Mapping the Research Landscape of Urban Sustainability Indicators: A Bibliometric Review and Thematic Analysis

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DOI: https://dx.doi.org/10.47772/IJRISS.2025.90400183

Received: 27 March 2025; Accepted: 03 April 2025; Published: 05 May 2025

ABSTRACT

Cities have evolved into hubs of economic, social, and cultural activities. The growing attraction of urban regions has resulted in unprecedented urban growth, demanding novel approaches to provide sustainable urban development. To assess sustainable urban development, numerous frameworks involving key sustainability features and indicators have been proposed in the literature. Several studies have identified indicators for environmental, social, economic, institutional and cultural factors; nevertheless, little scholarly effort has been given to mapping the overview of this research area. The purpose of this study is to map the landscape of existing literature on indicators for sustainable urban planning using bibliometric analysis of 205 papers retrieved from the Scopus database. The study used the VOS viewer and Bibliophagy packages to demonstrate the progress status of scientific production. The data shows a continual growth in the number of publications during the last five years. According to the keyword analysis, the most frequently occurred terms were sustainable development, sustainability, and urban growth. The text analysis in VOS viewer identified three thematic areas including the framework for urban sustainability assessment, research and models for smart city, and stakeholder engagement and implementation strategies. A thorough analysis of each thematic area was conducted, and future study directions were identified. Thematic evolution on the topic revealed that the terms "urban economy" and "smart city" have lately acquired prominence, beginning in 2018, indicating a shift toward incorporating cutting-edge technologies and economic aspects into urban development processes. Furthermore, a review of the most frequently adopted sustainability assessment indicators was undertaken, and the limitations of the existing frameworks were identified. The study also identified trending topics and potential future hotspots in the field of sustainable urban planning.

Keywords: Sustainable Urban Planning (SUP), Sustainability Assessment Frameworks, Thematic Evolution

INTRODUCTION

Over the last few decades, growing urbanization has transformed cities into hubs of economic activities, cultural interactions, and social innovations (1). Urbanization and worldwide population growth are predicted to increase the share of urban population to 68% by 2050(2). This unprecedented urban growth, however, has resulted in significant issues such as environmental degradation, resource depletion, and rising socioeconomic disparities(3). In this context, the concept of sustainability has arisen as an important paradigm for guiding urban development, with the goal of balancing the requirements of current and future generations(4). Hence, sustainable urban development is regarded as critical for both local regions and states, as well as on a worldwide scale (5).

Sustainable urban development is most commonly defined as a balance between three fundamental dimensions of sustainability: environmental, social, and economic, that work together to create a healthy and resilient habitat

for existing populations while preserving future generations' ability to experience the same (6). Urban planning plays a crucial role in ensuring sustainable urban development by addressing environmental concerns, promoting economic growth, and enhancing the quality of life in cities. As urban populations grow, the complexity and necessity of sustainable urban planning have intensified. Cities are widely acknowledged as critical areas for addressing global sustainability concerns, necessitating a comprehensive framework to assess urban sustainability using the established sustainability thematic areas (7). Consequently, researchers and practitioners have started developing comprehensive indicators to guide and evaluate sustainable urban development.

Recently, various studies have published urban sustainability assessment frameworks and outlined numerous indicators pertaining to key sustainability thematic dimensions. Some of the studies have emphasized the use of indicators related to three sustainability dimensions including environmental, social, and economic, while others considered the fourth dimension of institutional (3). The fourth dimension was developed to involve authorities in developing, implementing, and enforcing sustainable policies and practices. Each of these dimensions encompasses a variety of indicators that play a pivotal role in guiding the policymakers for the evaluation of progress towards sustainability goals. Numerous studies have thoroughly analyzed the available frameworks and indicators; however, a comprehensive study revealing the research landscape and mapping of bibliographical characteristics of publications remains deficient. On that note, this study conducts a bibliometric analysis and provides a landscape of the published literature in the area of indicators for sustainable urban planning. This study extracted 205 documents from the Scopus database. The extracted documents were analyzed to identify key trends, influential publications, and prevalent themes within this domain.

