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EDITED BY
Jaeyoung Jay Lee,
Central South University, China

REVIEWED BY
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Uneb Gazder,
University of Bahrain, Bahrain
Renata Zochowska,
Silesian University of Technology, Poland

*CORRESPONDENCE
Syafieq Fahlevi Almassawa
✉ dosen01855@unpam.ac.id

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The relationship between regional development, smart mobility and transportation planning: a bibliometric analysis

Syafieq Fahlevi Almassawa[1]*, Ernan Rustiadi[2], Akhmad Fauzi[3] and Ridwan Sutriadi[4]

[1]Department of Management, Pamulang University, South Tangerang, Banten, Indonesia, [2]Department of Land and Land Resources, Institut Pertanian Bogor (IPB) University, Bogor, West Java, Indonesia, [3]Department of Resources and Environment Economics, Institut Pertanian Bogor (IPB) University, Bogor, West Java, Indonesia, [4]Department of Urban and Regional Planning, Bandung Institute of Technology, Bandung, West Java, Indonesia

This paper presents a bibliometric analysis of publications from the Scopus database on regional development, smart cities, smart mobility, and transportation planning. The study retrieved 397 documents published between 2010 and 2023, utilizing keywords relevant to the research topic, and analyzed them using VOSviewer software. The findings indicate a steady increase in research output in this field since 2010. The most frequently used terms identified in this study include the main keywords: sustainability, regional planning, and smart transportation. It is recommended that "Regional Development" and "Transportation Planning" serve as primary target journals for disseminating the results of this research analysis, as they may eventually supersede previous dominant themes. Additionally, the findings suggest that researchers from countries with lower contributions to this field should explore these topics further to add depth and nuance. Research linking these keywords should be expanded and replicated to enrich the existing literature.

KEYWORDS

regional development, smart city, smart mobility, sustainable cities, transportation planning, bibliometric, VOSviewer

1 Introduction

The World Commission on Environment and Development has emphasized the importance of ensuring that development is sustainable. This means that the needs of the present generation should be met without compromising the ability of future generations to fulfill their own needs (Ogryzek and Wolny-Kucińska, 2021). Sustainable economic development is essential for any country and must be characterized by long-term consistency. At a macro level, it should contribute to the establishment of a robust economy, while at a micro level, it should enhance the quality of life for households and generate profits for businesses. Building on this foundation, various concepts have been developed to describe the processes of initiating and stimulating regional development (Tejada-Gutiérrez et al., 2023). With the rapid growth of cities worldwide, there is increasing recognition of the need to actively design smart and sustainable urban environments, as sustainable urban development is crucial for creating a viable future (Kåresdotter et al., 2022).

The concept of smart mobility is part of the Smart City concept used globally to overcome mobility problems such as congestion, excessive use of private vehicles, accessibility of public transportation, and non-motorized vehicle problems

(Velaga et al., 2012). The concept of smart mobility is also used in developing countries with high population density and rapid population growth (Billones et al., 2021). Smart mobility is a comprehensive conception that aims to improve the sustainability of transportation networks by improving transportation services, harmonizing the use of technology with social, economic, and environmental factors (Zawieska and Pieriegud, 2018). Smart Mobility is the ability to access transportation services from an integrated platform that gathers communities and presents intense data processing from users to match the forecasted demand. Infrastructure must be smart with connected and sustainable vehicles (Docherty et al., 2018). Smart mobility is related to transportation and the use of communication and information technologies to promote accessibility and improve the quality of life (Ahad et al., 2020). Smart Mobility is the integration of sustainable, intelligent, and cooperative vehicle technology with cloud servers and big data-based vehicle networks (Kim et al., 2015).

Cities are a defining aspect of human civilization and play a significant role in shaping new ways of thinking that ultimately lead to profound transformations in how people live and impact the world. Over the last 40 years, sustainability has emerged as one of the most influential paradigms in urban development (Bibri, 2021). It is a crucial principle in city governance, particularly in the transport sector, where it must be environmentally friendly, accessible to all, and socially and economically viable. To achieve sustainable urban development, specific theories and regulations need to be developed and implemented (Russo and Rindone, 2021). Enhancing the sustainability of urban regions depends on transforming suburban spaces, infrastructure, practices, and cultures. While the reduction of car use has peaked in city centers for both empirical and political reasons, there remains significant potential in the suburban hinterlands. To foster greener and more sustainable mobility patterns, new policy and planning initiatives are focused on ongoing densification around public transport hubs and nodes (Nenseth and Røe, 2023).

Rural areas typically have poorer access to employment opportunities, key services, and leisure activities compared to urban areas. This disparity is largely due to low-density residential patterns and scattered development, which often result in longer distances to travel for work and services. Furthermore, rural areas are heavily reliant on private car travel because of the limited availability of public transportation services (McHenry et al., 2023). Urban areas play a crucial role in achieving sustainability goals both globally and locally, as they face unique sustainability challenges stemming from high concentrations of people, economic activity, and environmental issues. To accelerate the transition toward a more resource-efficient socioeconomic system, it is essential to integrate sustainability into the decision-making processes of urban areas. This integration is becoming increasingly accepted and recognized at both global and local levels (Buzási and Jäger, 2021).

Transportation planning involves decisions regarding the design and provision of infrastructure and services across various areas. It is a component of spatial planning, which can be utilized to create sustainable frameworks for social, environmental, and economic development over the long term. Spatial planning has two main functions: to regulate development and to guide it in order to promote urban, regional, and national growth, conserve resources, and encourage investment. According to the Agenda 2030 framework, transportation planning and its related decisions should contribute to achieving sustainable mobility for both people and goods. A well-structured plan aligns theories, regulations, and implementation. The process is deemed successful when planned policies are effectively put into action (Russo and Rindone, 2021).

The transportation planning process involves gathering information about the current state of the transportation system, including its various components. This information is then used to make informed decisions with appropriate tools, such as supply, demand, and interaction models. The objective is to achieve stated goals transparently. The process also includes identifying interventions that can be made to the transportation system or its components to meet objectives while respecting existing constraints (Russo et al., 2022).

Transport refers to the movement of people and goods using various means of transportation. It is categorized into road, rail, air, and sea transport. Different modes of transport include cars, bicycles, trams, passenger ships, planes, trains, and buses, while various forms encompass public transport, cycling, private car use, walking, boating, and flying. Transport also serves primary and secondary functions, leading to multiple classifications based on different criteria (Macioszek and Jurdana, 2023). Furthermore, factors such as right-of-way failures and driver inattention are significant contributors to pedestrian and vehicle accidents. The risk of serious or fatal injuries to pedestrians increases notably when they are at fault in an accident. Key factors influencing serious pedestrian injuries include lighting conditions, road classification, speed limits, types of traffic control, incident type, and the pedestrian's age and gender. Alcohol consumption also significantly raises the likelihood of serious injury for pedestrians (Macioszek et al., 2023). On the other hand, there is a push to reduce pollutant emissions from transportation. This strategy involves shifting from road transport to more ecological modes, including rail. The goal is to create a competitive and sustainable transport system, aiming for a 60% reduction in emissions while simultaneously enhancing mobility (Macioszek, 2024).

Sustainable transportation plays a vital role in fostering development and has been recognized as a longstanding global trend. Many developed countries continue to invest in physical infrastructure and mobility, which are essential drivers of sustainable transportation (Bamwesigye and Hlavackova, 2019). Numerous cities in Europe have established public transport systems, and there have been recent advancements in multimodal mobility and planning interventions aimed at reducing traffic congestion and promoting healthier modes of active travel. While sustainable transportation has become a priority in urban areas, long-term processes of rural marginalization have created significant challenges in transport accessibility for rural regions, often requiring longer travel distances. This situation adversely affects certain groups, particularly those who do not own a private vehicle or possess a driving license. Consequently, car ownership is often seen as a necessity to mitigate the risk of social exclusion (Bauchinger et al., 2021). Over the past 2 centuries, urbanization has rapidly accelerated globally, viewed as a crucial development

strategy. In China, this trend has surged, especially following the economic reforms and opening policies of the late 1970s, with the urban population rising from 17.9% of the total population in 1978 to over 57.31% in 2016 (Gao et al., 2021).

