

## ARTICLE / ARAŞTIRMA

## Spatial Justice and Spatial Data Infrastructures in the Context of Urban Transformation: A Bibliometric Analysis (1997–2025)

*Kentsel Dönüşüm Bağlamında Mekânsal Adalet ve Mekânsal Veri Altyapıları: Bibliyometrik Bir İnceleme (1997–2025)*

Fatih Taktak

Uşak University, Department of Urban and Regional Planning, Faculty of Architecture and Design; Graduate School, Head of Urban Transformation Graduate Program, Uşak, Türkiye

## ABSTRACT

This study presents the first comparative bibliometric analysis of two foundational but traditionally siloed domains within urban transformation research: spatial justice and spatial data infrastructures (SDI). While spatial justice scholarship emphasizes equity, participatory governance, and rights-based urbanism, SDI research has primarily focused on geospatial technologies, data management, and digital planning. Despite these differences, growing concerns about digital inequality, algorithmic exclusion, and the politics of data reveal an emerging thematic convergence. Drawing on 608 peer-reviewed journal articles published between 1997 and 2025 in the Web of Science Core Collection, the study applies bibliometric methods (Bibliometrix R-package and Biblioshiny) to map publication trends, collaboration networks, keyword co-occurrence, thematic clusters, and historiographic trajectories. Findings indicate that SDI-related research is characterized by rapid technological advancement and interdisciplinary collaboration, whereas spatial justice remains more fragmented but provides conceptual depth. A shared research frontier is identified, highlighting a gap in integrating justice-oriented planning principles with technical infrastructures. The study proposes an integrative framework situating SDIs within equity-driven urban governance, offering insights for planners and policymakers seeking to institutionalize inclusivity, transparency, and representational justice in data-informed urban transformation.

**Keywords:** Digital urbanism; spatial data infrastructure; spatial inequality; spatial justice; urban governance; urban transformation.

## ÖZ

Bu çalışma, kentsel dönüşüm araştırmalarının iki temel ancak geleneksel olarak ayrı ilerleyen alanı olan mekânsal adalet ve mekânsal veri altyapılarının (SDI) karşılaştırmalı bibliyometrik analizini sunmaktadır. Mekânsal adalet literatürü eşitlik, katılımcı yönetim ve hak temelli kentleşmeye odaklanırken; SDI araştırmaları daha çok coğrafi bilgi teknolojileri, veri yönetimi ve dijital planlama süreçlerine yönelmiştir. Bu farklılıklara rağmen, dijital eşitsizlik, algoritmik dışlanma ve verinin siyaseti gibi konular etrafında giderek artan bir kavramsal yakınsama gözlenmektedir. 1997–2025 yılları arasında Web of Science Core Collection’da yayımlanmış 608 hakemli makaleye dayanarak yürütülen bu çalışma, Bibliometrix R paketi ve Biblioshiny arayüzü kullanılarak yayın eğilimlerini, işbirliği ağlarını, anahtar kelime eş-oluşumlarını, tematik kümeleri ve tarihsel atıf akışlarını incelemiştir. Bulgular, SDI araştırmalarının hızlı teknolojik gelişim ve disiplinler arası işbirliğiyle öne çıktığını; mekânsal adalet çalışmalarının ise daha parçalı olmakla birlikte güçlü bir kuramsal derinlik sunduğunu göstermektedir. Ortaya çıkan ortak araştırma alanı, adalet odaklı planlama ilkelerinin teknik altyapılarla bütünleştirilmesi gereğine işaret etmektedir. Çalışma, SDI’ların eşitlik temelli kentsel yönetim çerçeveleriyle uyumlaştırılmasına yönelik bütünleştirici bir yaklaşım önererek, kapsayıcılık, şeffaflık ve temsili adaletin veri odaklı planlama süreçlerinde kurumsallaştırılmasına katkı sağlamaktadır.

**Anahtar sözcükler:** Dijital kentleşme; mekânsal veri altyapısı; mekânsal eşitsizlik; mekânsal adalet; kentsel yönetim, kentsel dönüşüm.

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Correspondence: Fatih Taktak  
e-mail: fatih.taktak@usak.edu.tr

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## 1. Introduction

Urban transformation encompasses more than physical restructuring; it involves systemic changes in socio-technical configurations, governance regimes, and spatial imaginaries (Lees, 2008; Collins, 2021; Ruming et al., 2021). While these processes may stimulate innovation and economic growth, they frequently intensify urban inequalities, resulting in socio-spatial exclusion, uneven development, and the displacement of marginalized communities. In this study, the term “urban transformation” is used as an umbrella concept encompassing processes such as urban regeneration, renewal, redevelopment, and restructuring, which are more commonly employed in international urban studies literature (Lees, 2008; Couch et al., 2011; Roberts et al., 2016; Chin et al., 2025). This conceptualization is also reflected in the bibliometric search strategy, where “urban transformation” is analyzed alongside these related terms to ensure consistency with global academic discourse and to capture a broader spectrum of urban change processes.

In response, the concept of spatial justice has gained prominence as a normative framework for assessing the socio-political consequences of urban redevelopment (Soja, 2010; Fainstein, 2014). Rooted in Lefebvre’s (1991) notion of the “right to the city,” this perspective calls for equitable access to urban resources, inclusive governance structures, and the redistribution of spatial opportunities.

In parallel, spatial data infrastructures (SDIs) have become essential pillars of digital-era urban planning. Initially designed to promote inter-institutional data sharing and support evidence-based decision-making, SDIs are widely regarded as instruments for enhancing planning transparency and administrative efficiency (Rajabifard et al., 2006; Sørensen et al., 2021). However, their implementation may inadvertently reinforce spatial injustices, particularly in contexts characterized by fragmented governance or unequal digital access (Kitchin, 2014; Qureshi et al., 2021; Yu et al., 2024).

Recent international policy agendas increasingly advocate for citizen-centered digital governance, emphasizing participatory approaches that prioritize rights, inclusion, and transparency. For instance, UN-Habitat (2020) underscores that smart city initiatives must be grounded in principles of people-centered development to prevent exacerbating digital divides and technocratic exclusion, especially in the Global South and under-represented communities.

Nevertheless, spatial justice and SDI have largely developed as separate and siloed fields of research. While the former is anchored in normative, rights-based discourse, the latter is rooted in technical rationality, emphasizing geospatial optimization and infrastructure design (Budhathoki et al., 2008; Ahmad, 2025). This disciplinary disconnection creates a critical blind spot in understanding how digital governance frame-

works shape equity, representation, and democratic participation in urban contexts (Katz, 2019).

Case studies such as the Galataport redevelopment in Istanbul exemplify how technocratic planning, when decoupled from justice-oriented principles, may produce exclusionary outcomes (Erbil & Erbil, 2024). Similarly, unless explicitly designed to incorporate participatory and redistributive mechanisms, many smart city models fail to address distributive and procedural equity (Odendaal, 2015; Yigitcanlar et al., 2019; Sadowski, 2020).

This study contributes to the literature by systematically bridging these previously disconnected research domains, spatial justice and spatial data infrastructure within the context of urban transformation. Although earlier studies have examined these themes independently, this research is the first to apply a comparative bibliometric approach to uncover their conceptual intersections, scholarly evolution, and potential for theoretical and practical integration. Through dual-cluster analysis, it maps the trajectories of both domains and identifies a shared frontier where digital governance and spatial equity intersect. This contributes to ongoing debates on how data-driven urbanism can be reconciled with rights-based planning to foster more inclusive, transparent, and just urban futures.

To fill this gap, the study analyzes 608 peer-reviewed journal articles published between 1997 and early 2025, employing the *Bibliometrix R-package* and *Biblioshiny* interface to examine publication trends, collaboration patterns, keyword configurations, and thematic developments within both literatures.

The contribution of this research is threefold: First, it provides the first bibliometric synthesis that explicitly compares spatial justice and SDI within the urban transformation discourse. Second, it identifies emerging conceptual overlaps and enduring thematic silos across these interdisciplinary strands. Third, it proposes an integrative perspective that links justice-oriented urbanism with digital infrastructure governance, thereby contributing to ongoing debates on digital governance and equitable urban development (Barns, 2018; Shelton et al., 2015; UN-Habitat, 2020).

Beyond descriptive mapping, the analysis shows that the intersection between spatial justice and SDI emerges through governance-oriented themes such as participation, sustainability, and planning. Rather than indicating a fully integrated research domain, these patterns point to an uneven form of convergence shaped by disciplinary boundaries and institutional contexts.

The primary contribution of this study is conceptual, supported by empirical bibliometric evidence, as it reframes SDI not merely as a technical infrastructure but as a governance mechanism through which spatial justice can be operationalized within urban transformation processes. The study also contributes methodologically by employing a dual-cluster com-

parative design that enables a systematic examination of relationships between previously disconnected research domains.

Accordingly, the study is guided by three analytical questions:

- Which thematic bridges are emerging between the spatial justice and SDI literatures,
- Whether hybrid research domains are beginning to form at their intersection, and
- How these convergences vary across geographic and institutional contexts.

## 2. Theoretical Background and Conceptual Linkages

Urban transformation has been theorized through a wide range of disciplinary lenses, acquiring different meanings across historical periods and geographical contexts. Since the 1970s, it has been associated with capital reinvestment in inner cities, the restructuring of post-industrial urban landscapes, and broader spatial reconfigurations (Smith, 1979; Lees, 2008; Hoffmann et al., 2023). Among its multiple forms, gentrification has emerged as a particularly visible and contentious manifestation of the tension between urban redevelopment and social justice (Marcuse, 1985; Anguelovski et al., 2019; Verlaan & Hochstenbach, 2022). The displacement of low-income populations, the financialization of housing markets, and the privatization of public spaces are frequently cited outcomes of neoliberal urban governance (Peck & Tickell, 2002; Harvey, 2017).

To interrogate the inequalities embedded within these dynamics, spatial justice has been proposed as a normative and analytical framework. Scholars such as Soja (2013) and Moroni (2020) argue that urban space is not a neutral backdrop, but a socio-political construct shaped by power relations. Lefebvre's (1991) concept of the "right to the city" asserts that urban residents are entitled not only to access space but also to participate meaningfully in its transformation. Expanding upon this, Fainstein's (2013) "just city" framework foregrounds inclusive governance, fair resource distribution, and justice-driven planning as central tenets of urban theory. In this respect, spatial justice can be understood as a multidimensional concept encompassing distributive, procedural, and participatory dimensions of urban governance.

In parallel, the increasing digitalization of urban governance has positioned SDIs as key instruments in contemporary decision-making. Designed to enable the integration and exchange of geospatial information across institutional boundaries, SDIs aim to support evidence-based and transparent planning processes (Rajabifard et al., 2006; 2010). However, they are far from politically neutral. Scholars such as Budhathoki et al. (2008) and Kitchin (2014) caution that SDI design and implementation must be critically examined in terms of data ownership, access control, and intended use. Concerns

over unequal digital access, algorithmic bias, and technocratic interpretations of participation further underscore how SDIs can potentially reinforce rather than alleviate spatial injustices (Yigitcanlar et al., 2019). In this sense, SDIs should not be viewed as neutral technical systems, but as socio-technical infrastructures shaped by power relations, data governance structures, and institutional arrangements.

