibliographic data source utilized for this investigation is the **Scopus database** (Elsevier). Scopus was selected over alternative repositories due to its extensive indexing of high-impact peer-reviewed journals, its superior coverage of publications in the social sciences, economics, and public management, and its strict quality control standards, which mitigate the risk of including predatory or low-impact literature (Mongeon & Paul-Hus, 2016).

To capture the complex intersection between computational urban technologies, institutional governance, and socio-spatial outcomes, a multi-perspective advanced search query was engineered. The search strategy targets titles, abstracts, and keywords (TITLE-ABS-KEY) across three intersecting core thematic axes: (i) the urban/territorial locus, (ii) the digital transformation/AI vector, and (iii) the social sustainability/justice outcome dimension.

The exact search string executed in the Scopus database is formulated as follows:

TITLE-ABS-KEY (("smart city" OR "smart cities" OR "urban" OR "territor*") AND ("artificial intelligence" OR "AI" OR "digital transformation" OR "smart technolog*") AND ("social" OR "justice" OR "equity" OR "inequalit*" OR "sustainability")) AND PUBYEAR > 1999 AND PUBYEAR < 2027 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SUBJAREA , "ECON") OR LIMIT-TO (SUBJAREA , "SOCI"))

b. Inclusion and Exclusion Criteria

To ensure a highly specialized corpus relevant to public economics, regional planning, and social governance, strict filtering criteria were applied directly during the query phase and subsequent metadata refinement:

- **Temporal Window:** The search was constrained to the years **2000 to 2026**. This 26-year temporal boundary encompasses the initial conceptualization of digital urbanism up to contemporary developments in algorithmic governance.
- **Linguistic Restriction:** Only documents published in **English** were included to ensure cross-institutional bibliometric standardization and international citation comparability.
- **Subject Area Refinement:** The dataset was restricted exclusively to the subject domains of **Social Sciences (SOCI)** and **Economics, Econometrics and Finance (ECON)**. Papers focusing purely on technical hardware engineering, computer science algorithms, telecommunications protocols, or material sciences were systematically excluded. This guarantees that the final corpus centers on the socioeconomic, institutional, and human impacts of technology.

c. Data Processing and Refinement

The execution of the search query yielded a raw corpus of **3,011 bibliographic records**. The metadata were exported from Scopus in both plain text (.txt) and comma-separated values (.csv) formats, containing complete bibliographic information (authors, affiliations, titles, abstracts, keywords, source sources, and citation matrices).

Data preprocessing was performed using the open-source **bibliometrix package** within the **R-Studio computational environment (v4.3.1)**. The data refinement pipeline involved:

1. **De-duplication:** Automatically scanning and merging overlapping records based on Digital Object Identifiers (DOIs) and primary author matching.
2. **Affiliation Standardization:** Harmonizing institutional names and macro-regional affiliations to resolve discrepancies caused by spelling variations or translations.
3. **Keyword Harmonization:** Normalizing singular/plural terms (e.g., merging "smart city" and "smart cities") and combining clear synonyms to ensure statistical accuracy during co-word network clustering.

d. Analysis and Bibliometric Mapping

The refined dataset was computationally processed to map both the performance and the conceptual architecture of the domain. The analytical toolkit consists of two primary tracks:

i. Performance Analysis (Descriptive Metrics)

- **Production Trends:** Calculating the annual scientific growth rate and document distribution across the 2000–2026 timeline.
- **Source Evaluation:** Applying **Bradford's Law of Scattering** to identify the core journals driving the integration of social sustainability indicators into smart urbanism discourse.
- **Actor Mapping:** Determining the most productive authors, institutions, and countries to uncover the global distribution of research powerhouses.

ii. Science Mapping and Network Modeling

- **Conceptual Structure (Co-Word Analysis):** By analyzing the co-occurrence of author keywords, this study uses **Callon's network metrics** (centrality and density) to build a **Thematic Map**. This map categorizes research themes into motor themes, niche themes, emerging/declining themes, and basic themes.
- **Intellectual and Collaboration Networks:** Constructing country collaboration networks and cross-institutional frameworks to visualize global knowledge flows.
- **Evolutionary Analysis (Three-Field Plots):** Generating relational diagrams linking the most prominent research countries, core keywords, and primary publication journals

over time to map the structural paradigm shift from techno-centric metrics to human-centric indicators.

5. Analysis and Overview

a. Macro-Structural Performance and Descriptive Metrics

The computational extraction of the Scopus dataset reveals a robust corpus of 2,999 peer-reviewed documents spanning a 22-year temporal horizon from 2004 to 2026. This dynamic domain is characterized by an exceptional annual scientific growth rate of 28.05%, signaling an exponential academic expansion and intensifying global interest in reconciling smart technologies with socio-spatial equity. Research within this field exhibits a highly interdisciplinary and dispersed nature, with the literature distributed across 1,229 distinct sources, yielding a low concentration index of approximately 2.4 documents per source. The structural communication matrix is heavily anchored in traditional scholarly formats, dominated by journal articles (n=1,380) and book chapters (n=933), which together constitute over 75% of the total output. This is supplemented by 202 review papers, indicating a field sufficiently mature to regularly synthesize cumulative knowledge, alongside a significant contingent of conference papers (n=257) and books (n=152) that reflect both rapid, cutting-edge dissemination and in-depth theoretical consolidation.

Figure 1: Summary Information

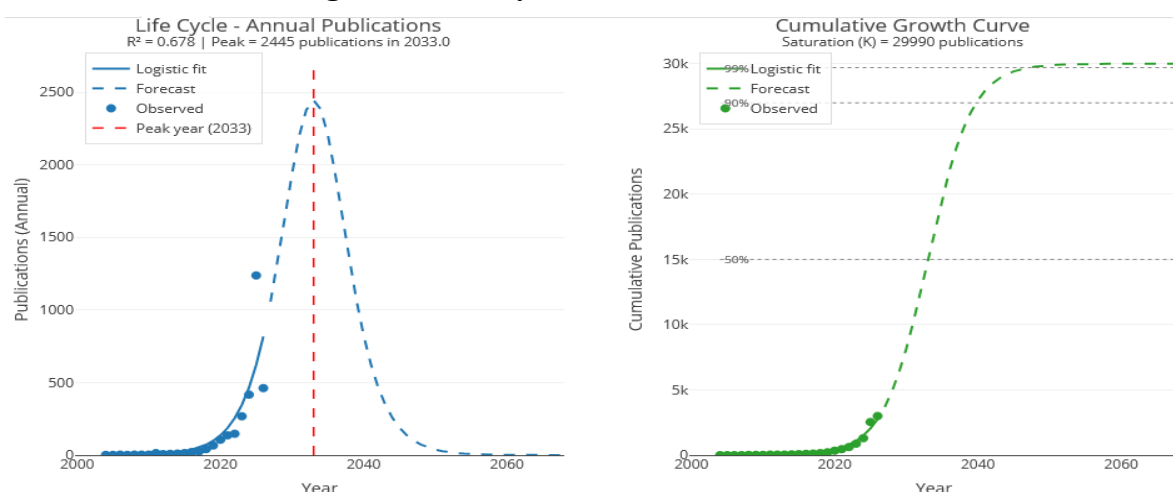


The human capital landscape operating within this domain is highly collaborative and globally integrated, supported by a network of 7,477 active researchers. Multi-authored publications represent the structural norm, as evidenced by a mean co-authorship index of 3.05 authors per document, although a resilient cohort of single-authored contributions (n=753) maintains a distinct conceptual space. Geographically, the field exhibits strong cross-border knowledge flows, with an international co-authorship rate of 25.91%. Regarding scientific impact, the corpus achieves an average of 11.62 citations per document; a remarkably high figure considering the exceptionally low average document age of 2.35 years, which underscores intense immediate engagement and immediate community uptake. However, a critical metadata constraint must be highlighted: the downloaded dataset registers an absolute absence of cited references (References=0). This specific technical omission temporarily precludes the generation of citation-network mapping—such as bibliographic coupling, co-citation, and direct algorithmic historiographs—thereby focusing the present empirical phase strictly on performance analysis and advanced co-word thematic mapping using the rich reservoir of available Author Keywords (n=7,482) and Keywords Plus (n=8,334).