Regional development is influenced by the quality of its transportation system. To achieve sustainable development, a well-planned transportation system is necessary. This study aims to explore the relationship between regional development, smart mobility, and transportation planning using bibliometric analysis of research from 2010 to 2023, sourced from the Scopus database based on the following research questions.

- What are the main source journals and discipline distribution in regional development, smart-city, smart mobility, and transportation planning research?
- What are the distributions of research power in terms of citation, countries, affiliation, and authorship?
- What are the core research topics and their knowledge bases?
- What are the research hotspots and trends?
- What do the research variables have any relationship?

This paper aims to address these inquiries by utilizing the Scopus Collection database and employing scientometric analysis and knowledge mapping techniques, focusing on diversity, time segmentation, and dynamics. VOSviewer and CiteSpace are utilized to conduct a comprehensive examination of literature in the field. The objectives include analyzing concentrations in research topics through the examination of research power distribution (across countries, organizations, and authors), identifying primary research areas across different timeframes, and exploring connections between regional development, smart-city initiatives, smart mobility, and transportation planning through document co-citation, keyword co-occurrence, and reference burst-detection analyses.

The following structure is adopted for the rest of the paper:

- Section 2 outlines the bibliometric and scientometric methods employed.
- Section 3 presents the annual quantitative distribution of publications, the primary source journals, interdisciplinary distribution, leading countries (territories), organizations, contributors, and their collaboration levels. It also discusses the outcomes obtained through document co-citation, reference burst-detection, and keyword co-occurrence analyses.
- Section 4 consists of the discussion and explores future prospects.

Bibliometric analysis can be used to find research gaps and novelty of a study, therefore bibliometric analysis was conducted in this study to find out how many journal articles examined regional development, smart city, smart mobility and transportation planning. In addition, it is also to find out whether it can be seen the extent of research conducted by previous researchers that link variable variability on this topic. However, it is expected that new research can be carried out that has never been done and is useful for science.

2 Data collection and research methodology

In Figure 1 can be seen the steps taken in the analysis using bibliography so that it is clear what is done to get articles that are really in accordance with the research topic.

The Scopus database was chosen for bibliometric analysis due to its status as one of the largest databases for scientific publication searches, continually expanding and updating its data compared to other databases. The author accessed Scopus data on January 23, 2024, using the following search query: "(TITLE-ABS-KEY (regional AND development) AND PUBYEAR > 2009 AND PUBYEAR < 2024) AND (smart AND cities) AND (smart AND mobility) AND (regional AND studies) AND (transportation AND planning) AND (sustainability)." This search yielded 397 documents (Step 1). Next, using a more refined search string: "(TITLE-ABS-KEY (regional AND development) AND PUBYEAR > 2009 AND PUBYEAR < 2024) AND (smart AND cities) AND (smart AND mobility) AND (regional AND studies) AND (transportation AND planning) AND (sustainability) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (EXACT KEYWORD, "Sustainable Development") OR LIMIT-TO (EXACT KEYWORD, "Regional Planning") OR LIMIT-TO (EXACT KEYWORD, "Sustainability))" the study found 128 documents (Step 2).

The next step involved selecting articles relevant to the research title, resulting in a final count of 89 articles. Following this, bibliometric analysis was conducted using VOSviewer software, which examined bibliographic data such as publication year, affiliations, authors, country of origin, journal keywords, and citations.

This research identified numerous papers on regional development, smart cities, smart mobility, and transportation planning published from 2009 to 2024. Researchers also observed publication trends related to these research topics, checked the countries and institutions of the authors' affiliations, and analyzed journals dedicated to these subjects, as well as articles with the highest citation counts. Finally, the researchers presented the results of the cooperation network analysis.

Figure 2 illustrates that the 397 documents consist of various types: 296 articles (74.7%), 27 conference papers (6.8%), 26 books (6.6%), 26 reviews (6.6%), 19 book chapters (4.8%), and 2 editorials (0.5%). Further details are visualized in Figure 2.

Figure 3 shows that the 397 documents analyzed in this study are distributed across several subject areas. Specifically, there are 248 documents in Social Sciences (27.3%), 161 in Environmental Science (17.7%), 115 in Engineering (12.6%), 102 in Energy (11.2%), 75 in Computer Science (8.2%), 51 in Business, Management, and Accounting (5.6%), 32 in Economics, Econometrics, and Finance (3.5%), 26 in Earth and Planetary Sciences (2.9%), 15 in Agricultural and Biological Sciences (1.6%), 15 in Decision Sciences (1.6%), and 14 in Mathematics. Additionally, 12 documents fall under other categories, accounting for 7.6% of the total. Further details can be found in Figure 3.

In Figure 4, we see the trend of paper documents from 2010 to 2023, and it looks up and down from 2010 to 2020, then the trend always goes up from 2020 to 2023.

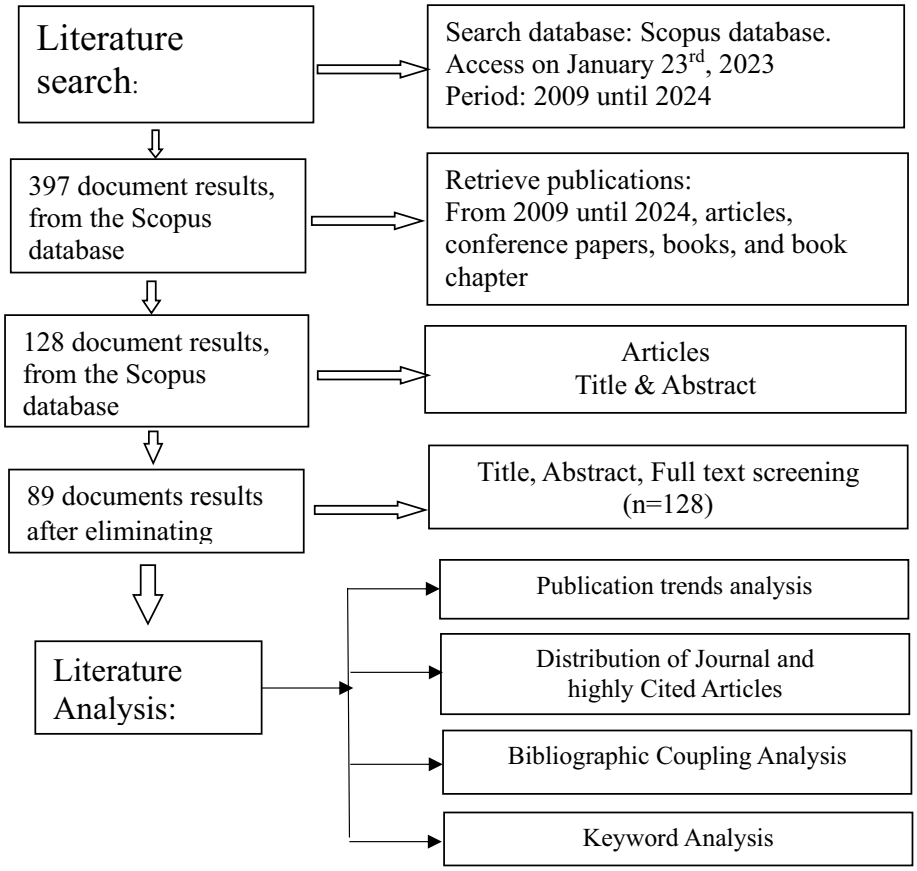

FIGURE 1
Retrieval process of study.

Figure 5 illustrates the number of documents published annually across various journal sources. The journals examined include the Swiss Sustainability Journal, Land Use Policy Journal, Journal of Cleaner Production, Cities Journal, and the Land Journal. From 2013 to 2018, the Land Use Policy Journal published only one paper each year. This number increased to two articles in 2019 and remained at one article per year from 2020 to 2022. The Swiss Sustainability Journal experienced fluctuations in publication from 2017 to 2020, but saw a significant rise in articles, jumping from 4 in 2020 to 13 in 2021, before dropping to 10 articles in 2023. The Journal of Cities also exhibited fluctuations in publication numbers from 2018 to 2023. In contrast, the Journal of Cleaner Production showed a variable trend from 2017 to 2022, with a notable increase in 2023, publishing three articles. Meanwhile, the Land Journal experienced a consistent rise in the number of articles published from 2021 to 2023.