Despite growing scholarly attention to both spatial justice and SDI, theoretical models that explicitly link these domains within the context of urban transformation remain underdeveloped. In particular, the degree to which urban transformation policies align or fail to align with justice-oriented principles, and how digital infrastructures mediate that alignment, is insufficiently explored. In data-driven planning contexts, fundamental questions of "who decides and for whom" are often left unaddressed. While some empirical cases illustrate the capacity of SDIs to support participatory governance, others expose their limitations in fostering meaningful inclusion (Erbil & Erbil, 2024).

This study argues that urban transformation, spatial justice, and SDI should be examined not as isolated constructs, but as interdependent frameworks shaped by political, technological, and social entanglements. Uncovering the intersections among these domains highlights that achieving just urban transformation requires more than technical expertise, it demands inclusive governance structures, critical reflexivity, and institutionalized mechanisms for sustained public participation.

Building on the above discussions, this study conceptualizes urban transformation as the broader structural context, spatial justice as a multidimensional normative framework (including distributive, procedural, and participatory dimensions), and SDIs as governance instruments that mediate how data-driven planning processes shape urban outcomes. This conceptualization provides the analytical foundation for the bibliometric analysis by linking theoretical constructs to observable thematic patterns such as governance, participation, and digital infrastructure.

These conceptual distinctions also inform the analytical structure of the bibliometric study. In particular, governance, participation, and sustainability are treated as key thematic dimensions through which the relationship between spatial justice and SDIs is examined, enabling the interpretation of keyword co-occurrence patterns and thematic clusters within a theoretically grounded framework.

## 3. Materials and Methods

### 3.1. Data Source and Search Strategy

This study employed a bibliometric methodology to systematically map the scholarly landscape and identify conceptual intersections between urban transformation, spatial justice, and SDI. As a quantitative analytical technique, bibliometric

**Table 1.** Data collection criteria and search parameters used in the bibliometric analysis

| Item                    | Details                                                                                                                                                                                                                                                                                                                          |
|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Keywords                | ("Urban Transformation" OR "Urban Regeneration" OR "Urban Redevelopment" OR "Urban Restructuring") AND ("Spatial Justice" OR "Spatial Equity" OR "Right to the City" OR "Planning Justice") AND ("Spatial Data Infrastructure" OR "Geospatial Data Infrastructure" OR "GIS" OR "Open Spatial Data" OR "Geospatial Data Sharing") |
| Boolean Operators       | Boolean logic: AND, OR                                                                                                                                                                                                                                                                                                           |
| Timeframe               | 1997–2025                                                                                                                                                                                                                                                                                                                        |
| Language                | English                                                                                                                                                                                                                                                                                                                          |
| Data Source             | Web of Science Core Collection                                                                                                                                                                                                                                                                                                   |
| Included Document Types | Peer-reviewed journal articles and reviews only                                                                                                                                                                                                                                                                                  |
| Excluded Document Types | Conference papers, books, book chapters, theses, research reports, technical/government documents, editorial materials, working papers                                                                                                                                                                                           |
| Search Period           | January – May 2025                                                                                                                                                                                                                                                                                                               |

analysis facilitates the assessment of publication trends, leading contributors, international collaborations, and the intellectual structure of a research domain.

The dataset was compiled through a comprehensive search in the Web of Science Core Collection, covering publications from 1997 to early 2025. Boolean operators (AND, OR) were applied to combine relevant keywords, including: "urban transformation," "spatial justice," "spatial data infrastructure," "GIS," "spatial equity," and "urban regeneration." The search was restricted to peer-reviewed journal articles and review papers, and results were exported in both RIS and BibTeX formats for compatibility with analytical tools.

### 3.2. Thematic Search Design and Queries

The inclusion of multiple related terms (e.g., urban regeneration, renewal, redevelopment) reflects the use of "urban transformation" as an umbrella concept in this study, thereby improving the international comparability and conceptual breadth of the dataset. The analysis was structured around two thematic clusters, both sourced from the *Web of Science Core Collection*. Only English-language, peer-reviewed articles and reviews published between 1997 and 2025 were included. Conference proceedings, book chapters, theses, editorials, and other forms of gray literature were excluded to ensure methodological consistency.

#### 3.2.1. Cluster A: Urban Transformation and Spatial Justice

This cluster focused on the intersection of urban transformation and spatial justice. The following Boolean search string was applied to the Title, Abstract, and Keyword fields:

("Urban Transformation" OR "Urban Regeneration" OR "Urban Redevelopment" OR "Urban Renewal" OR "Urban Restructuring" OR "Urban Redevelopment Projects") AND ("Spatial Justice" OR "Spatial Equity" OR "Social Justice" OR "Right to the City" OR "Planning Justice" OR "Urban Equity").

#### 3.2.2. Cluster B: Urban Transformation and SDI

The second cluster focused on the relationship between urban transformation and SDI. The Boolean query used was:

("Urban Transformation" OR "Urban Regeneration" OR "Urban Redevelopment" OR "Urban Renewal" OR "Urban Restructuring" OR "Urban Redevelopment Projects") AND ("Spatial Data Infrastructure" OR "Geospatial Data Infrastructure" OR "Geographic Information Systems" OR "Spatial Data Management" OR "Open Spatial Data" OR "Spatial Data Sharing" OR "GIS OR SDI")

### 3.3. Inclusion and Exclusion Criteria

The inclusion and exclusion criteria are summarized as follows:

#### Inclusion Criteria

- Document type: Peer-reviewed journal articles and review papers
- Language: English
- Timeframe: 1997 to May 2025
- Database: Web of Science Core Collection
- Search fields: Title, Abstract, and Keywords

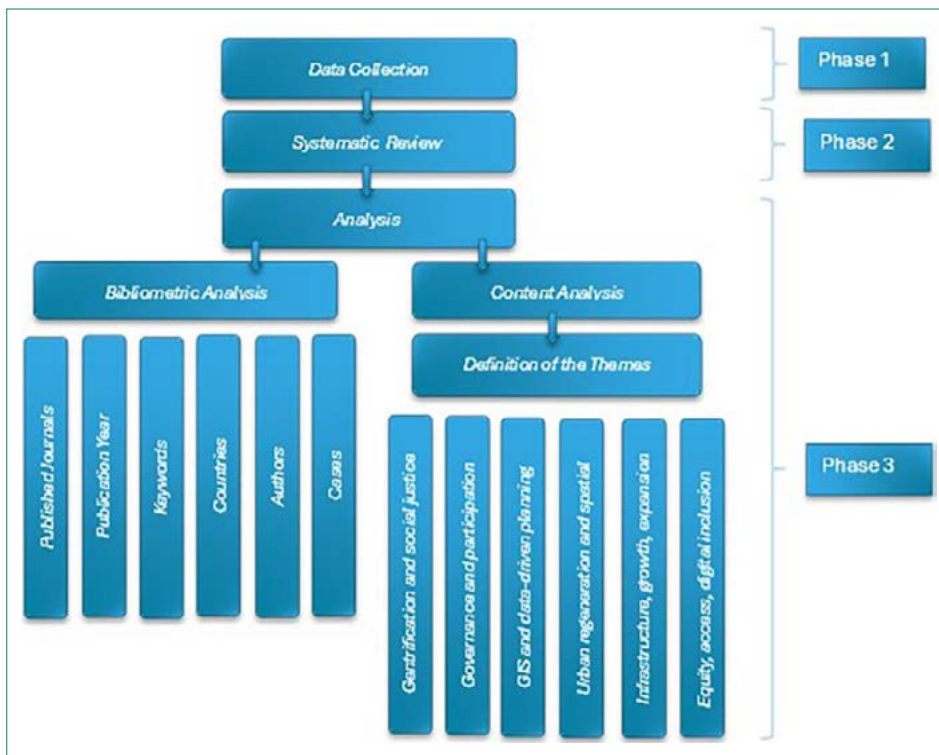
#### Exclusion Criteria

- Document types excluded: Conference papers, book chapters, books, theses, reports, editorials, and other gray literature.

These dual-query strategies formed the basis for a comparative bibliometric analysis of the intersections between:

- (1) urban transformation and spatial justice, and
- (2) urban transformation and spatial data infrastructure.

Table 1 below summarizes the data collection criteria and search parameters.



**Figure 1.** Bibliometric and content analysis process: A three-stage methodological framework.

### 3.4. Analytical Tools and Workflow

All bibliographic records were processed using the *Bibliometrix R-package* and the *Biblioshiny* web interface, an open-source toolset developed by Aria and Cuccurullo (2017) for comprehensive bibliometric and scientometric analysis.

Data preprocessing involved:

- Standardizing author names (e.g., “Smith J.” vs. “Smith, John”)
- Harmonizing journal abbreviations
- Removing duplicate records

The analysis covered the following components:

- Annual publication trends
- Top contributing authors and journals
- Country-level scientific output and collaboration
- Keyword co-occurrence networks
- Thematic clustering
- Citation analysis of most influential publications
- Historiographic mapping of conceptual developments

The methodological workflow followed a three-stage sequential structure combining quantitative and qualitative techniques (Fig. 1):

1. Stage I – Systematic literature retrieval and data extraction

2. Stage II – Parallel bibliometric and content analysis

3. Stage III – Integration of insights to identify dominant themes and research trajectories

While bibliometric analysis emphasized structural attributes (e.g., co-authorship, keyword networks), content analysis enabled the identification of emerging thematic domains, including:

- Gentrification and justice
- Participation and governance
- Data-driven planning
- Urban regeneration and transition
- Infrastructure and economic growth
- Digital equity and access

This mixed-methods framework offers a comprehensive lens through which to understand both the conceptual convergence and divergence across the spatial justice and SDI literatures in the context of urban transformation.