b. Life Cycle of Scientific Production and Growth Dynamics

To evaluate the structural maturity and evolutionary velocity of the domain, the empirical dataset was modeled using a classic logistic growth framework, capturing the macro-historical trajectory and forecasting the systemic saturation of the literature. The cumulative publication trajectory exhibits a classic S-shaped curve, while the annual output follows a distinct bell-shaped lifecycle distribution. The mathematical estimation yields a moderate statistical fit ($R^2=0.678$; $RMSE=152.206$), indicating that while the deterministic logistic model explains 67.8% of the cumulative variance, recent observed data points — particularly post-2020 — slightly exceed the fitted curve. This systematic underestimation reveals an unmodeled growth momentum, reflecting an intensive socio-technical acceleration that surpasses linear historical projections. The model identifies a critical inflection point (t_0) at the year 2033.02, representing the exact juncture where cumulative acceleration reaches maximum velocity, and annual production is forecasted to peak at approximately 2,445 documents before entering a decelerating phase toward a calculated environmental carrying capacity (K) of 29,990 publications.

Figure 2: Life Cycle of Scientific Production



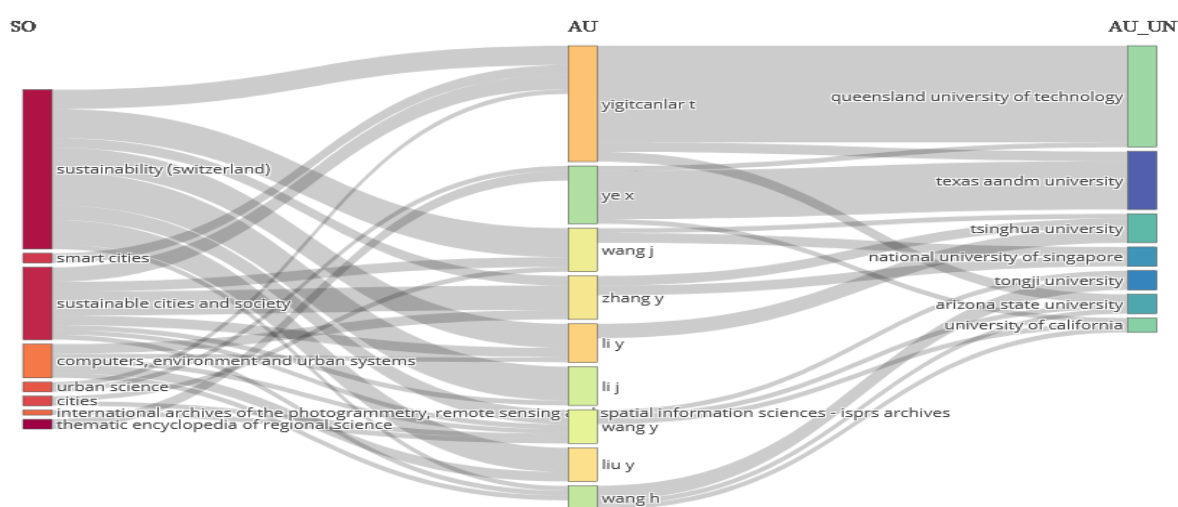
The chronological life cycle of the domain can be structurally segmented into three distinct evolutionary phases driven by shifting paradigms in public administration and regional planning. The *Emergence Phase* (2004 to approx. 2015/2020) was characterized by single or low double-digit annual outputs and a flat cumulative trajectory, representing nascent conceptualizations of digital urbanism and baseline social justice concerns. Conversely, the domain is currently operating within a highly vibrant *Expansion Phase* (spanning from 2015/2020 toward the 2033 inflection point), characterized by an exponential year-over-year surge in publications. This rapid acceleration is sociologically driven by increased dedicated public research funding, the widespread availability of advanced data-analytics software, and a growing institutional mandate to rectify algorithmic biases within municipal public services. The characteristic growth duration parameter ($\Delta t=13.48$ years) confirms that the vast majority of the expected global intellectual capital will be concentrated within this compressed window. Post-2033, the model projects a *Maturity and Saturation Phase*, wherein the cumulative curve asymptotically approaches its carrying capacity around the 2050s, indicating that the core conceptual structures will solidify, shifting the academic output from revolutionary framework-building to localized, incremental niche refinements.

c. Structural Mapping of the Intellectual Pipeline via Three-Field Plot

To visualize the tripartite relational flow governing the intellectual pipeline of this domain, a Sankey-based Three-Field Plot was executed to map the structural connections between

primary publication venues (Left Field: SO), leading authors (Central Field: AU), and institutional affiliations (Right Field: AU_UN). The structural configuration reveals a highly concentrated knowledge network heavily anchored in specialized sustainable urbanism and techno-social governance. On the left axis, Sustainability (Switzerland) emerges as the absolute dominant publication locus, exhibiting a disproportionately thick bar that dwarfs alternative high-impact outlets such as Smart Cities, Sustainable Cities and Society, and Computers, Environment and Urban Systems. Smaller yet highly specialized flows extend toward Urban Science and Cities, confirming that while the corpus is rooted in the fields of economics and social sciences, its conceptual applications are explicitly directed toward smart metropolitan frameworks and spatial justice metrics.

Figure 3: Three-Field Plot



In the central and right domains of the pipeline, Tan Yigitcanlar from the Queensland University of Technology stands out as the most prolific author and intellectual anchor of this collection. A massive, singular ribbon connects Yigitcanlar to his institution and projects a high-volume publication trajectory directed primarily into Sustainability (Switzerland), alongside secondary contributions to Smart Cities. Other core intellectual vectors are driven by X. Ye, firmly affiliated with Texas A&M University, and J. Wang, whose relational ribbons split between Tsinghua University and Arizona State University. This multi-institutional bridging highlights cross-border collaborative dynamics, academic mobility, or large-scale international research initiatives. Additional primary intellectual nodes are established by Y. Zhang (Tongji University), Y. Li (National University of Singapore), and J. Li (University of California), demonstrating a robust, globally distributed research community spanning Australia, North America, and East Asia. This tight alignment between top-tier authors, prestigious global universities, and dedicated sustainability journals underscores a well-institutionalized academic ecosystem committed to embedding territorial equity and social indicators into the algorithmic architecture of the future city.