3 Research findings and discussion

3.1 Research finding

Based on the search results in Figure 6, academic papers on regional development, smart cities, smart mobility, and transportation planning have been published in 70 countries (or territories) worldwide. The top 10 countries (or territories) with the highest number of published papers, totaling 397, are illustrated in Figure 6. Most of these papers originate from developed countries in Europe, as well as the United States, Canada, Australia, and the Netherlands. China leads as the most active country in researching regional development, smart cities, smart mobility, and transportation planning, with 117 papers published. The United States follows in second place with 61 papers, while Italy ranks third with 38 papers. Australia and the United Kingdom share fourth and fifth places, each with 27 papers published. Finally, Canada, the Netherlands, and Germany round out the list with 16 papers each.

Figure 7 illustrates that 169 authors collaborated on articles related to regional development, smart cities, smart mobility, and transportation planning from 2010 to 2023. The top 10 authors, ranked by the number of papers they have published, are presented in Figure 6. The first place is held by Yigitcanlar, T., with 7 papers, followed by Russo in second place and Bibri, S. E., in third place, both with 6 papers. F. Trecozzi, M. R., ranks fourth with 5 papers, while Iiritano, G., also has 5 papers, securing fifth place. Pellicanò, S. occupies the sixth position with 5 papers, followed by Kamruzzaman, M., in seventh place with 4 papers. Petrungaro, G.,

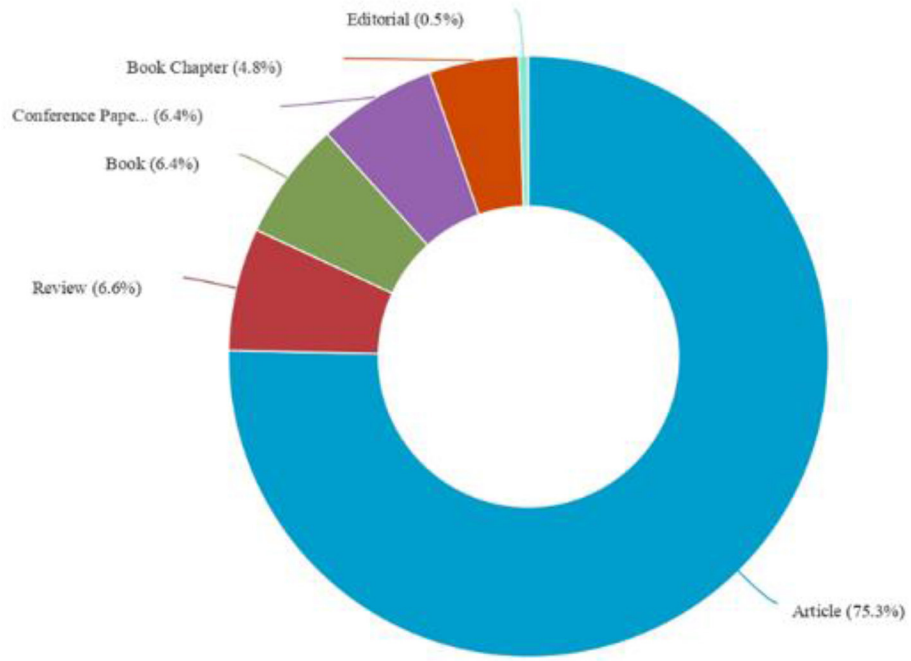

FIGURE 2
Document by type.

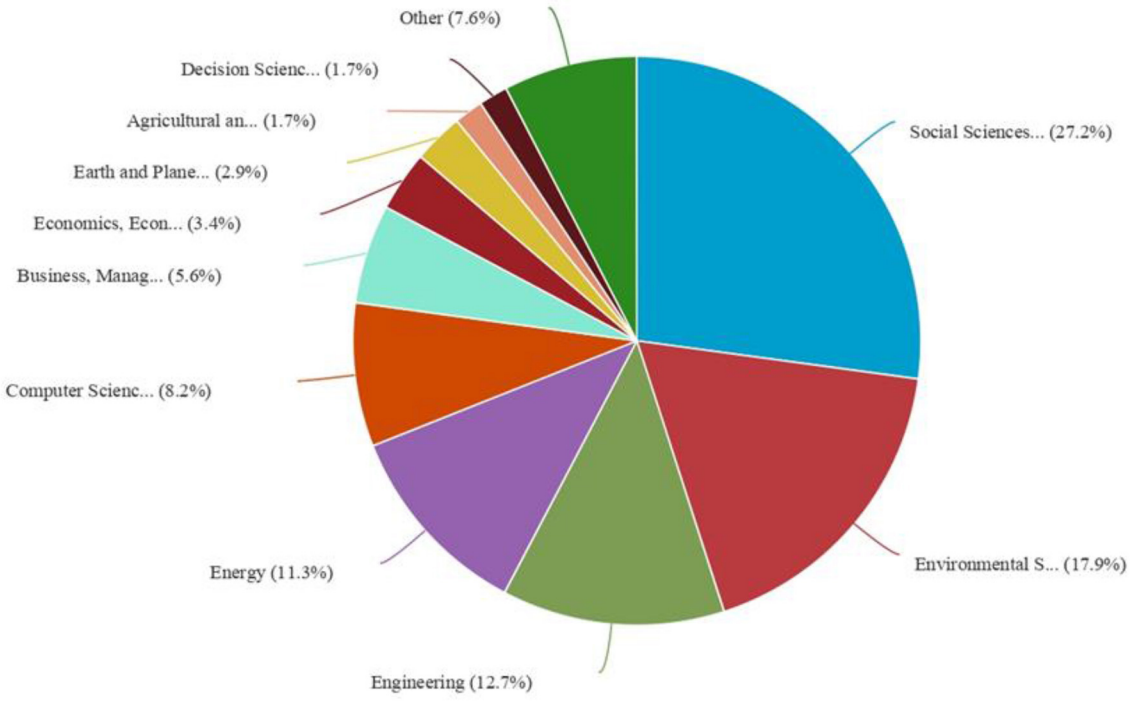

FIGURE 3
Document by subject area.

holds eighth place with 4 papers, while Calabrò, T. is in ninth place with 3 papers. Finally, Dierwechter, Y., rounds out the list in 10th place, also with 3 papers.

This study identified the top 10 affiliated institutions based on the number of published articles. The Chinese Academy of Sciences ranks first with 13 documents, followed by the Institute

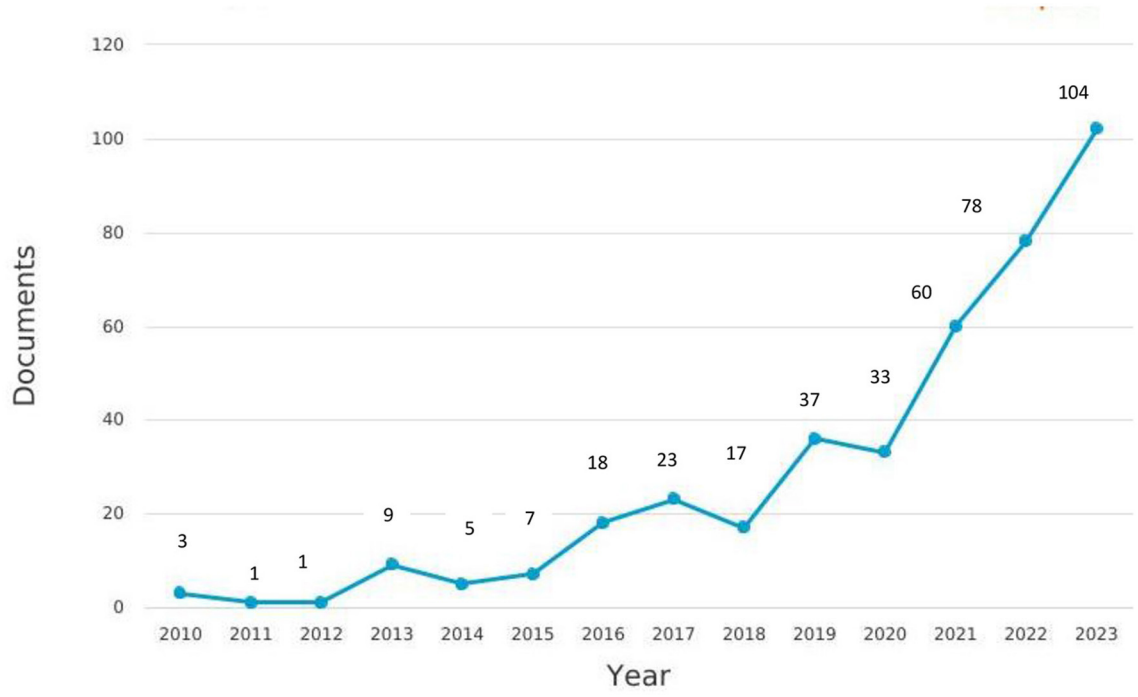

FIGURE 4
Trend document by year of publication.