While bibliometric analysis was employed to map structural patterns such as co-authorship networks, keyword co-occurrence, and thematic clustering, an interpretive content analysis was also conducted to provide contextual and conceptual depth to these patterns. Specifically, clusters identified through co-word and thematic mapping techniques were qualitatively examined to interpret their underlying



**Table 2.** Comparative bibliometric indicators of the literature on spatial justice and SDI in the context of urban transformation

| Urban transformation and spatial justice |           | Urban transformation and SDI     |           |
|------------------------------------------|-----------|----------------------------------|-----------|
| Description                              | Results   | Description                      | Results   |
| Main information about data              |           | Main information about data      |           |
| Timespan                                 | 2000:2025 | Timespan                         | 1997:2025 |
| Sources (Journals, Books, etc)           | 160       | Sources (Journals, Books, etc)   | 219       |
| Documents                                | 219       | Documents                        | 389       |
| Annual growth rate %                     | 4.49      | Annual growth rate %             | 10.87     |
| Document average age                     | 6.8       | Document average age             | 7.2       |
| Average citations per doc                | 13.77     | Average citations per doc        | 13.95     |
| References                               | 11086     | References                       | 16897     |
| Document contents                        |           | Document contents                |           |
| Keywords plus (ID)                       | 404       | Keywords plus (ID)               | 744       |
| Author's keywords (DE)                   | 828       | Author's keywords (DE)           | 1420      |
| Authors                                  |           | Authors                          |           |
| Authors                                  | 415       | Authors                          | 1269      |
| Authors of single-authored docs          | 94        | Authors of single-authored docs  | 53        |
| Authors collaboration                    |           | Authors collaboration            |           |
| Single-authored docs                     | 95        | Single-authored docs             | 55        |
| Co-authors per doc                       | 1.96      | Co-authors per doc               | 3.63      |
| International co-authorships %           | 16.44     | International co-authorships %   | 19.79     |
| Document types                           |           | Document types                   |           |
| Article                                  | 178       | Article                          | 286       |
| Article; book chapter                    | 11        | Article; book chapter            | 12        |
| Article; early access                    | 3         | Article; early access            | 2         |
| Article; proceedings paper               | 4         | Article; proceedings paper       | 3         |
| Editorial material                       | 1         | Book                             | 1         |
| Editorial material; book chapter         | 2         | Editorial material; book chapter | 1         |
| Letter                                   | 1         | Proceedings paper                | 80        |
| Proceedings paper                        | 13        | Review                           | 4         |
| Review                                   | 6         |                                  |           |

meanings and to categorize them into broader thematic domains (e.g., governance, digital equity, participation, and urban regeneration).

This interpretive step enabled the translation of quantitative bibliometric outputs into theoretically meaningful insights, allowing for the identification of conceptual convergence, disciplinary boundaries, and emerging hybrid research domains. In this way, the study integrates quantitative mapping with qualitative reasoning, ensuring that bibliometric findings are not treated as purely descriptive outputs but as analytically grounded representations of evolving research trajectories.

#### 4. Analysis and Findings

A comparative bibliometric analysis was carried out to examine two thematic domains within urban transformation research: (1) the intersection of urban transformation and spatial justice, and (2) the relationship between urban transformation and SDI. Utilizing the *Bibliometrix R-package* and its *Biblioshiny* interface, the analysis identified notable distinctions in terms of publication volume, growth dynamics, conceptual focus, and collaboration patterns between the two literatures.

As shown in Table 2, the SDI-related literature comprises a higher number of publications (389 documents) compared

| Analysis Category                                                                                                                                   | Methodological Approach                                                                                                                                          | Analytical Objectives                                                                                                                                |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Descriptive Bibliometrics</b> <ul style="list-style-type: none"> <li>• Annual Scientific Production</li> <li>• Most Relevant Sources</li> </ul>  | <ul style="list-style-type: none"> <li>• Author Collaboration Networks</li> <li>• Country-Level Scientific Output &amp; Collaboration</li> </ul>                 | <ul style="list-style-type: none"> <li>• Identify temporal publication trends</li> <li>• Assess journal and source productivity</li> </ul>           |
| <b>Conceptual Structure Analysis</b> <ul style="list-style-type: none"> <li>• Keyword Co-occurrence networks</li> <li>• Thematic Mapping</li> </ul> | <ul style="list-style-type: none"> <li>• Keyword Co-occurrence Networks</li> <li>• Thematic Mapping</li> <li>• Multiple Correspondence Analysis (MCA)</li> </ul> | <ul style="list-style-type: none"> <li>• Detect research themes and clusters</li> <li>• Explore thematic evolution and conceptual density</li> </ul> |
| <b>Historiographic Analysis</b> <ul style="list-style-type: none"> <li>• Most Cited Documents</li> <li>• Citation Networks</li> </ul>               | <ul style="list-style-type: none"> <li>• Most Cited Documents</li> <li>• Citation Networks</li> <li>• Historiographic Map</li> </ul>                             | <ul style="list-style-type: none"> <li>• Trace intellectual development</li> <li>• Identify influential works and citation trajectories</li> </ul>   |

**Figure 2.** Categories of bibliometric analysis, methodological approach, and analytical objectives.

to the spatial justice corpus (219 documents) and exhibits a significantly greater annual growth rate (10.87% vs. 4.49%), reflecting its rapid expansion in response to the global digitalization of planning since the early 2000s. Average citation rates are comparable across both domains (13.95 for SDI and 13.77 for spatial justice), indicating similar academic influence.

Keyword diversity is markedly higher in the SDI domain, with 1,420 author keywords and 744 Keywords Plus terms, compared to 828 and 404, respectively, in the spatial justice literature. This reflects SDI's broader disciplinary reach, incorporating fields such as GIS, geoinformatics, and digital governance.

Author collaboration patterns also differ significantly. SDI-related publications demonstrate a higher average number of co-authors per article (3.63 vs. 1.96) and a greater share of international co-authorships (19.79% vs. 16.44%), indicating the technical and globally networked nature of spatial data research.

Differences in document types further underline the divergent scholarly cultures of the two fields. The spatial justice literature features more review articles, indicating its conceptual and normative orientation. In contrast, the SDI literature includes a higher number of conference proceedings and practice-based contributions, highlighting its applied and solution-driven focus.

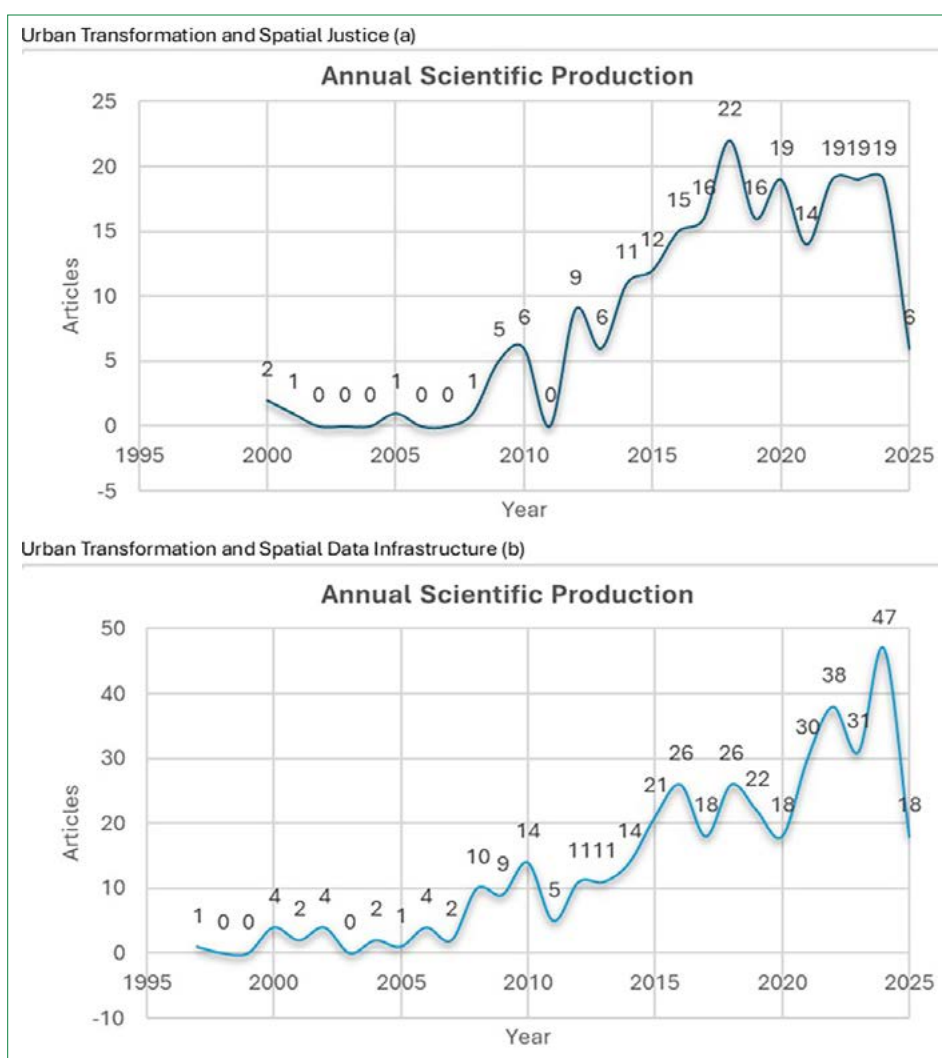
These findings suggest that the SDI literature is characterized by rapid growth, interdisciplinary engagement, and technical collaboration, while the spatial justice literature remains grounded in critical urban theory and normative discourse. The conceptual intersection of these literatures particularly regarding the societal implications of digital and data-driven urban planning has not yet been fully explored.

To address this research gap, the study further investigates how SDI can be conceptualized not only as a technical tool but also as a governance mechanism capable of promoting spatial justice. The convergence of these fields points to the necessity for integrated frameworks that critically assess the distributive, procedural, and participatory dimensions of digital urban governance.

The bibliometric indicators analyzed encompass a range of analytical categories, including publication trends (Annual Scientific Production), source impact (Most Relevant Sources), authorship and collaboration structures (Author Collaboration Networks), geographic distribution (Country Scientific Production & Collaboration), keyword configurations (Keyword Co-occurrence), thematic clusters (Thematic Maps), and citation patterns (Most Cited Documents & Historiographic Maps).

Figure 2 illustrates the overall bibliometric framework, classifying the types of analysis performed, the methodological categories employed, and the analytical objectives pursued. The framework integrates four key components: (i) descriptive performance indicators (e.g., annual output), (ii) actor and source mapping (e.g., key authors, journals, countries), (iii) conceptual structure analysis (e.g., co-word analysis and thematic evolution), and (iv) historiographic mapping (e.g., citation trajectories and landmark studies). Collectively, these components facilitate a multidimensional understanding of how spatial justice and SDI discourses are evolving within the broader field of urban transformation research.

To avoid descriptive repetition and enhance analytical depth, the interpretation of visual outputs is integrated with critical discussion throughout the Results section. Rather than reiterating graphical information, the analysis focuses on identifying underlying patterns, conceptual implications, and their rel-



**Figure 3.** Comparative distribution of annual publication counts on urban transformation in the contexts of spatial justice and SDI (1997–2025).

SDI: Spatial data infrastructures.

evance to broader debates on digital governance and spatial justice. This approach ensures that visual materials support, rather than duplicate, the interpretive narrative.