The remainder of this paper is divided into four sections. Section 2 discusses the method adopted for the searching, screening, extraction and analyzing the publications. In Section 3, the basic bibliometric results and citation metrics pertaining to the most productive and dominant articles, countries, and organizations are presented. Thematic evolution and research hotspots are also discussed in section 3. Section 4 highlights the most frequently adopted indicators for different sustainability dimensions. In Section 5, the conclusions are presented based on reviewed studies thereby enhancing the capacity of urban planners and policymakers to foster sustainable and resilient urban environments.

METHODS

A step-based methodology was applied for the search, extraction, mapping and analysis of the published documents related to indicators for sustainable urban planning. The process started with the definition of study topic and scope, followed by the selection of database and extraction of relevant documents. The overall flow of steps is shown in Figure 1.

Step 1: Search criteria – This step involved the definition of the keywords, scope in terms of time frame and selection of the database for the extraction of relevant published literature on the intended topic. The study considered the Scopus database for the search of relevant literature by using a compiled search string based on the definitions and keywords. Scopus database, being one of the largest online databases, was chosen for the search of documents since it extensively covers academic publications as compared to other databases such as Web of Science or Google Scholar. Furthermore, it is consistently being expanded and updated(8). Based on the defined topic and keywords, the resulting query comprising of several terms concerning both sustainable urban planning and indicators was applied in Scopus database in May 2024 and resultant documents were refined and extracted for further analysis.

Step 2: Selection – A search in Scopus database was made by using the complied query which resulted in 221 documents. The obtained results were refined based on the language and subject area filters. All documents in English language and published before the search date were selected. The papers under the subject area of “medicine”, “nursing”, “health professions”, “agriculture and biological science”, “neurosciences”, “immunology and microbiology”, and “dentistry” were excluded from the selection. After applying screening, a total of 205 documents were extracted for analysis and review.

Step 3: Bibliometric analysis – In this phase, citation metric records and network maps were generated from bibliographic data exported from the database through the application of analyzing and visualizing tools.

Following tools were deployed to obtain the desired outputs:

- Microsoft Excel was used to show the basic matrix of extracted documents, document types and annual growth trends.
- Harzing's Publish and Perish tool was used to compute the citations metrics.

VOS viewer was used to create and visualize bibliometric networks.

- The Bibliometrix R-package was used to create collaboration networks, word trees and thematic evolution maps.

Step 4: Review – This step involved the review and discussion on the key topics and research hotspots based on retrieved information from previous steps pertaining to the established indicators for sustainable urban planning.