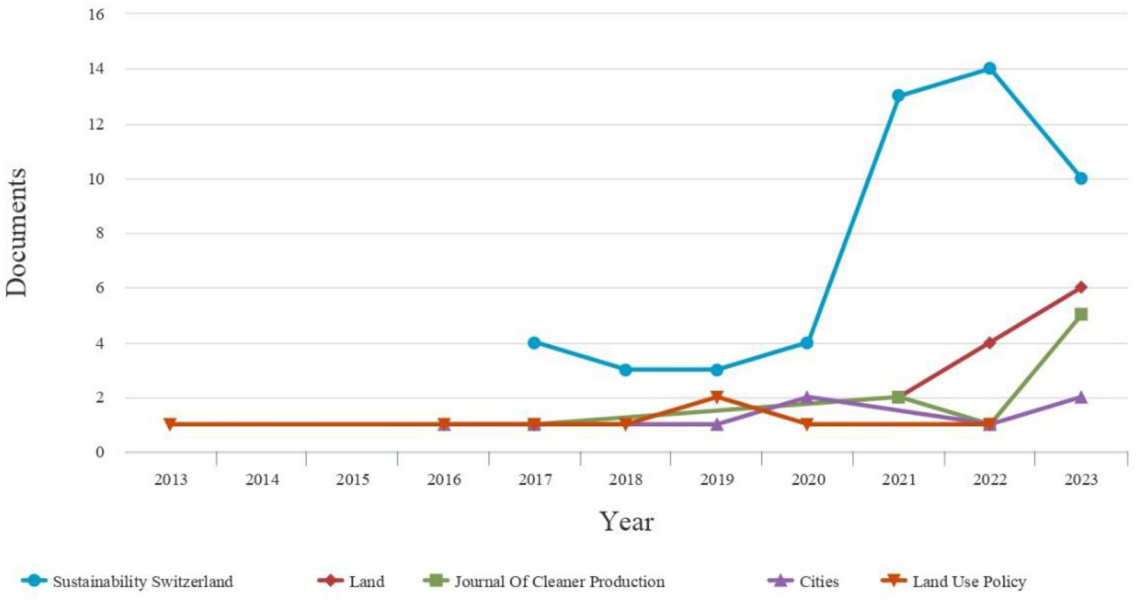

FIGURE 5
Trend document per year by source.

of Geographic Sciences and Natural Resources Research, also from the Chinese Academy of Sciences, with 11 documents. University College London comes in third with 9 documents, while Queensland University of Technology and the University of Chinese Academy of Sciences each have 8 documents, securing fourth and fifth places, respectively. Shenzhen University and the Ministry of Natural Resources of the People's Republic of China both have 6 documents, placing them in sixth and seventh positions, respectively. Calabria Regione ranks eighth with 5 documents, followed by Southeast University and Norges Teknisk-Naturvitenskapelige Universitet, both of which also have 5 documents, rounding out the list in ninth and

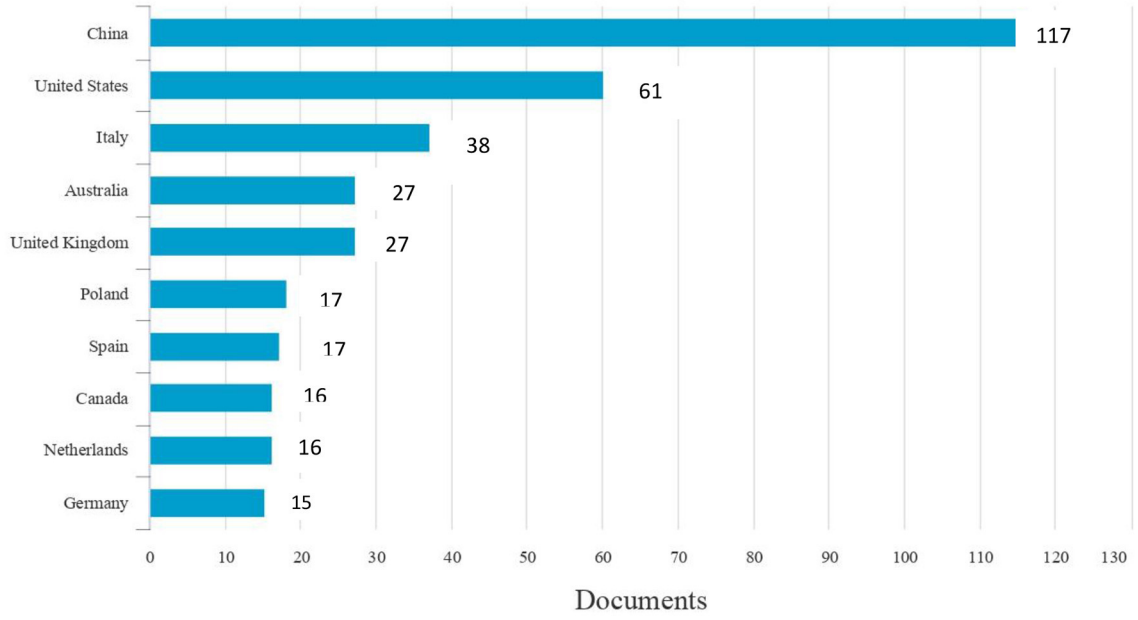

FIGURE 6
Number of document by country.

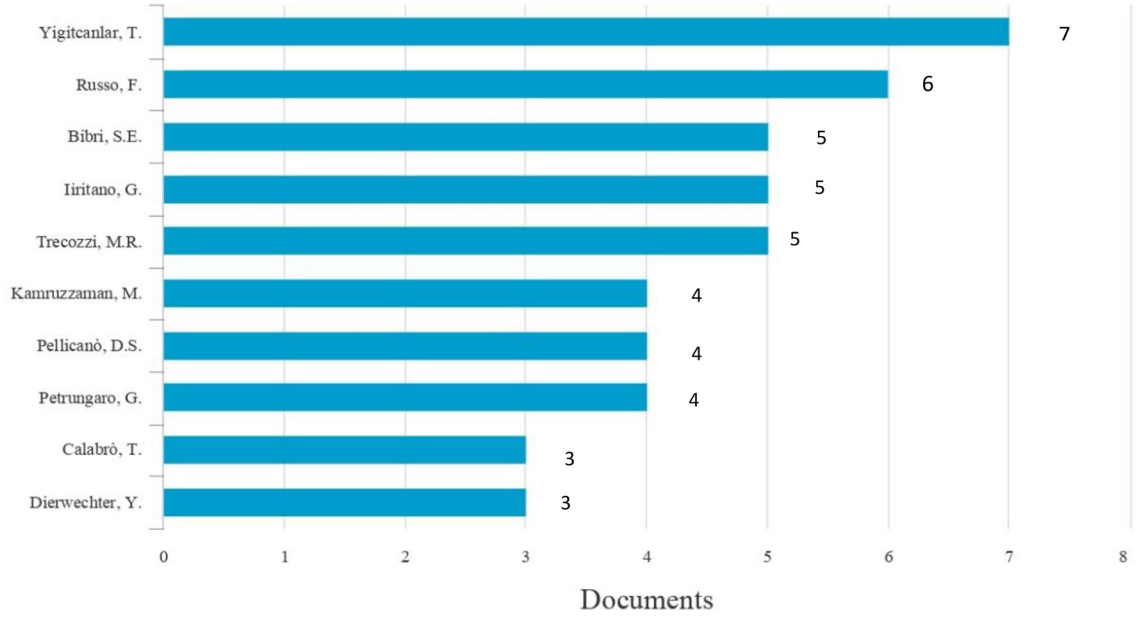

FIGURE 7
Number of documents by author.