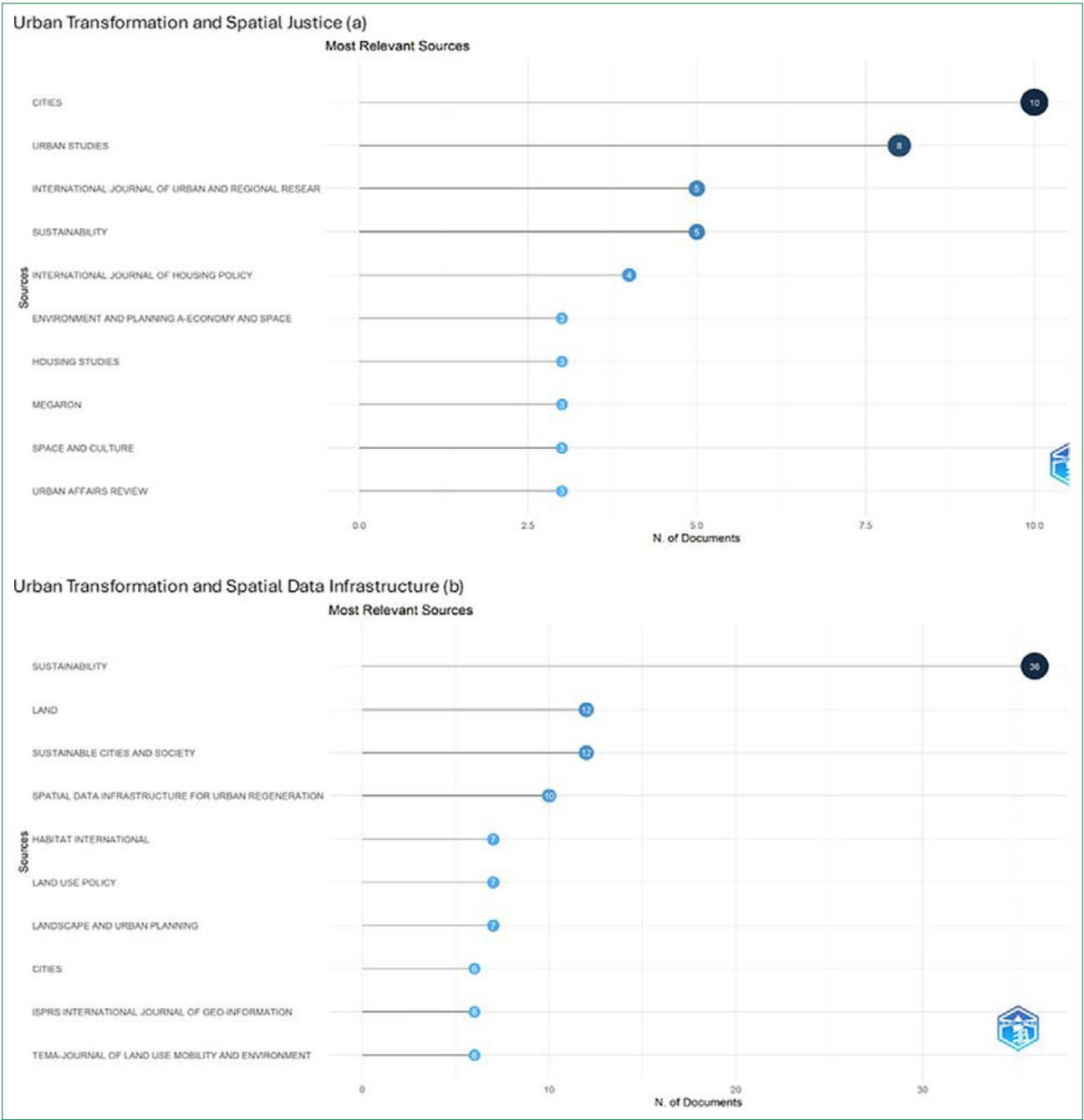
#### 4.1. Annual Scientific Production

Figure 3 presents a comparative overview of annual publication trends at the intersection of urban transformation with two thematic domains: spatial justice and SDI. The findings reveal that studies addressing spatial justice in the context of urban transformation were virtually absent before 2000. A notable surge occurred after 2010, with the period from 2015 to 2020 representing the peak of scholarly activity, during which annual publication counts ranged between 15 and 22. The apparent decline in 2025 should be interpreted cautiously, as it may reflect incomplete indexing due to the ongoing nature of the publication year.

In contrast, the literature on urban transformation linked to SDI began to emerge earlier and demonstrated steady growth following 2005. Since the early 2010s, a consistent upward trend has been observed, culminating in a peak of 47 publications in 2024. This growth highlights the increasing relevance of digitalization, geospatial data management, and smart city frameworks within urban studies.

Taken together, the comparative trajectories suggest that SDI-related research has evolved as a technically driven, interdisciplinary, and rapidly expanding field. Conversely, spatial justice scholarship has followed a more gradual trajectory, characterized by conceptual depth and normative inquiry, albeit with lower publication volumes. Importantly, the convergence of these two strands since the 2010s signals the emergence of a new research frontier one that critically explores how data-driven urban governance intersects with principles of social justice.





**Figure 4.** Most relevant sources in the literature on urban transformation and its linkages to spatial justice and SDI.

This convergence reinforces the conceptual integration proposed in this study, offering timely insights into ongoing debates surrounding equity, digital infrastructures, and governance in the context of urban transformation.

4.2. Most Relevant Sources

This section identifies the most frequently cited academic journals within the two distinct literature sets related to urban transformation: spatial justice and SDI. Figure 4 provides a

comparative visualization of these sources, offering valuable insight into the disciplinary orientations and knowledge domains that structure scholarly engagement with each thematic strand.

A review of the most influential publication outlets reveals a clear disciplinary divergence between the two domains. Journals frequently cited in the spatial justice literature such as *Cities*, *Urban Studies*, *International Journal of Urban and Regional Research*, *Housing Studies*, and *Urban Affairs Review* are embedded in critical urban studies and the broader social sciences. These

**Table 3.** Most productive authors and fractional publication count in the urban transformation literature: Spatial justice vs. SDI

| Urban transformation and spatial justice |          |                           | Urban transformation and SDI |          |                           |
|------------------------------------------|----------|---------------------------|------------------------------|----------|---------------------------|
| Authors                                  | Articles | Articles (Fractionalized) | Authors                      | Articles | Articles (Fractionalized) |
| Arthurson K                              | 2        | 1.33                      | Wang H                       | 11       | 2.73                      |
| Chen H                                   | 2        | 0.58                      | Kim JJ                       | 5        | 1.58                      |
| Diaz Parra I                             | 2        | 1.50                      | Wang Y                       | 5        | 1.29                      |
| Eder M                                   | 2        | 1.00                      | Chen J                       | 4        | 0.68                      |
| Feitosa F                                | 2        | 0.67                      | Li J                         | 4        | 0.68                      |
| Hearne R                                 | 2        | 1.50                      | Liu Y                        | 4        | 0.87                      |
| Hewidy H                                 | 2        | 1.50                      | Shen Q                       | 4        | 1.04                      |
| Li X                                     | 2        | 0.67                      | Wang C                       | 4        | 0.76                      |
| Marques JL                               | 2        | 0.67                      | Xie Y                        | 4        | 0.84                      |
| Oz O                                     | 2        | 1.00                      | Zhang X                      | 4        | 0.87                      |

SDI: Spatial data infrastructures.

journals commonly address normative themes such as equity, participation, gentrification, and socio-spatial inequality, often drawing on theoretical and interdisciplinary perspectives.

Conversely, SDI-related publications are concentrated in more technically oriented and application-driven outlets, including *Sustainability*, *Land*, *Sustainable Cities and Society*, *ISPRS International Journal of Geo-Information*, and *Landscape and Urban Planning*. These journals emphasize geospatial data processing, GIS-based urban planning tools, land-use simulation models, and digital infrastructure development. Their focus reflects the increasing centrality of digital transformation and spatial data systems in contemporary urban governance.

This comparison underscores the epistemological divide between conceptually driven and technically driven research paradigms. While spatial justice research tends to originate from critical, theory-based traditions, SDI scholarship is largely situated within systems-thinking and solution-oriented frameworks. Bridging this persistent disciplinary gap where normative values and technological capacities are often addressed in isolation remains a critical challenge. Advancing integrative approaches that embed equity considerations into data-driven urban transformation agendas is both necessary and timely.

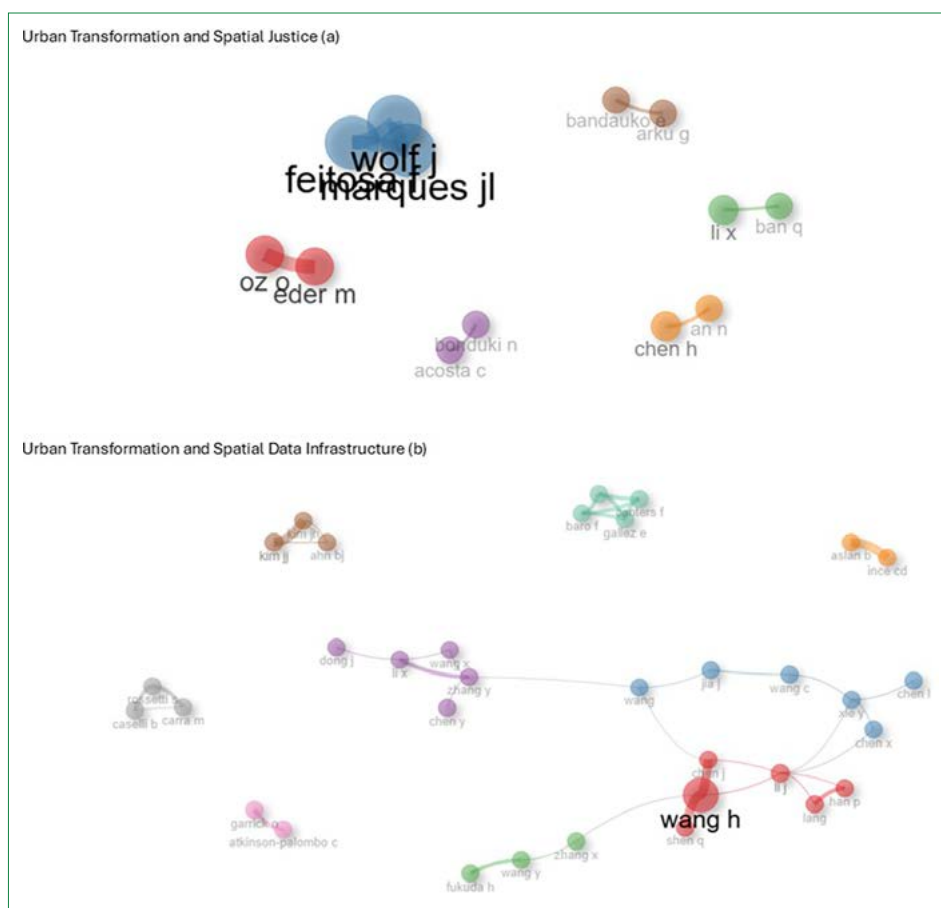
#### 4.3. Most Productive Authors and Collaboration Networks

This section provides a comparative analysis of author productivity and collaboration patterns within the urban transformation literature, with a particular focus on the domains of spatial justice and SDI. Table 3 lists the most productive

authors in each domain based on both full and fractional publication counts. Complementing this, Figure 5 visualizes co-authorship networks, offering insights into the degree of clustering, the centrality of actors, and the disciplinary cohesion in each research stream.