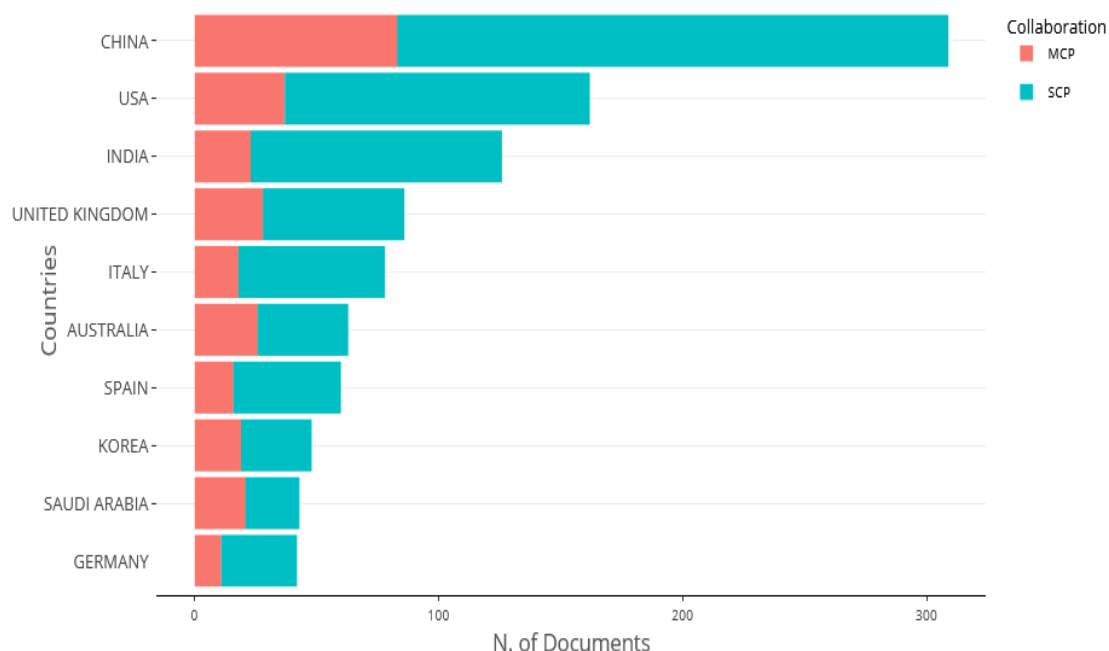
6. Bibliometric Analysis by Country

a. Corresponding Author Country Analysis

The geographic distribution of corresponding authors highlights the global powerhouses and structural dynamics defining research at the intersection of smart urbanism and spatial equity. Performance metrics reveal that China is the most prolific nation, leading global production with 309 articles, followed by the United States with 162 articles and India with 126 articles. The United Kingdom (n=86) and Italy (n=78) also emerge as significant contributors, underscoring the dominant role of established Western and rapidly expanding Asian research infrastructures. A deeper evaluation of Single Country Publications (SCP) versus Multiple

Country Publications (MCP) illustrates that the top three nations rely heavily on internal research capacity. China achieves 226 SCPs alongside a modest MCP ratio of 26.9%, the United States generates 125 SCPs with an MCP ratio of 22.8%, and India records 103 SCPs with one of the lowest international collaboration rates at 18.3%. This trend indicates a high degree of self-sufficiency and substantial domestic funding dedicated to localized smart governance initiatives within these larger economies.

Figure 4: Affiliation Productivity Over Time

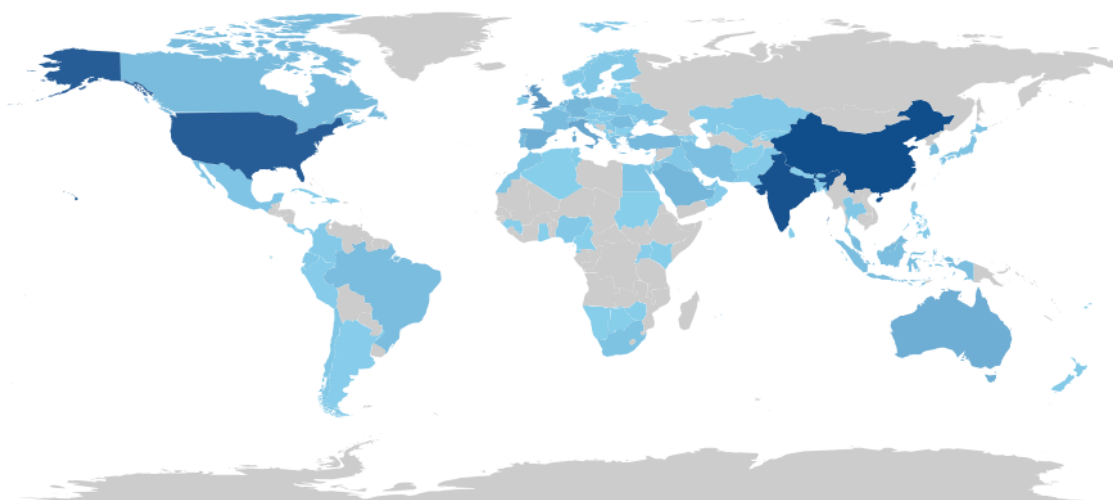


Conversely, the Multiple Country Publication ratio (MCP %) exposes distinct structural variations in how countries engage with global knowledge networks. Emerging research hubs and smaller, highly integrated economies show a strong strategic reliance on international partnerships to accelerate their scientific impact. Saudi Arabia leads this collaborative paradigm with an MCP ratio of 48.8%, where nearly half of its 43 corresponding author publications involve cross-border co-authorship, closely followed by Malaysia at 48.3%. Australia also demonstrates an outward-looking research environment with an MCP ratio of 41.3% (n=63), alongside notable integration from South Korea (39.6%), the Netherlands (37.5%), and the United Kingdom (32.6%). In contrast, countries such as Romania (11.1% MCP) and Turkey (15.2% MCP) exhibit a predominantly domestic focus. This polarization divides the global landscape into self-sufficient research giants with vast internal structures, globally integrated nations that balance domestic strength with international network alignment, and emerging collaborators using strategic alliances to expand their territorial governance research capacity.

b. Scientific Output Analysis by Country

The total scientific output aggregated by country confirms a highly concentrated global distribution of intellectual capital, dominated by three major geopolitical powerhouses. China leads the absolute volume of scientific production with 806 documents, followed closely by India with 781 documents and the United States with 704 documents. This massive scientific output demonstrates that these nations serve as the primary engines of research in smart urban transformations, utilizing their expansive institutional structures and extensive research networks to drive the global literature. The high volume of publications coming from both China and India reflects substantial academic investments in evaluating automated governance, big data infrastructure, and socio-spatial indicators within heavily populated, rapidly expanding urban regions.

Figure 5: Scientific Output by Country



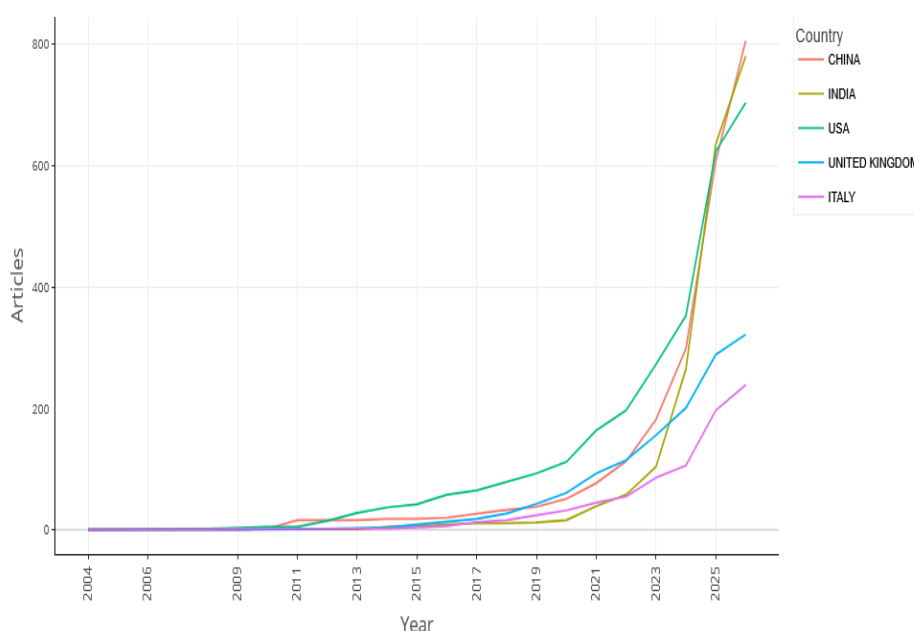
Beyond this leading trio, European and Anglo-Saxon nations form a highly productive second tier that bridges technological advancement with institutional critique. The United Kingdom ranks fourth globally with 322 documents, followed by Italy (n=239), Spain (n=191), and Australia (n=188). This strong performance is completed by Germany (n=144), Saudi Arabia (n=137), and the Netherlands (n=136). While these Western European nations and Australia show lower absolute volumes than China or the United States, their significant output represents a deeply institutionalized research community. This segment of the literature is particularly focused on conceptualizing social sustainability indicators, regulatory governance frameworks, and data justice principles within smart city planning.