10th places. A visualization of these findings can be seen in Figure 8.

Table 1 displays the top 10 articles with the highest citation counts among the 397 documents reviewed. The article with the most citations is titled "Can Cities Become Smart Without Being Sustainable? A Systematic Review of the Literature," authored by Yigitcanlar, T., Kamruzzaman, M., Foth, M., da Costa, E., and Ioppolo, G. Published in 2019 in the journal Sustainable Cities and Society, this article has garnered a total of 409 citations, averaging 136 citations per year. Conversely, the article with the lowest citation count is "Sustainable Environmental Development from the Regional Perspective—The Interesting Case of Poland," authored by Torabi Moghadam, S., Delmastro, C., Corgnati, S. P., and Lombardi, P. Written in 2017, it has received 88 citations and was published in the Journal of Cleaner Production. All relevant details can be found in the Table 1.

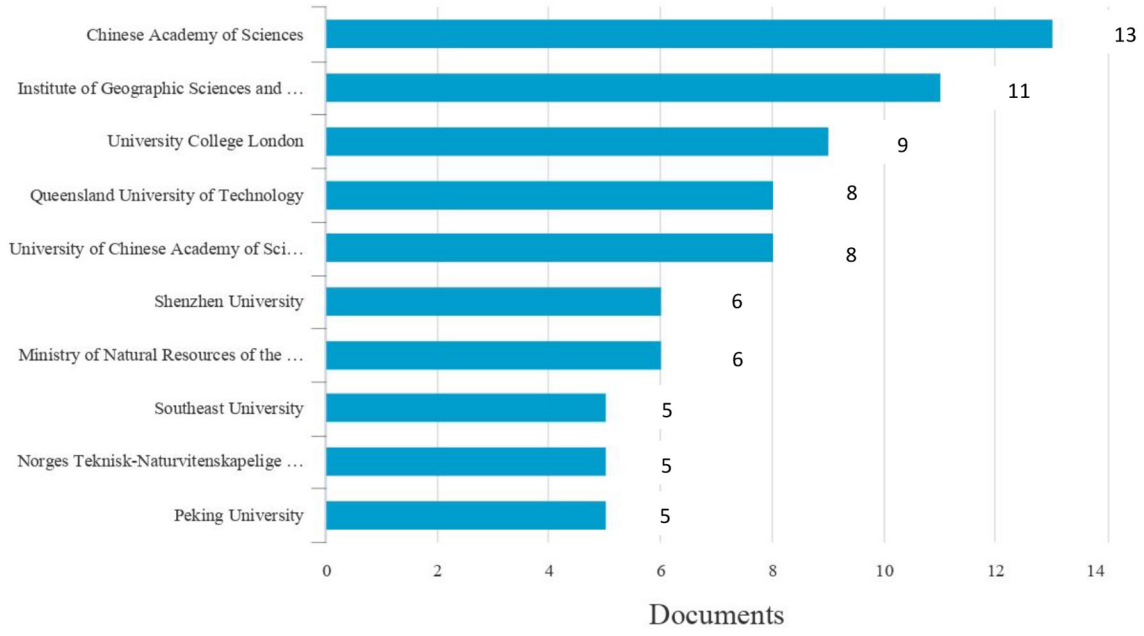

FIGURE 8
Number of documents per year by source.

3.1.1 Keyword co-occurrence analysis

Figure 9 illustrates the importance of keywords in research papers, as they encapsulate essential information about the content. Systematically examining keywords within specific research domains facilitates a clear understanding of developmental trends and disparities within that field. Co-occurrence analysis of keywords, often used to assess the connections among various terms across multiple documents, provides deeper insights into the relationships and structures within academic disciplines, highlighting the forefront of research in that area. Consequently, keyword co-occurrence analysis has become a widely utilized method in scientometrics.

Out of the 11,587 keywords analyzed, 321 met the designated threshold of a minimum occurrence of 10 instances across all gathered literature related to regional development, smart city initiatives, smart mobility, and transportation planning. After screening with VOSviewer, these qualifying keywords were reduced to 193. This screening process resulted in a co-occurrence network of keywords comprising 9,518 links distributed across six clusters.

Keyword co-occurrence analysis has universal applicability in scientometric examination. Its primary focus is on assessing the strength of connections among co-occurring keywords across a diverse array of literature. The main objective is to explore the internal dynamics of an academic domain and reveal its research frontiers. These frontiers encompass a blend of contemporary research themes, fundamental inquiries, as well as emerging theoretical trends and unexpected topics gaining prominence. As illustrated in Figure 9, keyword co-occurrence analysis allows for the division of primary research trajectories into six clusters, where keywords within clusters of the same color demonstrate significant similarities.

3.1.1.1 Cluster 1 (red)

This cluster comprises 55 items, with co-occurring keywords including sustainability, regional policy, urban planning, and smart city. Notable titles within this cluster include "Can Cities Become Smart Without Being Sustainable? A Systematic Review of the Literature" (Yigitcanlar et al., 2019), "Compact City Planning and Development: Emerging Practices and Strategies for Achieving the Goals of Sustainability" (Bibri et al., 2020), "Smart Economy in Smart Cities" (Vinod Kumar and Dahiya, 2017), "Smart City Concept: What It Is and What It Should Be" (Zubizarreta et al., 2016), "Analysis of Sustainable Transport for Smart Cities" (Bamwesigye and Hlavackova, 2019), "Urban Sprawl Among Chinese Cities of Different Population Sizes" (Liu et al., 2018), "Regional Smart City Development Focus: The South Korean National Strategic Smart City Program" (Yang et al., 2021), "Connecting the Smart Village: A Switch Towards Smart and Sustainable Rural-Urban Linkages in Spain" (García Fernández and Peek, 2023), and "Exploratory Analysis of Urban Sustainability by Applying a Strategy-Based Tailor-Made Weighting Method" (Buzási and Jäger, 2021).

3.1.1.2 Cluster 2 (green)

This cluster contains 37 items, with co-occurring keywords such as accessibility, multimodal, public transport, and sustainable mobility. Notable titles within this cluster include "BRT TOD: Leveraging Transit-Oriented Development with Bus Rapid Transit Investments" (Cervero and Dai, 2014), "Accessibility and Centrality for Sustainable Mobility: A Regional Planning Case Study" (Rubulotta et al., 2013), "Integrated Transport System of the South-Moravian Region and Its Impact on Rural Development" (Šťastná et al., 2015), "The Impact of Intelligent Transportation System Implementations on the Sustainable

TABLE 1 Highly referenced papers (Top 10).

Rank	Document title	Authors	Sources	Year	Number of citation
1st	Can cities become smart without being sustainable? A systematic review of the literature	Yigitcanlar, T., Kamruzzaman, M., Foth, M., da Costa, E., Ioppolo, G	Sustainable cities and society, 45, pp. 348–365	2019	409
2nd	Compact city planning and development: emerging practices and strategies for achieving the goals of sustainability	Bibri, S.E., Krogstie, J., Kärrholm, M.	Developments in the built environment, 4, 100021	2020	216
3rd	From Garden City to Eco-urbanism: the quest for sustainable neighborhood development	Sharifi, A.	Sustainable cities and society, 20, pp. 1–16	2016	181
4th	BRT TOD: leveraging transit-oriented development with bus rapid transit investments	Cervero, R., Dai, D.	Transport policy, 36, pp. 127–138	2014	134
5th	Research progress in the development of natural gas as fuel for road vehicles: a bibliographic review (1991–2016)	Khan, M.I., Yasmeen, T., Khan, M.I., Farooq, M., Wakeel, M.	Renewable and sustainable energy reviews, 66, pp. 702–741	2016	124
6th	Smart city concept: what it is and what it should be	Zubizarreta, I., Seravalli, A., Arrizabalaga, S.	Journal of urban planning and development, 142(1), 04015005	2016	117
7th	The emerging data–driven smart city and its innovative applied solutions for sustainability: the cases of London and Barcelona	Bibri, S.E., Krogstie, J.	Energy informatics, 3(1), 5	2020	111
8th	Prototype business models for mobility-as-a-service	Polydoropoulou, A., Pagoni, I., Tsirimpa, A.,...Kamargianni, M., Tsouros, I.	Transportation research Part A: policy and practice, 131, pp. 149–162	2020	99
9th	Computational socioeconomics	Gao, J., Zhang, Y.-C., Zhou, T.	Physics reports, 817, pp. 1–104	2019	92
10th	Urban energy planning procedure for sustainable development in the built environment: a review of available spatial approaches	Torabi Moghadam, S., Delmastro, C., Corgnati, S.P., Lombardi, P.	Journal of cleaner production, 165, pp. 811–827	2017	88

Growth of Passenger Transport in EU Regions" (Stawiarska and Sobczak, 2018), "Regional Transport Plans: From Direction Role Denied to Common Rules Identified" (Russo and Rindone, 2021), "Sustainable Suburban Mobilities: Planning Practices and Paradoxes" (Nenseth and Røe, 2023), and "Towards Sustainable Transportation in Urban Areas: A Case Study" (Pujiati et al., 2022).