In the spatial justice domain, author productivity appears highly fragmented; none of the top contributors has published more than two articles. This suggests a dispersed and decentralized research environment where numerous scholars contribute occasionally, leading to a loosely structured field. The co-authorship network further supports this pattern most clusters are small and only weakly interconnected, with minimal evidence of central or bridging figures. Authors such as Marques JL, Feitosa F, and Oz O are located in relatively isolated subgroups, indicating limited interdisciplinary or institutional collaboration. Such a configuration aligns with the literature's emphasis on critical urban theory, which often privileges individual or small-group theoretical contributions.

By contrast, the SDI literature is characterized by higher productivity levels and denser collaboration networks. For example, Wang H stands out with 11 publications, illustrating the role of key domain specialists. Among the top ten contributors, article counts range from four to eleven, indicating sustained engagement and expert concentration. The corresponding network is more integrated, featuring larger clusters and multiple central nodes such as Shen Q, Xie Y, and Li J, suggesting a highly collaborative and interdisciplinary ecosystem. This reflects the applied, data-intensive, and project-based nature of SDI research, which often requires multi-institutional partnerships.



**Figure 5.** Author collaboration networks: (a) Spatial Justice, (b) SDI.

These divergent structures of authorship and collaboration underscore distinct modes of knowledge production. Spatial justice research is typically theory-driven, decentralized, and often solo-authored, while SDI studies are team-based, technically oriented, and shaped by collaborative research cultures. Bridging these modes necessitates not only conceptual integration but also institutional innovation, enabling normative considerations to be effectively embedded in data-driven urban transformation frameworks.

#### 4.4. Country-Level Scientific Output and International Collaboration

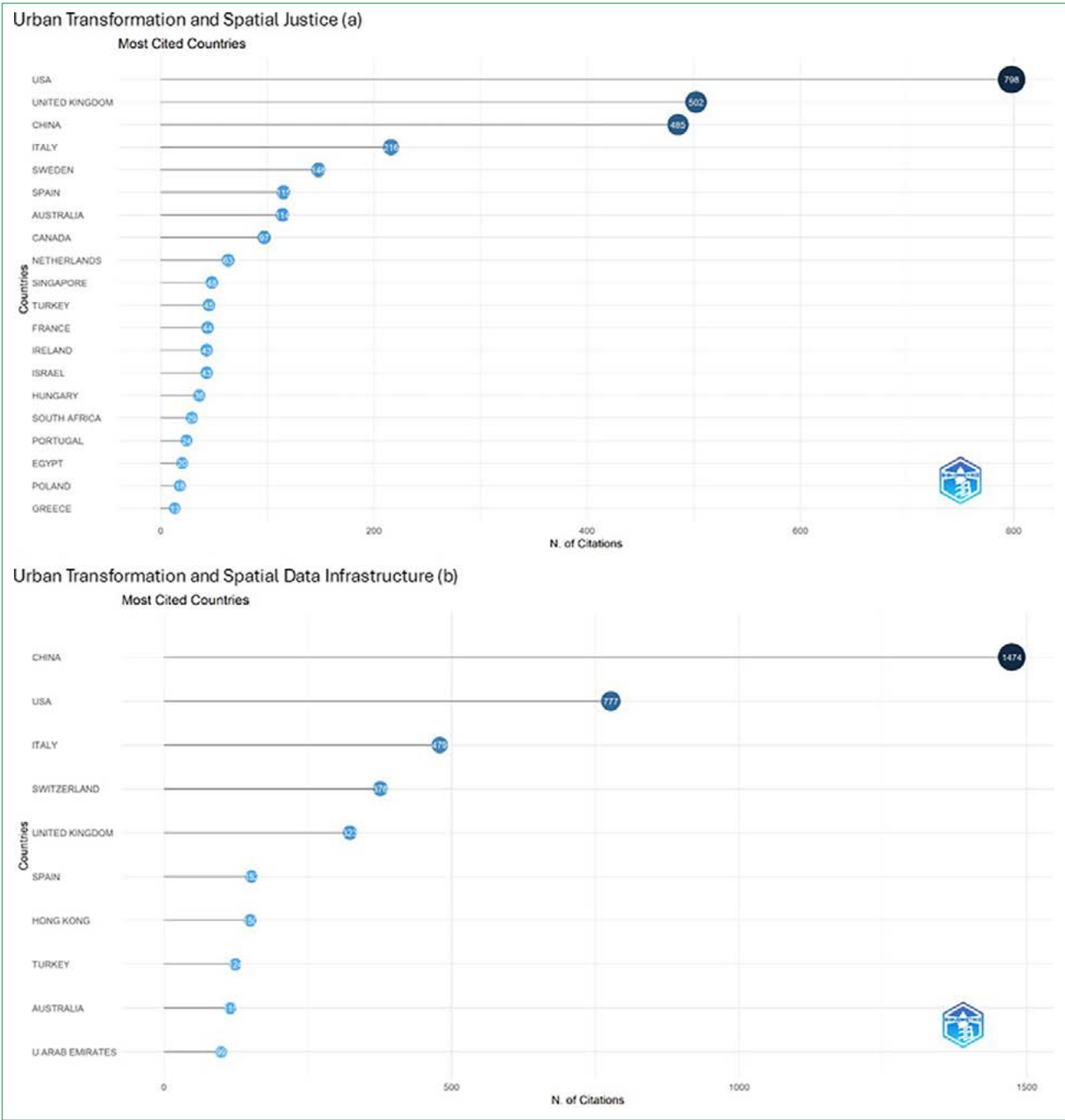
This section presents a comparative bibliometric analysis of national scientific productivity and international collaboration networks within the urban transformation literature, with a specific focus on two thematic axes: spatial justice and SDI. Figure 6 illustrates the geographical distribution of the top-cited countries in each domain, while Figure 7 maps co-authorship networks to uncover underlying patterns of scholarly interaction.

The spatial justice literature is predominantly shaped by contributions from the United States (103 publications),

China (71), the United Kingdom (66), Spain (41), and Italy (28). These figures suggest that the development of spatial justice research has been largely concentrated within Anglo-American and Western European academic traditions. The United States stands out as a central actor in both citation impact and international co-authorship, frequently collaborating with European countries and Australia. This pattern reflects a relatively closed and normatively anchored knowledge network focused on socio-political and theoretical dimensions of urban change.

In contrast, SDI-related scholarship demonstrates a broader and more globally distributed authorship pattern. China leads with a significant margin (339 publications), followed by Italy (131), the United States (101), and Spain (75). Notably, emerging research hubs such as Japan, South Korea, Iran, Germany, Türkiye, Romania, and India have also shown increasing engagement. This highlights the widespread diffusion of SDI frameworks beyond the Global North and underscores the importance of technological capacity in shaping contemporary urban studies.

The country-level collaboration networks further reinforce these differences. In the spatial justice domain (Fig. 7a), co-

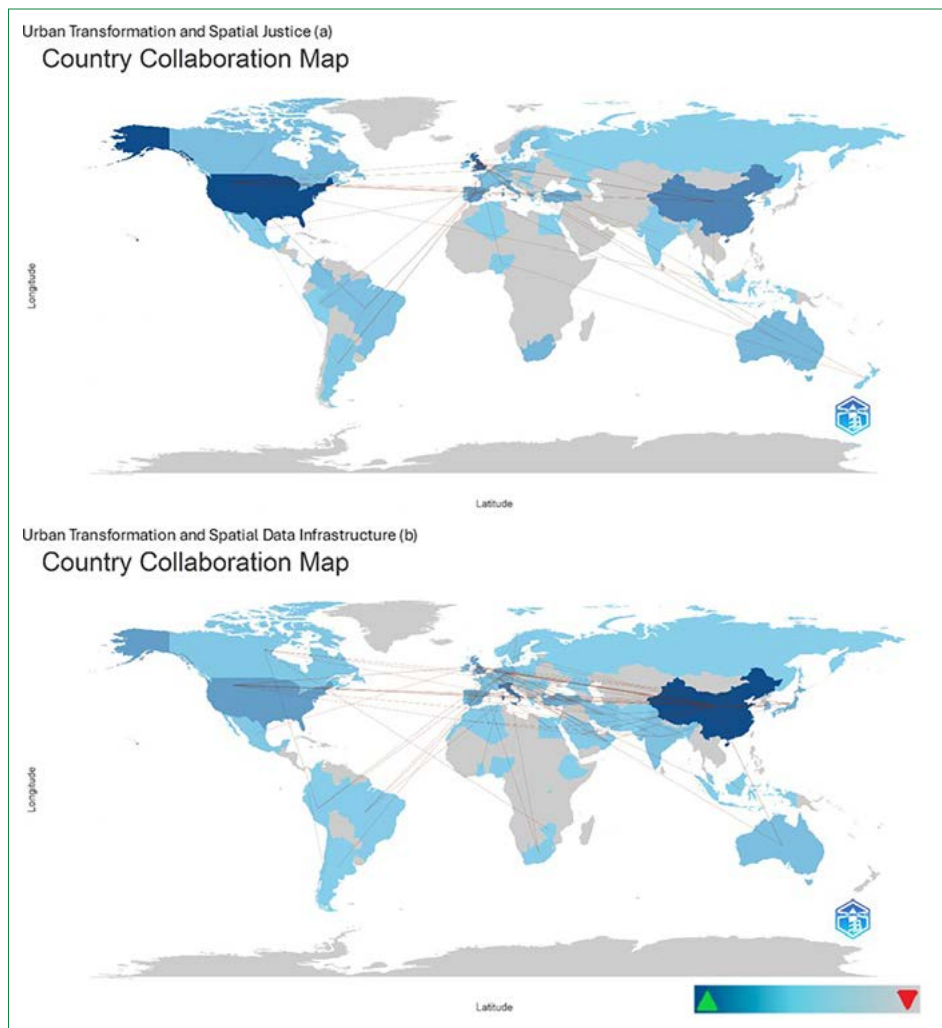


**Figure 6.** Top-cited countries in urban transformation research: **(a)** Spatial Justice, **(b)** SDI.

authorship patterns are mostly bilateral and concentrated among a limited group of developed countries. This structure suggests a conceptually rich but geographically narrow academic landscape. By contrast, the SDI domain (Fig. 7b) displays a more decentralized and multi-nodal architecture, with countries such as China, Italy, the United States, and Germany serving as prominent hubs in an expansive global network. These countries maintain collaborative ties with research institutions across Asia, Africa, the Middle East,

and Oceania, reflecting the inherently technical and data-driven nature of SDI research, which relies on international interoperability and shared digital platforms.