c. Longitudinal Analysis of National Scientific Production

The longitudinal evolution of scientific production across the leading nations reveals distinct temporal trajectories and shifting centers of gravity over the 22-year period. In the initial decade (2004–2014), the domain experienced a protracted period of conceptual incubation, primarily anchored by the United States and India. The United States pioneered early outputs, accelerating from a single document in 2006 to 37 annual publications by 2014, establishing the baseline literature for socio-technical urban transitions. Conversely, during this same nascent phase, China and the United Kingdom maintained near-zero or single-digit outputs until approximately 2011, when China recorded a sudden structural increase to 16 annual publications. Italy exhibited a similar slow initial pattern, producing no more than two articles per year until 2014, reflecting a period when algorithmic governance and territorial justice indices remained peripheral to core macroeconomic and sociological research.

A critical inflection point occurred post-2020, precipitating an unprecedented exponential surge in annual scientific output across all major nations and shifting global leadership. India experienced a remarkable transition, climbing from 16 documents in 2020 to 104 in 2023, before surging to 781 cumulative publications by 2026. China followed an identical pattern of hyper-acceleration, rising from 51 papers in 2020 to 299 in 2024, and peaking at 806 publications by 2026, surpassing the United States to become the most productive national framework. The United States maintained a highly resilient and steady expansion, increasing from 112 documents in 2020 to 704 in 2026. This macro-level surge is mirrored across Europe, with the United Kingdom and Italy growing from 61 and 32 documents in 2020 to 322 and 239 publications in 2026, respectively. This synchronized global explosion reflects the deep institutionalization of artificial intelligence in public administration and a widespread scholarly imperative to formalize spatial equity and social sustainability indicators within national regional planning agendas.

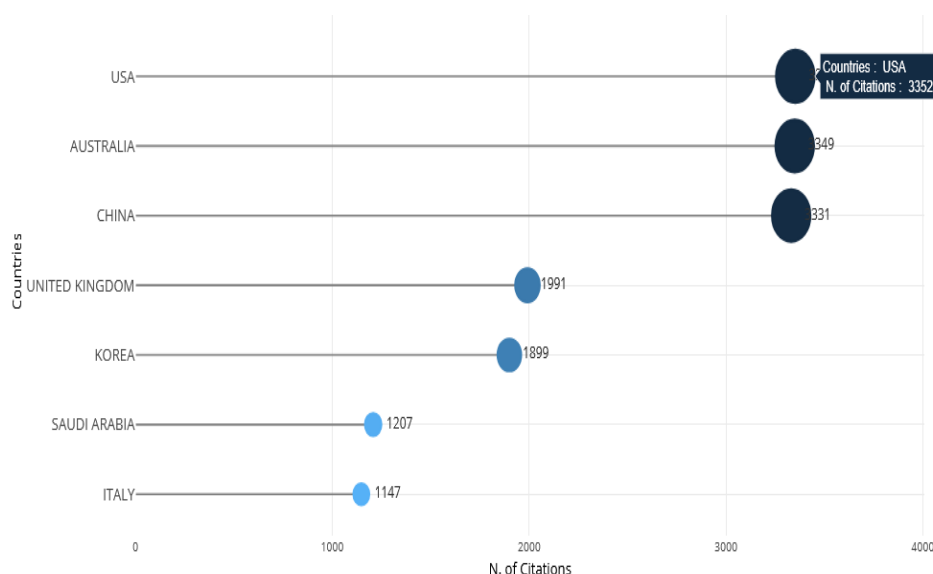
Figure 6: Countries' Production over Time.



d. Citation Impact and Academic Influence by Country

An evaluation of citation metrics uncovers a distinct structural divergence between absolute citation volume and relative academic influence across participating nations. In terms of gross academic footprint, three global poles form a dense primary tier, each accruing over 3,300 total citations. The United States leads with 3,352 total citations, followed directly by Australia with 3,349 and China with 3,331. This high concentration confirms that these three nations serve as the foundational intellectual anchors of the domain, shaping the conceptual grammar of automated urbanism and spatial indicators. However, looking at the average citations per document changes this hierarchy completely. China, despite its massive publication volume, records a modest average citation rate of 10.80, whereas the United States maintains a balanced average of 20.70. This pattern indicates that while China drives the absolute volume of the literature, its immediate relative influence per paper is somewhat diluted compared to the long-standing foundational texts produced within North American research networks.

Figure 7: Most Cited Countries

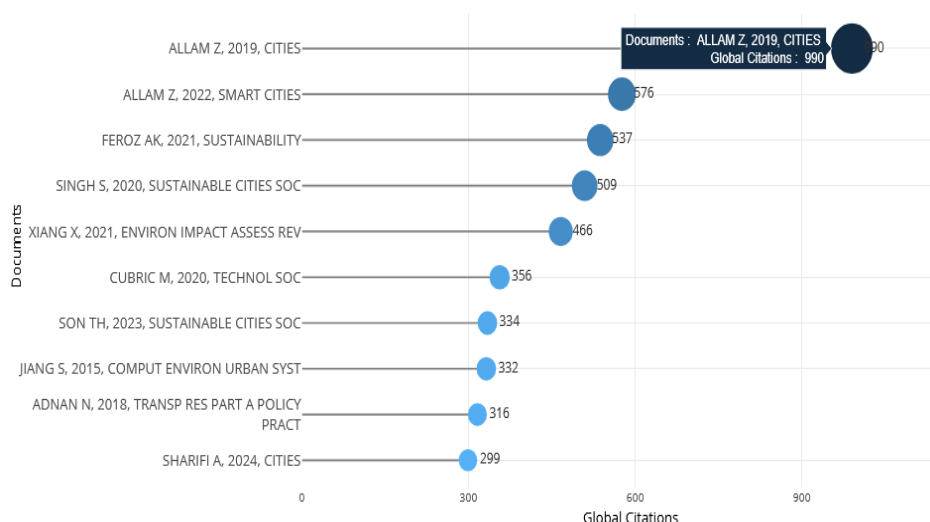


In contrast, several smaller, highly specialized economies achieve exceptional average citation rates, demonstrating superior intellectual efficiency and per-document impact. Australia leads this dimension with a remarkable average citation score of 53.20, establishing its institutions as the primary drivers of high-impact theoretical frameworks in smart city governance. Similarly, France (n=733 total citations) and South Korea (n=1,899 total citations) display high qualitative performance, registering mean citation rates of 48.90 and 39.60, respectively, followed closely by Singapore (38.30). This cohort of highly cited nations is completed by the United Kingdom (23.20), Saudi Arabia (28.10), Spain (16.10), and Italy (14.70). These high relative metrics highlight how targeted scientific strategies in Western Europe, the Anglo-Saxon sphere, and advanced Asian economies successfully generate core methodologies and highly influential social sustainability frameworks that guide global research directions.