3.1.1.3 Cluster 3 (blue)

This cluster comprises 37 items, with co-occurring keywords such as economic growth, regional differences, smart transportation, urban sprawl, and urbanization. Notable titles within this cluster include "Urban Planning and Degrowth: A Missing Dialogue" (Xue, 2022), "Regional Transport Plans: From Direction Role Denied to Common Rules Identified" (Russo and Rindone, 2021), and "Towards Sustainable Transportation in Urban Areas: A Case Study" (Pujiati et al., 2022).

3.1.1.4 Cluster 4 (yellow)

This cluster contains 36 items, with co-occurring keywords such as regional planning, policymaker, and planner. Key titles in this cluster include "The Regional and Urban Policy of the European Union: Cohesion, Results-Orientation, and Smart Specialization" (McCann, 2015), "Towards Sustainable Regional Planning: Potential of Commuter Rail in the Madrid Urban Region" (Solís et al., 2023), "Urban Sustainability and Counter-Sustainability: Spatial Contradictions and Conflicts in Policy and Governance in the Freiburg and Calgary Metropolitan Regions" (Miller and Mössner, 2020), and "Specialized Governance and Regional Land-Use Outcomes: A Spatial Analysis of Florida Community Development Districts" (Deslatte et al., 2019).

3.1.1.5 Cluster 5 (purple)

This cluster contains 19 items, with co-occurring keywords including geography and urban agglomeration. Key titles in this cluster include "Making Urban Design a Public Participatory Goal: Toward Evidence-Based Urbanism" (Dyer et al., 2017) and "The Impact of Urban Development Patterns on Travel Behavior: Lessons Learned from a British Metropolitan Region Using Macro-Analysis and Micro-Analysis in Addressing the Sustainability Agenda" (Aditjandra, 2013).

3.1.1.6 Cluster 6 (light blue)

This cluster consists of 9 items, with co-occurring keywords including regional development, spatial pattern, and traffic

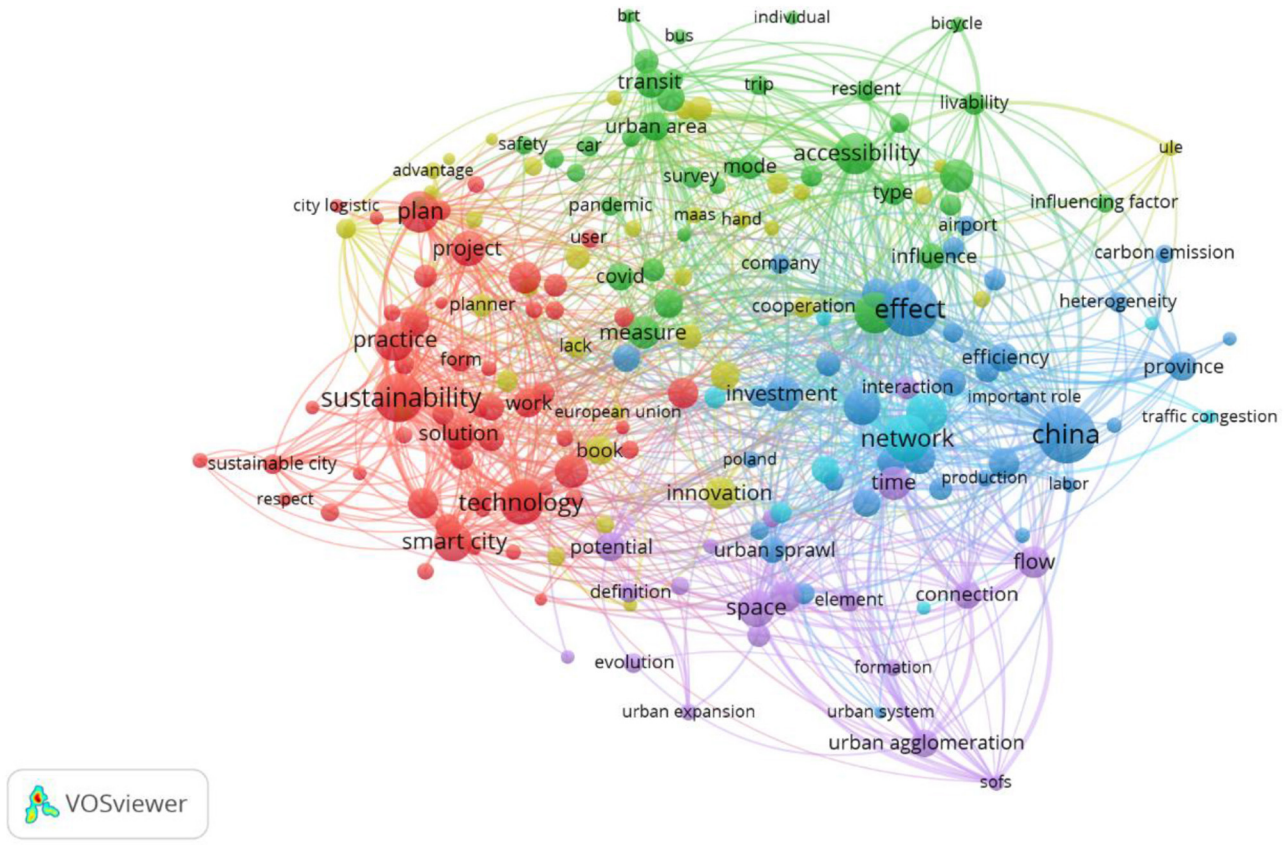

FIGURE 9
Network visualization in keywords co-occurrence.

congestion. Notable titles in this cluster are "The UK Regional-National Economic Problem: Geography, Globalization, and Governance" (McCann, 2016), "Integrated Regional Development: Comparison of Urban Agglomeration Policies in China" (Li et al., 2022), and "Sustainable Environmental Development from the Regional Perspective—The Interesting Case of Poland" (Tejada-Gutiérrez et al., 2023).

3.1.2 Keyword overlay network visualization

In Figure 10, we observe the changing patterns of keyword co-occurrence in the fields of regional development, smart cities, smart mobility, and transportation planning over the past few years. Analyzing these trends provides valuable insights into the latest research in these areas. The color spectrum in Figure 10, ranging from blue to yellow, illustrates the shifts in keyword co-occurrence from 2019 to 2022. The blue color indicates keywords from articles published between 2019 and 2020, while the colors transition from blue to green for articles published from 2020 to 2021, and from green to yellow for articles published from 2021 to 2022. Overall, Figure 10 visually represents the evolving research landscape in these domains over time.

In Figure 10, research related to sustainability, sustainable cities, regional planning, urban planning, policymakers, and urban areas is shown in blue, indicating that these studies were published between 2019 and 2020. In green, we see keywords such as accessibility, smart cities, regional development, rural areas, and economic growth, reflecting research published from 2020 to 2021. Finally, in yellow, keywords related to urban agglomeration, regional policy, policymakers, and smart transportation represent research published from 2021 to 2022.

3.1.3 Keyword density network visualization

In Figure 11, the map illustrates the density of research clusters, as discussed earlier in the network and overlay visualization. The colors—yellow, green, and blue—represent varying degrees of density. Bright yellow indicates high research density, while green suggests moderate density, and blue signifies areas with little to no research. The analysis primarily focuses on the densely populated yellow regions, although the green areas also indicate additional opportunities for exploration.