Collectively, these findings reveal that while spatial justice scholarship is rooted in normative and theory-driven inquiry with limited international dispersion, SDI research has evolved as a globally interconnected field grounded in technical expertise and multidisciplinary collaboration. This diver-



**Figure 7.** International collaboration networks: (a) Spatial Justice, (b) SDI.

gence underscores both the structural and epistemological gaps between the two literatures and affirms the imperative for integrative frameworks that bridge digital planning infrastructures with equity-oriented urban policy agendas.

The country collaboration analysis further indicates that the emerging thematic connections between spatial justice and SDI literatures are not uniformly distributed across geographic regions. While technologically advanced countries exhibit stronger integration of data-driven planning and governance-oriented themes, regions with limited digital infrastructure tend to emphasize normative and justice-oriented concerns. This suggests that the development of hybrid research domains is shaped by institutional capacity, technological maturity, and governance frameworks, leading to geographically differentiated patterns of convergence.

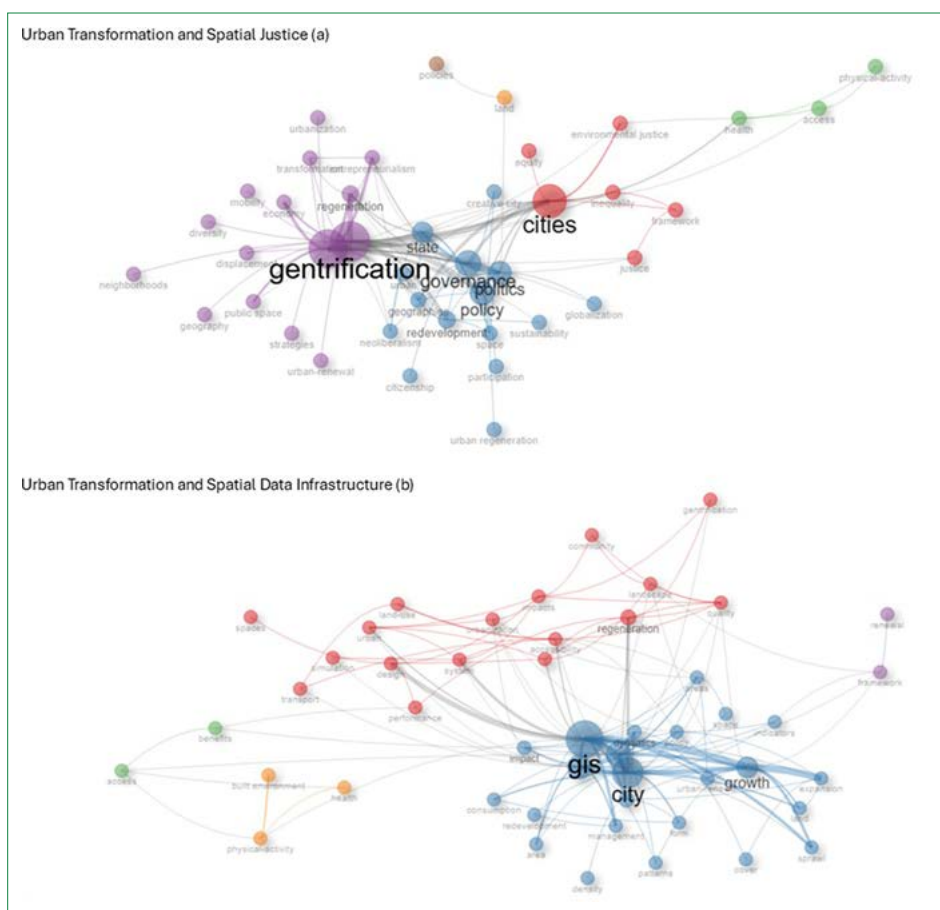
These geographically differentiated patterns can be interpreted through the lens of uneven digital capacity and institutional development. Countries with advanced geospatial

infrastructures and stronger governance frameworks are more likely to integrate SDI-driven approaches with governance-oriented themes, fostering convergence between technical and normative domains. In contrast, regions with limited technological capacity or fragmented governance tend to emphasize justice-oriented discourse without effectively incorporating data-driven planning tools. This indicates that the integration of spatial justice and SDI is not universal, but contingent upon institutional capacity and technological development across different contexts.

#### 4.5. Keyword Co-occurrence Networks

Figure 8 visualizes the keyword co-occurrence networks in the literature on urban transformation, focusing separately on the domains of spatial justice (a) and SDI (b). These visual maps illustrate thematic clusters, structural centrality, and semantic interconnections, employing color-coded groupings to highlight the conceptual architectures and disciplinary orientations embedded within each research stream.





**Figure 8.** Keyword co-occurrence networks in urban transformation literature: **(a)** Spatial Justice, **(b)** SDI.

In the spatial justice domain, core nodes such as “cities,” “governance,” “policy,” “gentrification,” and “justice” emerge as dominant thematic anchors. Among these, gentrification appears as a highly interconnected term, signifying its central role in framing urban transformation through lenses of displacement, spatial inequality, and neoliberal restructuring. Related concepts such as participation, public space, citizenship, and governance underscore the field’s normative orientation, drawing from critical urban theory, particularly Lefebvrian perspectives on the right to the city.

Peripheral clusters include terms like environmental justice, equity, state, and inequality, indicating broader concerns with socio-spatial redistribution and the political economy of urban development. This structure reflects a conceptual focus on participatory governance, socially embedded urbanism, and justice-centered spatial policies.

By contrast, the SDI-related co-occurrence network is more technically structured, centered around operational keywords such as GIS, city, model, growth, and regeneration. The tight interlinkage between “GIS” and “model” points to a methodological emphasis on spatial simulation, digital mapping, and predictive modeling tools. Additional core terms land use,

infrastructure, spatial analysis, and sustainability highlight the field's functional and data-intensive orientation, particularly in support of evidence-based urban planning.

Furthermore, the inclusion of terms such as resilience, transition, and transformation suggests that SDI scholarship increasingly addresses urban change processes from a systems-thinking perspective, integrating geospatial intelligence with long-term planning frameworks.

Table 4 summarizes the thematic distinctions by juxtaposing the most frequent keywords and their associated conceptual foci.

This comparative analysis reveals a clear conceptual divergence between the two domains. Spatial justice scholarship is anchored in normative, socially grounded, and politically engaged frameworks, whereas SDI research is oriented toward technical, quantitative, and application-driven methodologies.

Nevertheless, these two trajectories can be viewed as complementary rather than mutually exclusive. The integration of critical urban theory with digital planning technologies presents a promising pathway toward developing urban

**Table 4.** Dominant keywords and thematic foci in spatial justice and SDI-oriented urban transformation research

| Domain          | Central terms                               | Thematic focus                                               |
|-----------------|---------------------------------------------|--------------------------------------------------------------|
| Spatial justice | Gentrification, governance, cities, justice | Social inequality, participation, rights-based planning      |
| SDI             | GIS, city, model, land use                  | Spatial analysis, digital planning, technical infrastructure |

transformation strategies that are both data-informed and equity-sensitive, fostering inclusive, responsive, and just urban futures.

The keyword co-occurrence analysis reveals several intermediary concepts that function as emerging thematic bridges between the spatial justice and SDI literatures. In particular, governance-related terms such as *urban governance*, *participation*, and *planning* appear in both clusters, indicating a growing convergence around decision-making processes. In addition, concepts such as *sustainability* and *urban regeneration* link data-driven planning approaches with normative concerns of equity and justice. These findings suggest that the intersection between the two domains is increasingly structured around governance-oriented and policy-relevant themes rather than purely technical or purely normative frameworks.

4.6. Thematic Mapping and Thematic Evolution

This section presents a comparative thematic mapping of the literature on urban transformation, focusing on two conceptual strands: both domains. The analysis was conducted using Biblioshiny’s thematic mapping function, which plots themes based on two axes: centrality (indicating their level of connectivity with other themes) and density (reflecting their internal development and coherence). Figure 9 illustrates the distribution of thematic clusters within four quadrants.

Thematic mapping was conducted by adapting co-word clusters using thematic analysis principles (Braun & Clarke, 2006). This approach enables the categorization of dominant and emerging themes based on both centrality and density, thereby offering interpretive depth beyond mere keyword frequency. The resulting insights help uncover the evolving conceptual architecture of both domains research within the urban transformation literature.

(a) Spatial Justice

*Driving Themes (High Centrality, High Density)*

Core concepts such as gentrification, cities, urban renewal, sustainability, and creative city emerge as both structurally central and intellectually mature. These themes reflect critical concerns about urban inequality, displacement, and the neoliberal restructuring of urban space.

*Basic Themes (High Centrality, Low Density)*

Keywords like poverty, neighborhoods, segregation, and re-generation show strong external connectivity but remain underdeveloped internally, indicating substantial opportunities for future theoretical and empirical exploration.

*Niche Themes (Low Centrality, High Density)*

Terms such as rights, land, and perspective are deeply elaborated yet weakly connected to the broader discourse. These likely represent specialized subfields or distinct normative trajectories within critical urban theory.

*Emerging or Declining Themes (Low Centrality, Low Density)*

Concepts like disparity, place, urban objects, and eviction appear at the margins suggesting either a decline in scholarly interest or the incipient development of new thematic directions.

(b) SDI

*Driving Themes*

SDI-related literature is anchored in technically oriented terms such as growth, expansion, urban renewal, space, and construction. These themes reflect a focus on infrastructure development, spatial optimization, and data-driven transformation.