7. Document-Level Bibliometric Analysis

An evaluation of the most globally cited documents identifies the primary intellectual anchors shaping the conceptual grammar of smart urbanism and social equity. At the apex of global academic influence sits the foundational work by Allam (2019) published in *Cities*, which has accrued 990 total citations and maintains a high annual citation rate of 123.80, alongside a normalized citation score of 25.68. This seminal study is supported by another high-impact work by Allam (2022) in *Smart Cities*, which has registered 576 total citations and a mean annual citation rate of 115.20. Together, these contributions establish the core theoretical baseline of the domain, critically evaluating early techno-centric urban structures and calling for a paradigm shift toward human-centric indicators. Following these works, a robust secondary tier of heavily cited papers includes Feroz et al. (2021) in *Sustainability* (n=537 total citations) and Singh et al. (2020) in *Sustainable Cities and Society* (n=509 total citations), which operationalize digital transformation and artificial intelligence within complex socio-environmental urban frameworks.

Figure 8: Most Global Cited Documents



Beyond these foundational works, recent high-impact publications demonstrate a strong scholarly effort to link technological implementation with rigorous social and environmental impact metrics. Xiang et al. (2021) in *Environmental Impact Assessment Review* has generated substantial engagement with 466 total citations, followed by Cubric (2020) in *Technology in Society* (n=356), and a rapidly rising study by Son et al. (2023) in *Sustainable Cities and Society* (n=334). Longitudinal context is provided by Jiang et al. (2015) in *Computers, Environment and Urban Systems* (n=332) and Adnan et al. (2018) in *Transportation Research Part A: Policy and Practice* (n=316), which trace early data-driven urban applications and mobility equity. Crucially, a recent study by Sharifi (2024) in *Cities* has achieved 299 total citations in a short

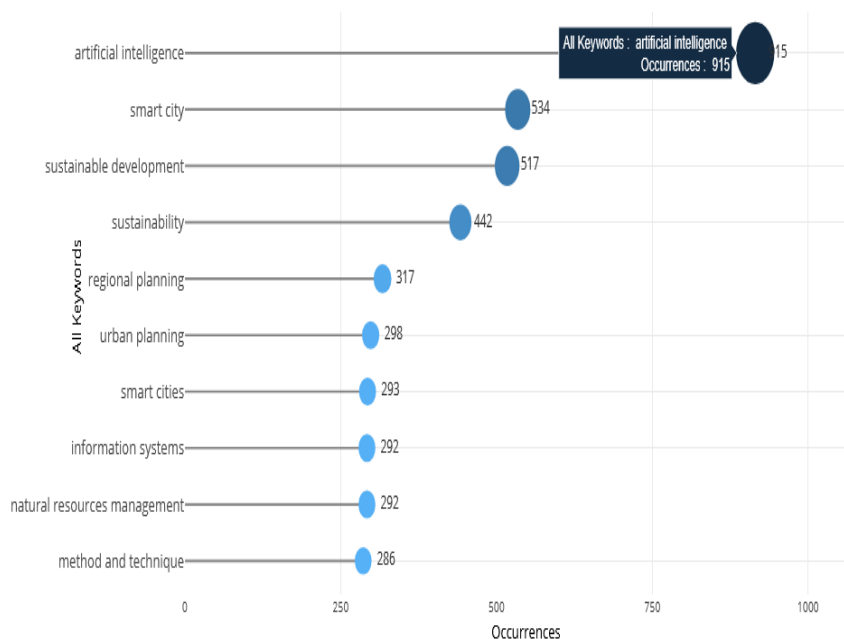
period, recording the highest normalized impact score in the dataset at 25.91. This concentrated cluster of highly cited literature highlights a well-defined intellectual core that has successfully transitioned from engineering-focused urban parameters to institutional governance frameworks, data justice principles, and social sustainability metrics.

8. Bibliometric Analysis by Keywords

a. 8.1. Lexical Density and Most Frequent Keywords

The lexical density of the analyzed corpus reveals a structured and cohesive vocabulary, heavily centered around the socio-technical intersections of automated governance. At the apex of lexical frequency, "artificial intelligence" serves as the primary thematic pillar with 915 occurrences, underscoring its role as the dominant technological vector in contemporary regional planning and public sector studies. This is tightly integrated with the urban locus, as evidenced by the high frequencies of "smart city" (n=534) and its plural variant "smart cities" (n=293). Together, these foundational terms confirm that the intellectual core of the dataset is anchored in the architectural transformation of modern municipal ecosystems through advanced algorithmic and automated decision-making architectures.

Figure 9: Most Frequent Words



The remaining high-frequency keywords demonstrate a substantial scholarly focus on the long-term impacts and regulatory frameworks of these digital interventions. The explicit target of these technologies is captured by "sustainable development" (n=517) and "sustainability" (n=442), indicating that the deployment of digital infrastructure is heavily evaluated through the lens of social, economic, and environmental preservation. Furthermore, the operationalization of these concepts within public administration is reflected in the prominent roles of "regional planning" (n=317) and "urban planning" (n=298). This planning dimension is structurally supported by a dense technological and methodological foundation, where "information systems" (n=292), "natural resources management" (n=292), and "method and technique" (n=286) complete the primary lexical cluster, tracing how modern public management relies on sophisticated socio-technical tools to pursue spatial equity and territorial balance.

b. 8.2. Conceptual Mapping and Word Cloud Topography

The word cloud topography provides a visual representation of the conceptual mapping of the domain, transforming lexical frequencies into a structured spatial hierarchy. At the geometric

Figure 11: WordCloud

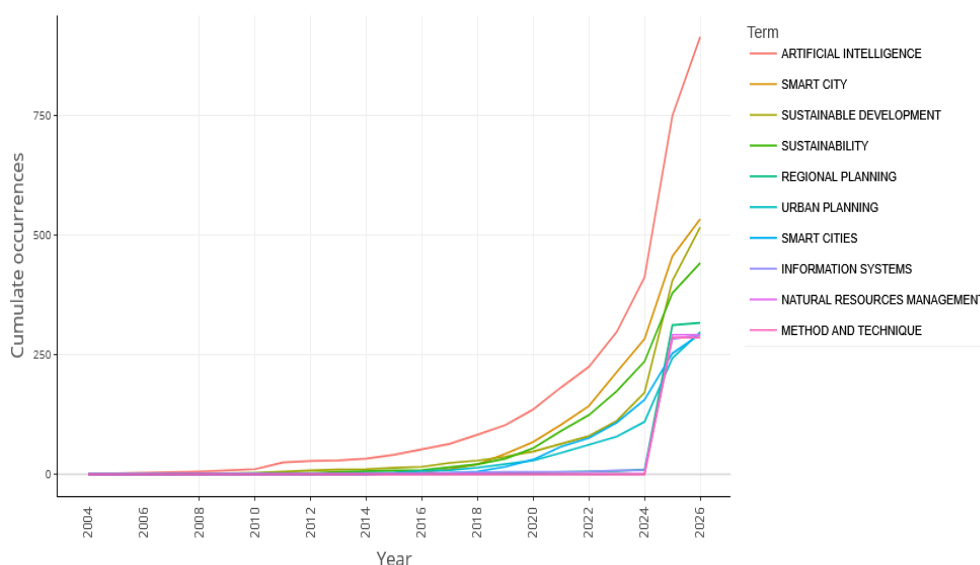


The remaining space within the treemap partition reveals a highly organized transition from technological drivers to strategic planning targets and methodology. The socio-ecological demands of algorithmic interventions are contained in the substantial, adjacent rectangles of sustainable development (n=517) and sustainability (n=442). The execution of these sustainable goals is neatly organized into the mid-tier spaces of regional planning (n=317), urban planning (n=298), and smart cities (n=293). Finally, the structural foundations that make these planning interventions possible are clustered in the remaining perimeter tiles, occupied by information systems (n=292), natural resources management (n=292), and method and technique (n=286). This spatial configuration outlines a multi-layered research domain where advanced informatics are consistently balanced by, and integrated with, the regulatory frameworks of territorial governance.

d. Longitudinal Word Frequency and Evolutionary Trajectories

The longitudinal trajectory of top-tier keywords over the 22-year period highlights a profound shift from a fragmented, tech-centric focus to an integrated paradigm of algorithmic territory management. In the earliest sub-period (2004–2014), the scientific framework remained highly specialized and conceptually isolated. "Artificial intelligence" grew gradually from a single mention in 2004 to 33 occurrences by 2014, whereas foundational themes like "smart city" were almost non-existent, registering their first single instances only around 2013. During this initial decade, ancillary pillars such as "sustainable development" and "sustainability" experienced slow, linear tracking, reaching just 11 and 7 occurrences by 2014, respectively. This sluggish growth pattern reveals an era when computational information systems and environmental indicators operated as separate research fields, without a unified vocabulary to bridge territorial planning and automated governance.