3.2 Discussion

Research conducted between 2010 and 2023 on regional development, smart cities, smart mobility, and transportation planning resulted in 397 articles produced by 70 different countries. Among these, 10 countries stood out for their significant

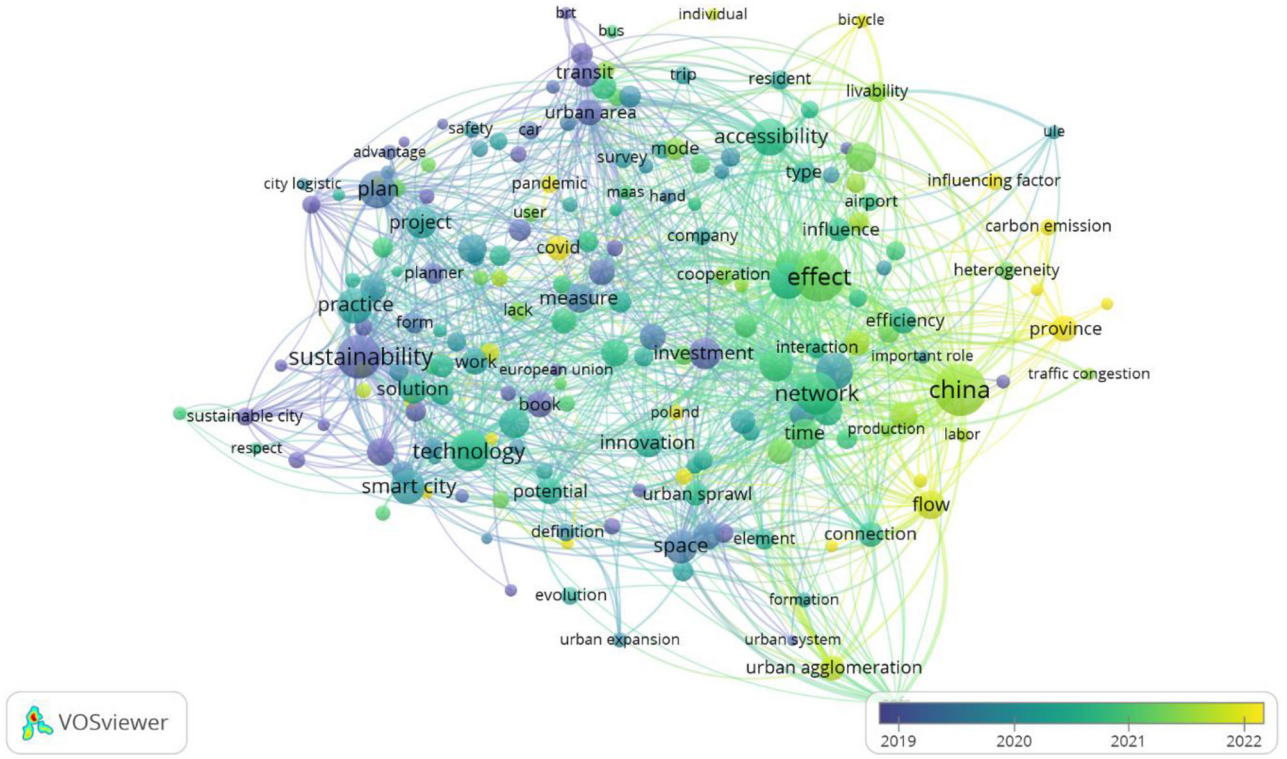

FIGURE 10
Overlay visualization in keywords co-occurrence.

contributions. China ranked first, followed by the United States in second place, Italy in third, Australia in fourth, and the United Kingdom and Poland tied for fifth. Canada secured seventh place, the Netherlands came in eighth, and Germany ranked tenth. Most of the countries involved in this research were from Europe, with additional contributions from the United States, Australia, and China in Asia.

Certain countries and regions excel in research on regional development, smart cities, smart mobility, and transportation planning due to a combination of factors. Economic investment in infrastructure and technology, particularly in nations like China and the United States, fuels innovation and addresses urban challenges. High population density in major cities drives the need for effective transportation solutions, while robust government policies and frameworks promote sustainability initiatives, as seen in countries like Italy and Australia. Additionally, strong collaborations between academia, government, and the private sector enhance research output, and cultural support for urban studies fosters a conducive environment for scholarly work. Consequently, nations grappling with significant urbanization and environmental issues prioritize research in these fields, leading to a notable disparity in output compared to others with less focus.

The results of this study also highlight the most prolific author, Yigitcanlar, T., whose research focuses on smart cities, smart mobility, and urban planning. One notable study is titled "Smart Cities and Mobility: Does the Smartness of Australian Cities Lead to Sustainable Commuting Patterns?" (Yigitcanlar and Kamruzzaman, 2019). In this study, Yigitcanlar finds that increased Internet connectivity may reduce remote work, public transportation use, and active transportation, while potentially increasing reliance on private vehicles. Addressing the need for car-based travel due to fragmented work activities while enhancing intelligence through improved broadband access should be a key agenda for Australia in making its cities more sustainable.

Russo emerges as another distinguished author with his study, "Regional Transport Plans: From Direction Role Denied to Common Rules Identified" (Russo and Rindone, 2021). This work delves into transportation planning, emphasizing a regional perspective. It proposes a methodical approach for the structured identification of plans within the framework of integrated spatial and transportation planning. The study focuses on regional transportation planning, examining its overall content while providing a detailed comparison and analysis of aspects related to public transport. It includes a case study centered on Italy, referencing the country's national guidelines and the transport plans ratified by its regions.

Another highly productive author is Bibri, S., who co-authored the work titled "Compact City Planning and Development: Emerging Practices and Strategies for Achieving the Goals of Sustainability" (Bibri et al., 2020). This study investigates the implementation and rationale behind the compact city model in urban planning and development, focusing on the three dimensions of sustainability. It explores whether advancements have been made in achieving sustainability goals through this approach.

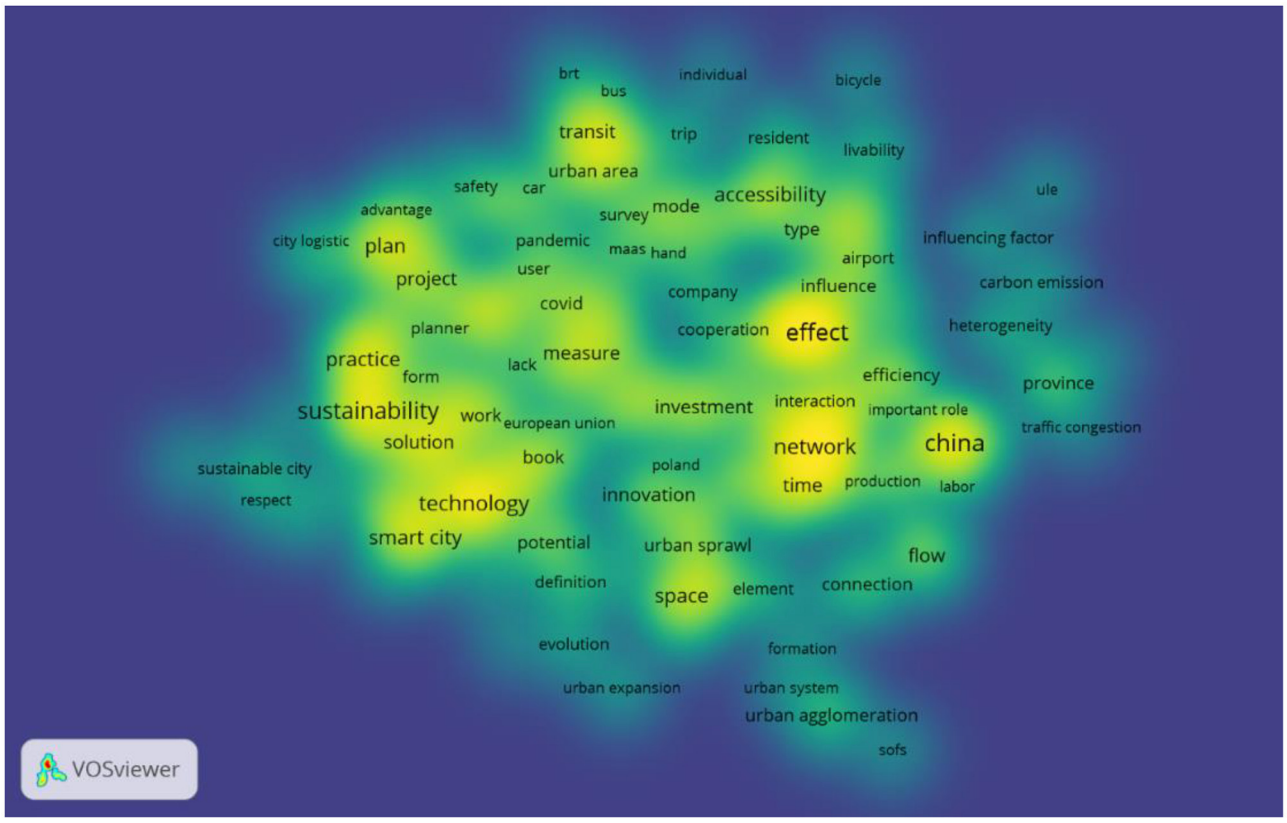

FIGURE 11
Density visualization in keywords co-occurrence.