*Basic Themes*

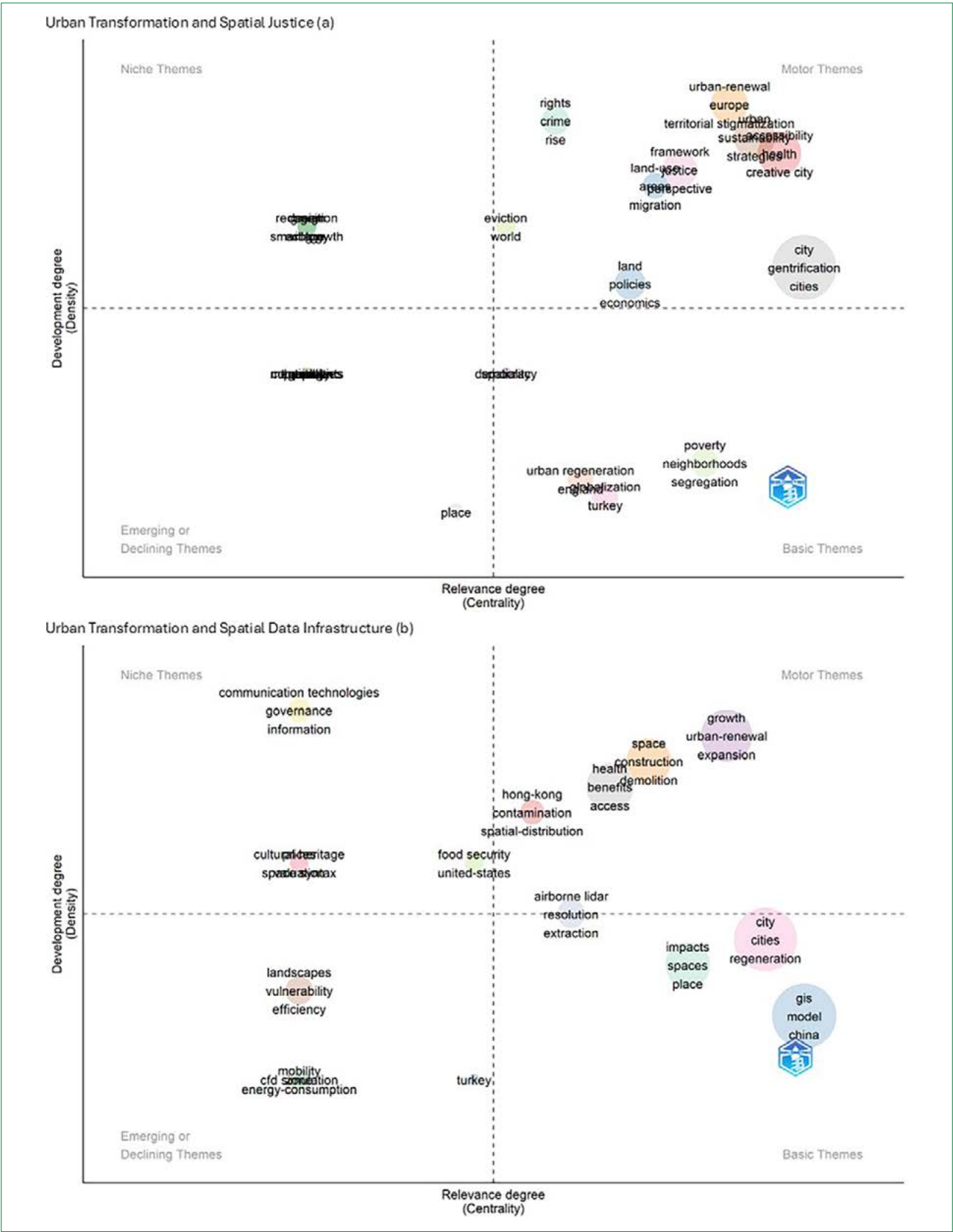
Frequently occurring but less conceptually developed terms include GIS, model, China, regeneration, and cities. Among these, GIS remains a cornerstone methodological tool that underpins most SDI-related analyses.

*Niche Themes*

Terms like communication technologies, information, governance, and spatial context suggest highly specialized sub-clusters dealing with digital infrastructures, data integration, and institutional dynamics.

*Emerging or Declining Themes*

Peripheral keywords such as landscapes, vulnerability, efficiency, energy consumption, and mobility currently exhibit low density and centrality, yet they may gain future prominence, especially within the context of climate-adaptive and sustainability-oriented planning frameworks.



### *Interpretation and Synthesis*

These thematic trajectories indicate distinct epistemological orientations. In SDI-focused literature, the thematic evolution progresses from technical tools (e.g., GIS) to broader urban development concerns (e.g., growth, expansion). In contrast, spatial justice literature moves from abstract normative concepts (e.g., justice, rights) toward tangible urban processes (e.g., gentrification, segregation).

This contrast reveals a potential thematic convergence along a continuum from data → governance → justice, reflecting the increasing need to bridge operational tools with normative urban values. While SDI research remains infrastructure- and growth-oriented, spatial justice scholarship continues to prioritize equity, participation, and rights-based planning. An integrative approach to these themes could foster more inclusive, responsive, and socially just urban transformation strategies.

The thematic mapping further suggests the emergence of hybrid research domains at the intersection of spatial justice and SDI literatures. In particular, themes such as participatory GIS, open data governance, and data-driven urban governance integrate technical geospatial infrastructures with normative concerns of equity, inclusion, and representation. These emerging clusters indicate a shift from isolated disciplinary approaches toward more integrative frameworks, where digital infrastructures are increasingly evaluated through justice-oriented perspectives, pointing to the formation of a new interdisciplinary research frontier.

Moreover, these patterns indicate that convergence between SDI and spatial justice is not incidental but occurs through identifiable mechanisms. Governance-related concepts such as participation, planning, and sustainability function as key intermediaries that translate technical infrastructures into socially relevant frameworks. This suggests that convergence is not driven by technological advancement alone, but by the institutionalization of governance practices that embed normative concerns into data-driven systems, reflecting a broader structural shift in the relationship between digital urbanism and justice-oriented planning.

### **4.7. Most Cited Documents and Historiographic Mapping**

The bibliometric findings demonstrate that the two principal thematic strands of urban—transformation spatial justice and SDI—are shaped by distinct theoretical foundations and methodological approaches. In the spatial justice literature, the most highly cited work is Fainstein's (2005) article in *Urban Affairs Review* (237 citations), followed by Degen (2012) (202) and Ponzini (2010) (167). These studies constitute the normative core of the field, addressing issues such

as equitable planning, gentrification, and critiques of neo-liberal urban redevelopment. Contributions by Lees (2018) and Weinstein (2009) further strengthen this tradition, offering critical perspectives on the social consequences of urban restructuring.

In contrast, the SDI-focused literature is dominated by technically oriented and application-driven research. The most cited article is Fonseca (2015) in *Applied Energy* (245 citations), followed by Srinivasan (2013) (237), Yuan (2014) (195), and Locke (2021) (154). These publications explore themes such as energy optimization, geospatial data integration, and urban systems modeling, underscoring the empirical and computational emphasis of the field. These citation patterns are illustrated in Figure 10, which presents a comparative overview of the most cited studies in each domain.

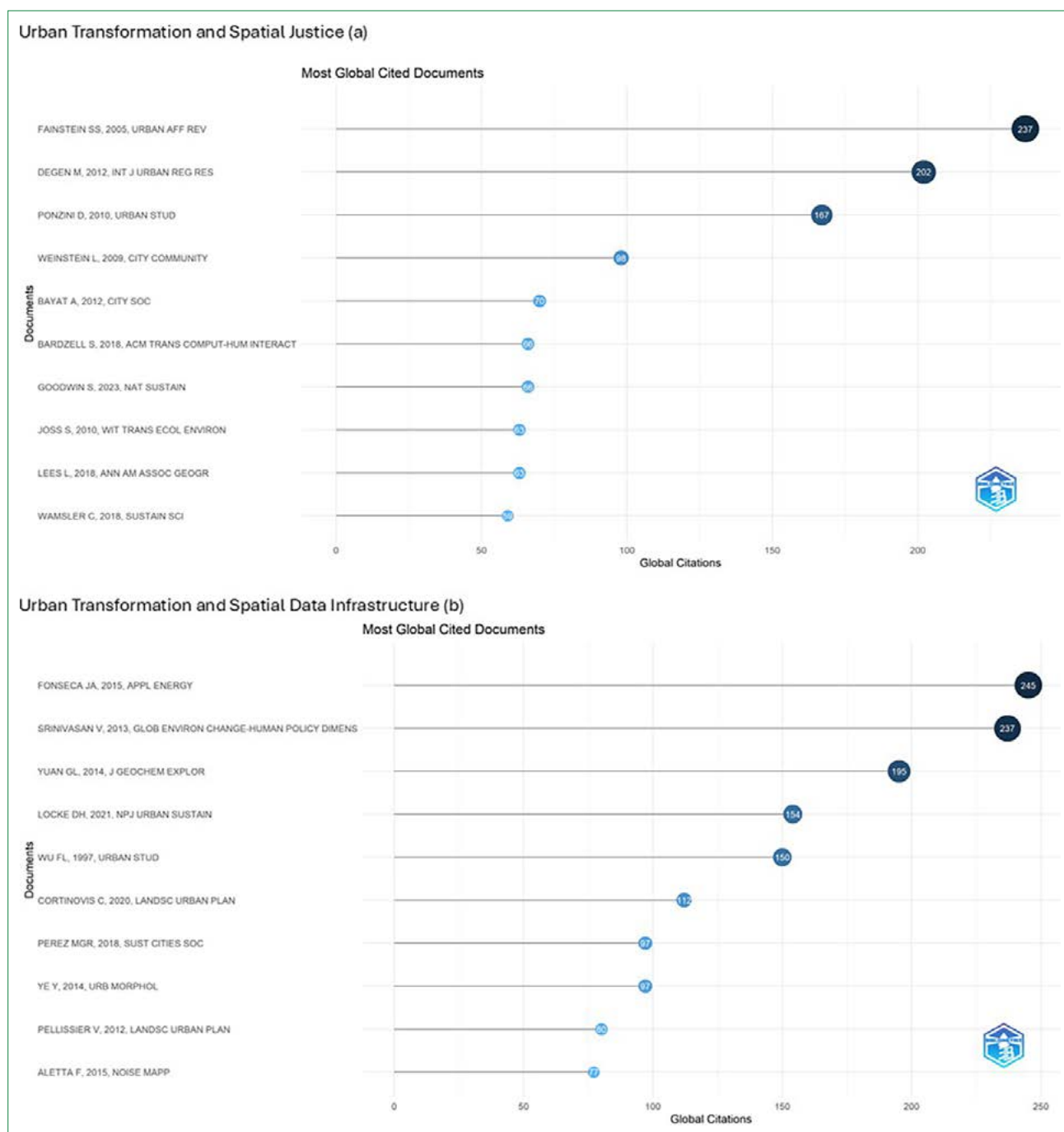
To trace the intellectual trajectories of these domains, historiographic mapping was employed to analyze citation linkages and thematic evolution. Within the spatial justice stream, Fainstein (2005) occupies a foundational and influential position, serving as a reference point for later studies such as Weinstein (2009), Ponzini (2010), and Lees (2018). Recent works, including Hewidy (2025), represent the ongoing development of this critical framework. The mapping reveals a relatively centralized citation structure, dominated by a limited number of key texts that continue to shape contemporary discourse on urban justice.

In contrast, the SDI historiography reflects a more decentralized and multidisciplinary structure. Foundational works by Yuan (2014) and Srinivasan (2013) have given rise to diverse subfields, including LIDAR technology, noise mapping, energy modeling, and geospatial analytics. This branching indicates a horizontal diffusion of research themes, as visualized in Figure 11, which compares the historiographic networks of both domains.

Together, these analyses highlight a structural divergence in scholarly development. Spatial justice research is shaped by a theory-driven, centralized knowledge base, whereas SDI literature is dispersed across multiple disciplinary intersections, driven by technical problem-solving and application-specific inquiries. These contrasting trajectories emphasize the necessity for integrative frameworks that reconcile normative urban theory with data-informed planning tools, enabling more equitable and responsive approaches to urban transformation.