Figure 12: Keyword Frequency Over Time

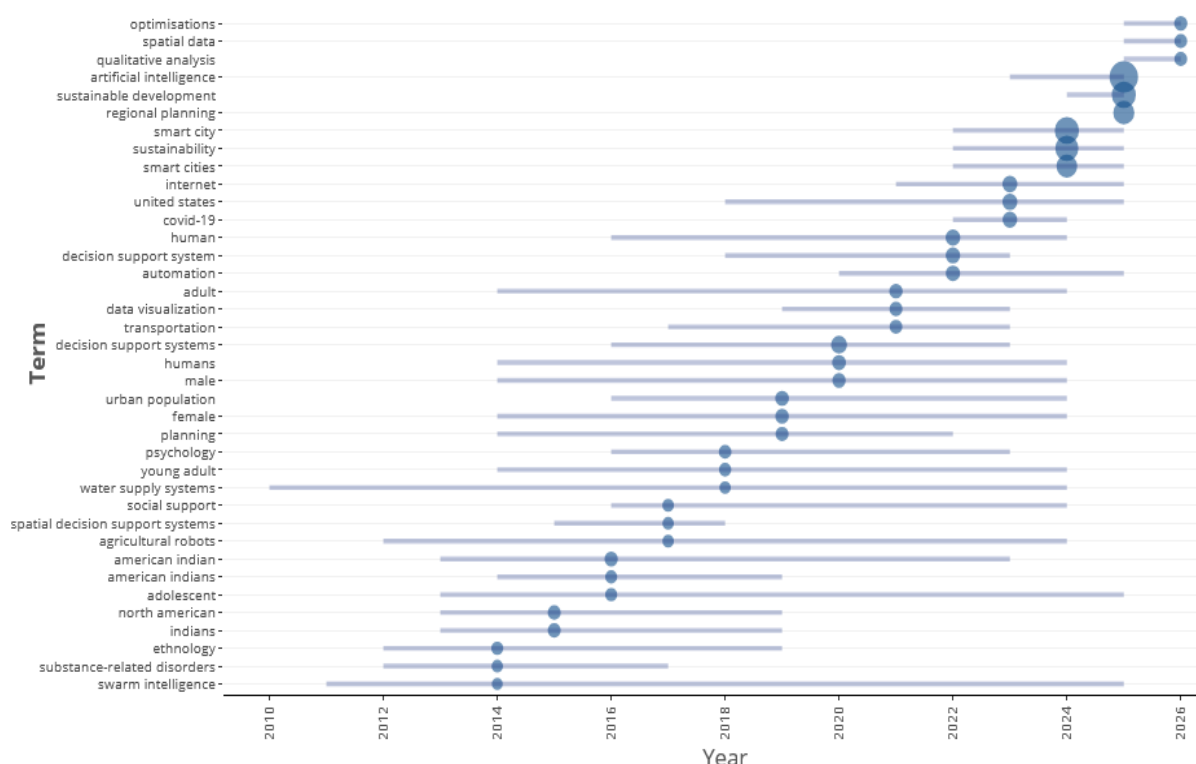


A major structural turning point occurred after 2020, bringing an unprecedented, exponential explosion in keyword occurrences that signaled a deep thematic convergence. "Artificial intelligence" expanded rapidly from 136 instances in 2020 to 412 in 2024, before skyrocketing to 915 by 2026. This technical expansion directly drove the growth of urban applications, with "smart city" jumping from 68 mentions in 2020 to 534 in 2026. Crucially, the period between 2025 and 2026 shows a massive structural consolidation across previously peripheral keywords. Long-dormant structural terms like "regional planning" (n=1 in 2022 to n=317 in 2026), "urban planning" (n=62 in 2022 to n=298 in 2026), and "natural resources management" (n=1 in 2022 to n=292 in 2026) surged simultaneously alongside dedicated processing frameworks like "method and technique" (n=286 in 2026). This synchronized lexical explosion highlights that the current state of the art has successfully evolved from theoretical concepts into a mature, highly operationalized discipline where advanced automated engineering is explicitly used to manage regional equity and spatial sustainability.

e. Emerging Frontiers and Thematic Evolution

The thematic evolution of the domain, analyzed through an annual frequency mapping of the top three merged keywords (KW_Merged) per year, reveals a clear structural shift from isolated, foundational methodologies to integrated, large-scale socio-technical applications. A longitudinal tracing of the temporal centers of gravity shows that early research (2014–2020) focused heavily on specific infrastructural components and human factors. Foundational nodes such as "Automation," "Decision Support System," and "Human" exhibit extended horizontal interquartile ranges stretching back to 2016. This long-term activity highlights a prolonged period of conceptual development that prioritized the direct technical mechanics of algorithmic interfaces. During the 2020–2022 sub-period, the literature adapted to global shocks and infrastructure upgrades, as shown by the sudden appearance of "COVID-19" and "Internet." These topics emerged alongside localized application studies in "Transportation" and "Data Visualization," mapping a fragmented research landscape where smart interventions were still evaluated within separate, sector-specific urban silos.

Figure 13: Trending Topics



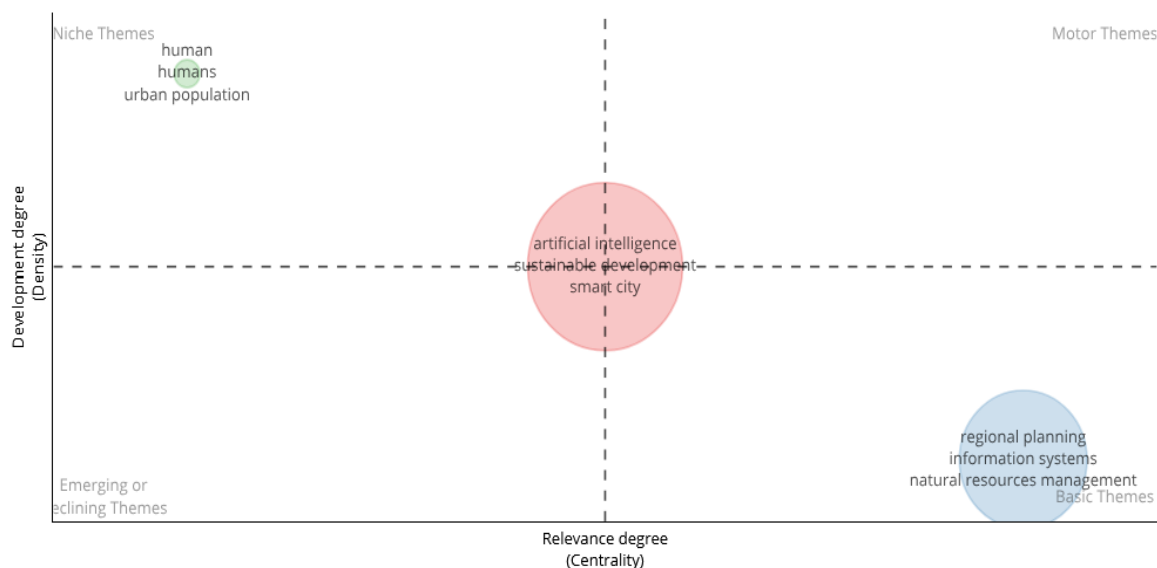
Conversely, the current state of the art (2023–2026) is characterized by an unprecedented convergence of terms, driven by massive surges in "Artificial Intelligence," "Smart City," and "Sustainability." The disproportionate size of the 2024–2025 keyword bubbles for these interconnected terms indicates a structural transition toward unified, macro-territorial research. Within this contemporary phase, artificial intelligence acts as the core technological driver, while smart city ecosystems serve as the spatial locus, and sustainable development forms the primary regulatory goal. This high-density cluster is supported by specialized, emerging methodologies that reflect a highly operational discipline. The recent growth of terms like "Optimisations" and "Spatial Data" points to advanced algorithmic resource-allocation techniques, while the rise of "Regional Planning" and "Qualitative Analysis" confirms a strong scholarly focus on institutional governance and socio-spatial equity indicators. This current distribution shows that the frontier of the discipline has moved decisively past technical exploration, establishing a mature, integrated framework where automated planning is explicitly evaluated through its systemic impact on territorial justice.