Additionally, Iiritano, G. has authored an article entitled "Regional Transportation Plan of Calabria: Mobility in Urban Areas" (Russo et al., 2022). This study discusses the outcomes of two completed measures aligned with the tasks of the region's supervisory body. It demonstrates the collaborative efforts of Calabria's regional authority and executive offices in achieving the "Urban Areas" objective, beginning with the approval of the preliminary plan proposal. The focus is on executing planned measures and interventions, such as city logistics and creating traffic-free areas for pedestrians. The paper's innovation lies in illustrating how a regional transport plan, despite lacking mandatory authority over local governments, can, through collaboration with municipalities, identify mutual goals and actions to achieve objectives with a clear methodology. It emphasizes that this case study reflects the situation in many European regions that face similar developmental delays.

In the study "Developing Policy Scenarios for Sustainable Urban Growth Management: A Delphi Approach" (Perveen et al., 2017), the authors address the challenge of formulating effective policy scenarios to guide sustainable urban development. Employing a methodological framework, the research includes a comprehensive review of existing literature and practices, along with a two-stage Delphi survey conducted with experts from the public, private, and academic sectors specializing in urban, environmental, and social planning, as well as transportation modeling and economic development. The research findings provide essential recommendations for planners, modelers, and policymakers, offering guidance on selecting appropriate methods, indicators, and policy priorities to facilitate the development of sustainable policy solutions.

In the study titled "From Global Goals to Local Development: The Role of Regional Plans for Sustainable Urban Mobility" (Russo et al., 2021), Pellicano examines how Calabria, as a regional public authority, has utilized its Regional Transport Plan to establish a comprehensive policy for transport and logistics. This policy encompasses urban areas and outlines measures aimed at promoting sustainability, including city logistics, restricted traffic zones, and various other initiatives. The objectives of these interventions are to reduce pollution emissions and transportation costs, enhance safe mobility, and improve accessibility. Calabria's case serves as a valuable model, providing insights for technicians and policymakers that are broadly applicable to other European regions.

Further discussion on related research can be conducted by analyzing the results of the keyword co-occurrence analysis. In Cluster 1, prominent items such as "sustainability" are linked to smart city concepts, including "sustainable city," "urban planning," "urban sustainability," and "plan." Sustainability is also associated with "urban areas," "accessibility," "public transport," and "transit" in Cluster 2. This cluster connects sustainable mobility with urban area keywords, indicating a robust body of research linking smart

city sustainability, smart city initiatives, and sustainable mobility with urban planning.

Cluster 3 includes "regional development," which is a key keyword for this research, and this item is connected to "urban agglomeration" in Cluster 5, suggesting research that integrates these two concepts. Interestingly, Cluster 4 reveals that "regional planning" is not linked to other clusters, indicating a lack of research connecting these topics.

Based on this analysis, it can be concluded that there is currently no research that simultaneously connects regional development, smart city concepts, smart mobility, and transportation planning. While numerous studies on smart cities and smart mobility emerged from 2019 to 2021, there appears to be a decline in research in this area from 2021 to 2022. Conversely, research on regional development and transportation planning has been relatively sparse between 2019 and 2022. This gap presents numerous opportunities for exploration, potentially leading to new discoveries and advancements in the field.

The current bibliometric analysis seems to overlook several important topics that could significantly enhance our understanding of regional planning, regional development, urban sustainability, sustainable mobility, sustainable cities, urban growth, smart transportation, and transportation planning. Investigating these topics could yield valuable insights into creating more livable and sustainable cities that meet residents' needs while minimizing environmental impact.

Sustainable development is crucial for meeting the needs of both current and future generations, emphasizing a long-term approach that balances economic growth with improved quality of life. As urban areas expand, the focus on designing smart, sustainable cities becomes increasingly critical. Effective governance, particularly in transportation, must prioritize environmental friendliness, accessibility, and economic viability. While urban centers present opportunities for sustainability, rural areas often encounter challenges due to dispersed development and reliance on private cars, which can lead to social exclusion.

Transportation planning is a key component of spatial planning that supports sustainable frameworks for social, environmental, and economic development. It involves regulating and guiding growth to conserve resources and attract investment while aligning with global initiatives like Agenda 2030. Effective planning requires the integration of theories, regulations, and practical implementation to make informed decisions based on a thorough understanding of transportation systems. Transportation encompasses various modes, including road, rail, air, and sea, each with its complexities influenced by factors such as driver behavior and environmental conditions. A shift toward more ecological transport modes, particularly rail, aims to significantly reduce emissions while promoting safer and more sustainable mobility.

Globally, sustainable transportation has become a priority, particularly in developed countries that are enhancing infrastructure and multimodal systems. However, rural areas continue to struggle with accessibility issues, particularly for individuals without vehicles. The rapid urbanization observed in regions like China highlights the urgent need for sustainable transport solutions that ensure equitable access to opportunities for all communities.

4 Conclusions

This study conducts a comprehensive analysis of the relationship between regional development, smart cities, smart mobility, and transportation planning. The analysis is based on a thorough literature review and meticulous bibliometric analysis, focusing on key themes explored in 397 research articles published between 2010 and 2023 in the Scopus database. This investigation uncovers critical insights with significant implications for both academic research and practical applications in the field.

Multiple issues related to the study were identified and categorized into six major themes: (1) sustainability, regional policy, urban planning, and smart cities; (2) accessibility, multimodal transport, public transport, and sustainable mobility; (3) economic growth, regional differences, smart transportation, urban sprawl, and urbanization; (4) regional planning, policymakers, and planners; (5) geography and urban agglomeration; and (6) regional development, spatial patterns, and traffic congestion.

The analysis reveals significant gaps in research connecting regional development, smart cities, smart mobility, and transportation planning, particularly the lack of integrated studies that address these areas simultaneously. There has been a noticeable decline in recent research on smart cities and mobility, especially from 2021 to 2022, along with insufficient focus on rural transportation challenges, which often leads to social exclusion. Future research should prioritize interdisciplinary approaches that link these fields, explore tailored transportation solutions for rural areas, and develop clear sustainability metrics. Additionally, integrating emerging technologies and collaborative models involving various stakeholders can enhance the effectiveness of transportation planning and urban development, ultimately fostering more sustainable and equitable systems.

This research adds value not only to academic knowledge but also offers practical guidance for policymakers and practitioners in achieving sustainable urban futures. From a scientific standpoint, this study enhances our understanding of the complex relationships between regional development, smart cities, smart mobility, and transportation planning. It identifies key themes and issues while laying a foundation for further research.

Finally, it is essential to conduct research that connects regional development, smart cities, smart mobility, and transportation planning, which can strengthen scientific knowledge and be applied to the development of regions and countries.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

SA: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Resources, Software,

Visualization, Writing – original draft, Writing – review & editing. ER: Conceptualization, Formal analysis, Investigation, Supervision, Validation, Writing – review & editing. AF: Conceptualization, Data curation, Formal analysis, Methodology, Supervision, Validation, Writing – review & editing. RS: Conceptualization, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

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Publisher's note

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