## **5. Critical Reflection and Discussion**

The bibliometric results of this study demonstrate both significant divergences and emerging intersections between two foundational strands of urban transformation research: spatial justice and SDIs. While SDI-related scholarships are predominantly defined by technocratic and application-fo-



**Figure 10.** Most cited publications in urban transformation literature: (a) Spatial Justice, (b) SDI.

cused approaches, spatial justice literature remains anchored in normative, rights-based urban theory. This contrast highlights the potential for an integrative planning paradigm that combines operational efficiency with equity-oriented values, although such integration remains uneven and evolving.

The keyword co-occurrence analysis indicates that governance-related concepts such as participation, planning, and sustainability act as key linkages between the spatial justice

and SDI literatures. Complementing this, thematic mapping points to the emergence of hybrid research domains that connect technical infrastructures with justice-oriented concerns.

Importantly, the analysis demonstrates that this convergence is neither automatic nor uniform. Instead, it develops selectively through governance-oriented pathways, while significant conceptual and structural gaps persist. This suggests that the integration of data-driven planning and justice-oriented





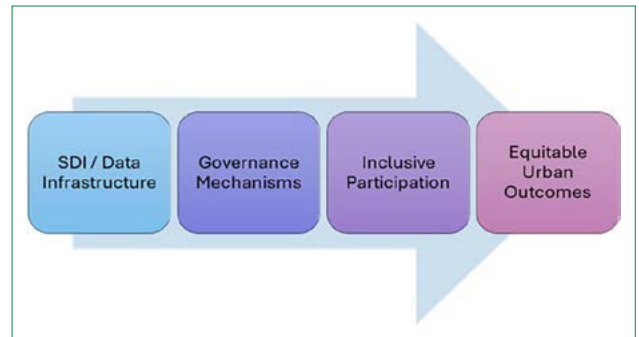
A relevant empirical illustration of these dynamics is evident in Istanbul. Recent smart city initiatives by the Istanbul Metropolitan Municipality (IMM), including the launch of its Open Data Portal represent progress toward digital transparency and citizen access to urban planning data (İBB, 2023). Participatory urban design efforts in districts such as Kartal and Başakşehir have also initiated limited forms of community engagement (Gün et al., 2020). Yet persistent challenges remain restricted access to spatial datasets and the consistent omission of informal settlements from official planning maps (Oktem Unsal, 2015; Ghouchani et al., 2023; Kurt Özman and Taşan-Kok, 2024) continue to hinder equitable urban governance. These constraints reflect the broader challenge of translating digital infrastructure into socially just planning outcomes, particularly within fragmented and exclusionary urban contexts.

This raises a critical question: Can SDI-based planning mechanisms truly advance spatial justice? Without explicit attention to data ownership, participatory frameworks, and governance transparency, SDIs risk reinforcing technocratic logics at the expense of democratic accountability. Furthermore, initiatives grounded in SDI often prioritize technical feasibility over social legitimacy, which may erode public oversight and diminish opportunities for deliberative governance.

Nevertheless, SDIs hold transformative potential if reimagined through a justice-oriented lens. Instruments such as open data platforms, participatory GIS, and equitable data governance protocols provide promising pathways to embed inclusivity and accountability within digital urban planning. Realizing this potential, however, requires not only technological innovation but also institutional reform and normative realignment.

In conclusion, this study contends that spatial justice and SDI constitute distinct yet converging epistemological domains. Their intersection signals the emergence of an integrative research frontier that demands not just technical coordination, but a reconfiguration of power, representation, and knowledge production through ethically grounded and equity-driven planning frameworks. Data may serve justice but only when justice actively informs and structures the production, access, and use of data.

Building upon this critical foundation, the following conceptual model (Fig. 12) outlines a justice-oriented reconfiguration of SDI and its integration into participatory urban governance. The conceptual model presented in Figure 12 is directly informed by the bibliometric findings of this study. Specifically, the initial stage of SDI/data infrastructure reflects the dominance of technically oriented research identified in the SDI cluster. The transition toward governance mechanisms corresponds to the keyword co-occurrence analysis, which highlights governance-related concepts such



**Figure 12.** Conceptual bridge between SDI and Spatial Justice: From data to equity.

as participation, planning, and sustainability as key thematic bridges between the two domains. The emphasis on inclusive participation is supported by the thematic mapping results, which indicate emerging convergence around participatory and policy-oriented frameworks.

Finally, the focus on equitable urban outcomes aligns with the normative foundations of the spatial justice literature. In this sense, the model does not represent a purely normative construct, but rather a synthesis of empirically observed patterns that describe how technical infrastructures may evolve into justice-oriented urban governance processes under specific conditions.

This framework delineates a staged trajectory for embedding SDIs into justice-oriented urban planning. While the process begins with the establishment of data infrastructures, it underscores that absent inclusive governance mechanisms and participatory frameworks, spatial data alone is insufficient to foster equitable outcomes. The model posits that urban justice must be institutionally enacted through democratic structures capable of translating digital information into socially inclusive and representative planning practices. In doing so, it offers a conceptual roadmap for transforming technocratic digital infrastructures into participatory, transparent, and equity-driven governance systems. This reconceptualization provides practical utility for policymakers seeking to integrate spatial justice principles into existing digital planning environments.

Importantly, this conceptual bridge asserts that achieving spatial justice through SDI implementation is not a linear technical progression but rather a multidimensional socio-institutional transformation. By identifying key enabling conditions including participatory governance, institutional accountability, and ethical open data standards the framework delivers actionable insights for translating digital infrastructures into instruments of equitable and democratic urban transformation.

## 6. Conclusion and Recommendations

Overall, the study makes a conceptual contribution by redefining the relationship between SDI and spatial justice, an empirical contribution by mapping their evolving convergence

through bibliometric analysis, and a methodological contribution by applying a dual-cluster comparative framework.

This study demonstrates that **spatial justice** and **SDI** represent two analytically distinct yet potentially complementary pillars within the broader field of urban transformation research. While SDI-related scholarship exhibits rapid growth and a multidisciplinary, application-oriented focus rooted in technological innovation, spatial justice research advances more gradually, offering deeper theoretical insights anchored in rights-based and normative frameworks. Despite their divergent trajectories, both domains remain largely siloed, with limited conceptual or methodological integration.

The bibliometric analysis reveals a persistent disconnect: SDI studies tend to prioritize data management, spatial optimization, and infrastructure efficiency, frequently overlooking issues of equity, inclusion, and representational fairness. Conversely, spatial justice literature emphasizes participatory and ethical concerns but often lacks concrete methodologies for embedding these principles into digital planning systems. This fragmentation poses risks in contemporary urban governance, where data-driven rationalities may inadvertently reinforce spatial inequities rather than resolve them.

In response, this study calls for future research to develop **integrative frameworks** that conceptualize urban transformation, spatial justice, and SDI as mutually constitutive dimensions of planning and governance. A combined analytical lens can offer deeper insight not only into how urban spaces are reshaped, but also whose interests are prioritized, whose voices are marginalized, and what social outcomes are produced. The thematic overlaps identified herein provide fertile ground for building interdisciplinary methodologies and hybrid theoretical models capable of addressing these questions.

From a policy perspective, the findings emphasize that data-centric urban planning cannot be reduced to a technical exercise. Instead, it must be understood as a political and ethical process, inherently tied to the distribution of power and resources. As digital infrastructures proliferate, planning institutions must redefine their understandings of participation, transparency, and justice. Without such redefinition, SDI implementation risks entrenching digital divides and producing new forms of spatial exclusion.

Empirical examples from international practice further illustrate the potential of justice-oriented SDI implementation. For instance, participatory GIS initiatives in cities such as Porto Alegre have demonstrated how citizen engagement in spatial decision-making can enhance transparency and inclusion in urban planning processes. Similarly, open data governance platforms in cities like Barcelona have enabled broader public access to urban data, supporting more accountable and participatory governance structures. These examples il-

lustrate that, when appropriately institutionalized, SDI-based practices can improve transparency, broaden access to planning information, and strengthen citizen engagement, thereby contributing to more equitable and inclusive urban outcomes.

This study therefore argues that bridging the normative and technical paradigms of urban transformation is both necessary and urgent. Spatial justice should not merely be a political aspiration; it must be treated as a **core design principle** for digital governance systems. Addressing this conceptual and operational gap is essential for cultivating an inclusive and socially responsive urban planning agenda.

The study concludes with several **policy recommendations** aimed at guiding the equitable deployment of SDIs within urban contexts:

### 1. Governance and Participation

- Integrate SDIs within participatory governance frameworks to promote inclusive decision-making.
  - Ensures spatial data systems reflect diverse community needs and perspectives.
- Incorporate community feedback mechanisms into digital planning platforms.
  - Tools such as participatory GIS can support democratic planning processes.

### 2. Legal and Institutional Reform

- Develop national legal frameworks that guarantee equitable access to and ownership of spatial data.
  - Prevents monopolization of data resources and strengthens institutional transparency.
- Require social impact assessments alongside technical audits in SDI projects.
  - Facilitates alignment of digital tools with social justice objectives.

### 3. Technical and Interdisciplinary Capacity

- Assemble interdisciplinary planning teams with expertise in geospatial analysis, law, and social equity.
  - Enables comprehensive consideration of technical, legal, and ethical dimensions.
- Ensure open data platforms include marginalized communities and informal settlements.
  - Promotes inclusive spatial representation and reduces structural exclusion.

### 4. Equity-Centered Investment

- Prioritize digital infrastructure investments in underserved urban areas.

- Supports balanced spatial development and addresses digital inequality.

These recommendations aim to foster the development of inclusive digital ecosystems where spatial justice is not treated as an ancillary goal but as a foundational element in the design and governance of urban planning technologies.

However, the transferability of justice-oriented SDI practices across different contexts remains inherently limited. Governance models, digital infrastructures, and participatory mechanisms are deeply shaped by institutional capacity, political frameworks, and socio-economic conditions. Practices such as participatory GIS or open data governance may yield positive outcomes in contexts with strong institutional support and digital maturity but may face significant challenges in regions characterized by limited technological infrastructure, fragmented governance, or restricted civic participation. Therefore, rather than assuming universal applicability, the implementation of justice-oriented SDI models should be understood as a context-dependent process requiring adaptation to local institutional and socio-political conditions.

More broadly, this study demonstrates that the relationship between SDI and spatial justice should not be understood as a given or inherent alignment, but as a structured, conditional, and context-dependent process. By empirically revealing how and where these domains intersect, the study moves beyond methodological mapping and contributes to a deeper understanding of the socio-technical dynamics shaping contemporary urban transformation. In doing so, it provides a more grounded and analytically robust foundation for future research and policy development in justice-oriented digital urban governance.

**Ethics committee approval:** As this study does not involve direct human participation or data that requires ethics committee approval, approval from the ethics committee was not obtained.

**Informed consent:** Since this study does not involve human participation, obtaining informed consent was not required.

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