9. Strategic Mapping and Thematic Coherence

The co-occurrence network structure, mapped via Callon's centrality (relevance degree) and density (development degree), reveals a distinct tripartite organization of the scientific landscape, heavily influenced by an influx of authoritative, cutting-edge publications. The red cluster, representing the intersection of "Artificial Intelligence," "Sustainable Development," and "Smart City," functions as the primary motor theme of the domain. Situated in the upper-middle quadrant with high centrality and density, this cluster demonstrates strong internal coherence and extensive external connections. Its leading position is validated by top-tier network nodes—notably Farag (2025, PageRank = 0.220) and Bibri (2025, PageRank = 0.218)—which highlight how advanced digital twins and circular economy concepts are driving contemporary urban resilience. Conversely, the green cluster ("Human," "Humans," "Urban Population") operates as a highly developed niche theme in the top-left quadrant. While internally robust, its lower centrality indicates specialized sub-disciplinary tracking. This is reflected in its lower network scores, where leading papers focus on distinct public health,

gerontology, and socio-demographic urban indicators rather than core technological frameworks.

Figure 14: Thematic Map

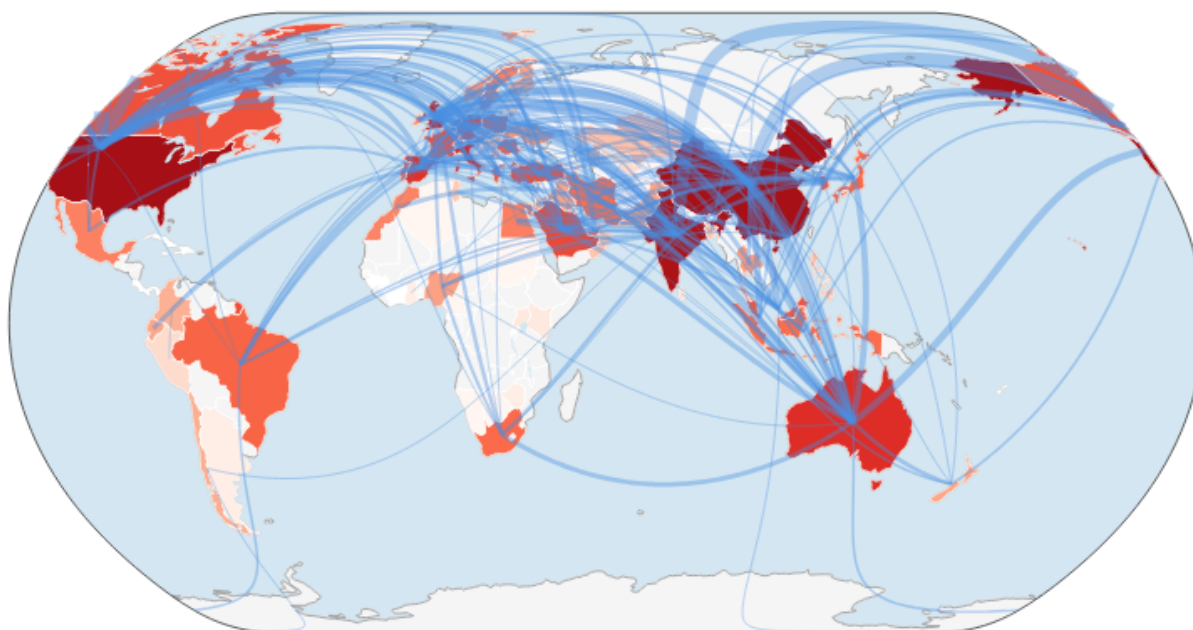


In contrast, the blue cluster, containing "Regional Planning," "Information Systems," and "Natural Resources Management," acts as the structural foundation of the entire field, occupying the bottom-right basic themes quadrant. This cluster displays high centrality but low density, operating as a broad, transdisciplinary umbrella that connects diverse applications without deep, localized technical specialization. The foundational nature of this cluster is explicitly demonstrated by its highest-ranking nodes—Delitheou (2025, PageRank =0.257) and Caragliu (2025, PageRank =0.242)—both emerging from the authoritative *Thematic Encyclopedia of Regional Science*. Finally, the substantial presence of unclustered nodes (n.a.) with a PageRank of zero reflects a long tail of recent, isolated papers (2023–2025). These pending nodes have not yet accumulated network links or met the Louvain algorithm's density thresholds (minfreq=14), representing a fertile frontier of isolated micro-themes that could restructure the network's future borders.

10. Countries' Collaboration World Map

The global spatial distribution of scientific production reveals a multi-polar research landscape anchored by highly developed research infrastructures across North America, Western Europe, and the Asia-Pacific region. Absolute volume metrics, represented by deep regional color intensities, identify the United States, Canada, China, and the United Kingdom as the dominant national poles directing the field's intellectual growth. This primary tier is supported by a highly productive European cluster containing Germany, France, Italy, Spain, and the Netherlands, alongside strong regional hubs such as Australia in Oceania, Brazil in South America, and South Africa and Saudi Arabia within the African-Middle Eastern axis. This geographic concentration shows that while the deployment of smart city technologies and social sustainability frameworks is a global imperative, the underlying academic discourse remains heavily concentrated within high-income economies and rapidly expanding Asian research systems.

Figure 15: World map of countries collaboration



The network architecture of international co-authorship links, mapped via cross-border relational vectors, exposes an intricate web of collaboration dominated by an intensive Transatlantic bridge and expanding Western-Asian axes. The United States and the United Kingdom operate as the primary super-hubs of this network, maintaining dense co-authorship lines that connect North American networks with a deeply integrated intra-European collaborative ecosystem. Concurrently, China, South Korea, India, and Japan drive strong regional knowledge flows while establishing robust bilateral links with both North American and European institutions. Furthermore, Australia functions as a critical structural bridge connecting Western methodologies with Eastern application contexts. This overall configuration reflects a hub-and-spoke model where emerging research economies route their partnerships through established Western and East Asian superpowers, reinforcing a global knowledge production system heavily driven by historical academic ties, shared digital infrastructures, and strategic North-North and North-South research alliances.

11. Discussion

The quantitative and spatial mappings extracted from the 2,999 documents in the Scopus dataset reveal an intense socio-technical transition in how automated governance intersects with spatial equity. The empirical results demonstrate that the research domain has shifted decisively from an early "Smart Cities 1.0/2.0" technical framework—which prioritized corporate-led data latency, infrastructure metrics, and economic cost reduction—toward a human-centric "Smart Cities 3.0" paradigm focused on social indicators, public well-being, and urban inclusion. This transition addresses a deep structural vulnerability in algorithmic urban design: the fact that optimizing spatial layouts via pure machine efficiency often masks deep socio-distributive imbalances, leading to "digital redlining" and the systematic marginalization of peripheral communities. By integrating Callon's strategic map metrics with international production trends, this section critically analyzes how global scholarship operationalizes multi-dimensional frameworks of territorial justice within automated environments.

The position of the red cluster ("Artificial Intelligence," "Sustainable Development," "Smart City") as a primary motor theme highlights a highly cohesive and rapidly expanding research domain at the forefront of urban planning. This cluster possesses high centrality and high density, meaning it has both a strong internal conceptual structure and extensive external connections across the literature. A defining feature of this cluster is its highly forward-looking

perspective, illustrated by prominent, high-PageRank nodes slated for 2025 publication, such as Farag (2025, PageRank =0.220) and Bibri (2025, PageRank =0.218). These papers integrate digital twins with climate resilience and circular metabolic cities, confirming that advanced computational intelligence is now being treated as a key infrastructure for long-term sustainability rather than an isolated technical tool. However, this intensive technological focus creates a sharp contrast with the green cluster ("Human," "Humans," "Urban Population"). Positioned squarely as a niche theme in the upper-left quadrant, the green cluster displays strong internal density but low external centrality. This configuration indicates that human-centric concerns, public health disparities, and demographic indicators (e.g., gerontology and patient preference) remain isolated in specialized sub-disciplinary silos. This disconnect implies that while the primary drivers of smart city literature are highly enthusiastic about technological optimization, they have not yet fully integrated socio-demographic indicators directly into core automated planning models.

This thematic separation is bridged by the blue basic themes cluster ("Regional Planning," "Information Systems," "Natural Resources Management"), which functions as the structural foundation for the entire field. Characterized by high centrality but low density, this cluster operates as a broad conceptual umbrella that connects various sub-topics without necessarily delving into highly specialized technical implementations. The authoritative nature of this cluster is demonstrated by its highest-ranking nodes—such as Delitheou (2025, PageRank =0.257) and Caragliu (2025, PageRank =0.242)—which emerge from the *Thematic Encyclopedia of Regional Science*. These encyclopedic entries act as foundational reference points that integrate information systems with resource management and territorial policy. This indicates that while regional planning provides the necessary regulatory and institutional frameworks for smart technologies, the low density within this cluster highlights a critical need to formalize clearer, more actionable metrics that explicitly connect broad planning principles with specific algorithmic justice outcomes. Furthermore, the large volume of unclustered documents (n.a.) with a PageRank of zero represents a long tail of very recent papers (2023–2025). Because these nodes have not yet accumulated citations or met the Louvain algorithm's density thresholds (minfreq=14), they represent an emerging frontier of micro-themes. Researchers should actively monitor these unclustered papers, as they likely contain early signals of a shift toward localized data justice, public data sovereignty, and participatory modeling.

From a geopolitical perspective, the spatial mapping of scientific production and international co-authorship networks exposes an unequal distribution of research power. Gross volume metrics show that absolute scientific production is heavily dominated by three major superpowers: China (806 documents), India (781 documents), and the United States (704 documents). This massive output reflects significant academic investment and large-scale domestic funding aimed at managing heavily populated, rapidly expanding municipal areas through big data and automated services. However, the Single Country Publication (SCP) versus Multiple Country Publications (MCP) ratios reveal that these three leading nations rely primarily on internal research capacity, with India showing one of the lowest international collaboration rates at 18.3%. This contrasts sharply with emerging research hubs like Saudi Arabia (48.8% MCP) and Malaysia (48.3% MCP), as well as highly integrated economies like Australia (41.3% MCP), which rely heavily on cross-border co-authorship networks to expand their research capacity. Crucially, looking at relative citation impact per document reverses the absolute volume hierarchy. While China drives absolute publication volume, it registers a modest average citation rate of 10.80, whereas the United States maintains a balanced average of 20.70. Meanwhile, Australia leads the entire domain with an extraordinary average citation score of 53.20, and France and South Korea follow with 48.90 and 39.60 citations per document. This polarization divides the global landscape into self-sufficient research giants with vast internal infrastructures, and smaller, highly specialized economies that generate the

highly influential theoretical frameworks, data justice principles, and social sustainability metrics that direct global research.

12. Conclusion

This study has provided a comprehensive scientometric review of 2,999 peer-reviewed documents extracted from the Scopus database, mapping the intellectual, geographic, and conceptual evolution of research intersecting smart cities, artificial intelligence, and territorial justice between 2004 and 2026. By applying computational science mapping workflows, the analysis successfully resolved the three core research questions established at the outset. Regarding RQ1, the macro-structural evolutionary trajectory follows a classic logistic growth model ($R^2=0.678$), showing a slow, fragmented incubation phase (2004–2014) followed by an unprecedented post-2020 exponential expansion phase driven by an annual growth rate of 28.05%. This rapid acceleration reflects an intensive global academic effort to address the institutional, socio-economic, and distributive implications of algorithmic governance as automated systems become core mechanisms of public administration.

In response to RQ2, the mapping of leading scientific actors identified a concentrated global distribution of research power alongside a hub-and-spoke international collaboration network. Geographically, China, India, and the United States function as the primary production engines of the field, supported by highly productive European clusters (the United Kingdom, Italy, and Spain) and advanced knowledge economies such as Australia. While the absolute volume of literature is heavily driven by large domestic investments within the top Asian and North American superpowers, relative intellectual influence is heavily directed by specialized networks in Australia, France, and South Korea, which achieve the highest average citations per document. Structurally, the publication venue *Sustainability* (Switzerland) serves as the absolute dominant locus of the domain, operating as a primary clearinghouse that bridges economic and social science research with smart municipal applications. This venue is closely linked to prolific intellectual anchors like Tan Yigitcanlar (Queensland University of Technology), who shapes the conceptual core of the field through well-institutionalized research networks spanning Australia, North America, and East Asia.

Regarding RQ3, the conceptual and thematic architecture of the domain reveals a significant paradigm shift from purely engineering-focused urban metrics to human-centric indicators of spatial equity. Lexical analysis shows that the core of the field is built on a highly cohesive vocabulary where "artificial intelligence" (915 occurrences) and "smart city" (534 occurrences) are balanced by "sustainable development" and "sustainability". Callon's thematic mapping confirms that while the technological intersections of AI and smart cities drive the field as a highly coherent motor theme, human-centric considerations, demographic indicators, and public health realities are still isolated as specialized niche themes. This structural configuration underscores that while global scholarship has successfully established the theoretical necessity of embedding territorial justice into smart infrastructures, a critical empirical gap remains in operationalizing specific, statistically auditable indices that directly counter automated exclusion and digital redlining.

Conclusively, this study delivers important theoretical and policy implications for the future of regional planning. Theoretically, it provides a comprehensive framework that upgrades traditional social sustainability indicators to encompass digital dimensions of vulnerability, organizing algorithmic governance around a tripartite framework of distributive, procedural, and recognitional justice. For policymakers and municipal administrators, the empirical findings highlight that technological innovation cannot be treated as an independent path to efficiency; instead, it must be guided by regulatory frameworks that ensure algorithmic accountability, public data sovereignty, and participatory co-design. The principal limitation of this study stems from a metadata constraint within the downloaded Scopus dataset, which

registered an absence of cited references, temporarily preventing the execution of citation-network coupling and algorithmic historiographs. Future research trajectories should resolve this technical limitation, extend the analysis to multi-word conceptual nuances using higher n-gram settings, and actively explore the large volume of currently unclustered papers to capture emerging micro-themes before they fully restructure the boundaries of the domain.

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