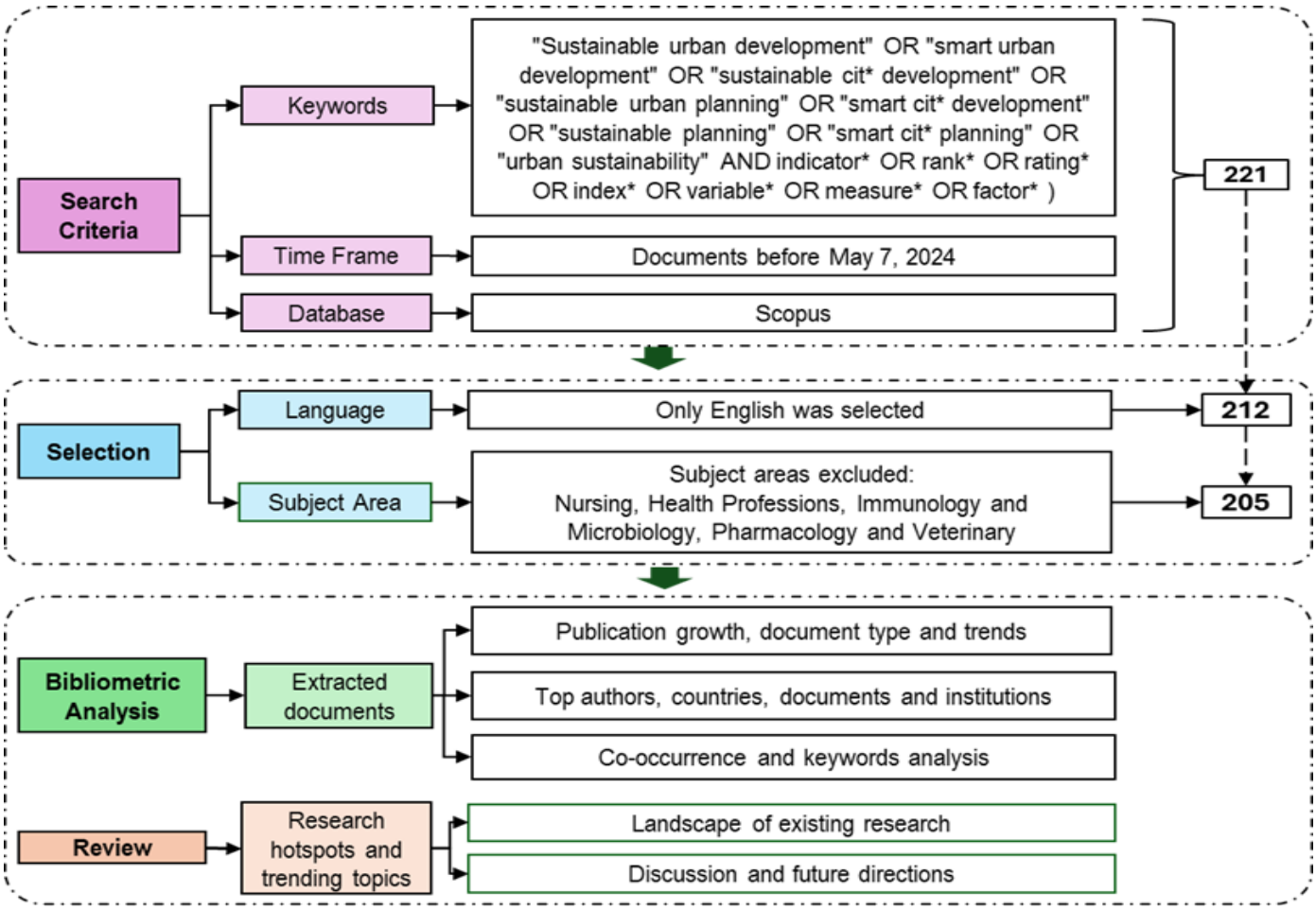

Figure 1 - Flowchart of research methodology

RESULTS AND ANALYSIS OF FINDINGS

Document Type and Publications Trend

This study extracted a total of 205 documents related to the topic of indicators for sustainable urban planning. The selection was made through a rigorous search strategy and screening process. Initially, the extracted data was organized into Microsoft Excel 365 to examine the statistical information of selected documents before making a preliminary conclusion. As shown in Figure 2, the documents were divided into six categories based on their type. Articles made up the highest share of 59% of the extracted documents, followed by the conference papers with around 18% share. The highest number of articles and conference papers may indicate the empirical nature of the studies on the topic.

Figure 2 – Documents types

Figure 3 shows the subject areas and the annual publication trend together with the exponential trend line for the indicators of sustainable urban planning over the years. An exponential model was considered to define the relationship between the year and number of publications. The number of studies increased at a moderate pace with less than 10 annual papers prior to 2017. Since 2017, on the other hand, there has been a consistent increase in the number of papers. After three years, in 2020, there has been a rise in the annual publications on the topic. During the last five years, around 100 studies discussing the indicators for sustainable urban planning were published, accounting for around 50% of all included studies. Additionally, potential subject areas for the published documents were also identified. Earliest publications on the topic referred to environmental sciences and social sciences. However, over the years, engineering, computer science, energy and decision sciences appeared as the potential subject areas contributing significant insights on the topic. Recently, environmental sciences, social sciences and engineering contribute the highest proportion of the publications. This trend of change in the subject area refers to the integration of emerging concepts and technologies in the urban planning field.

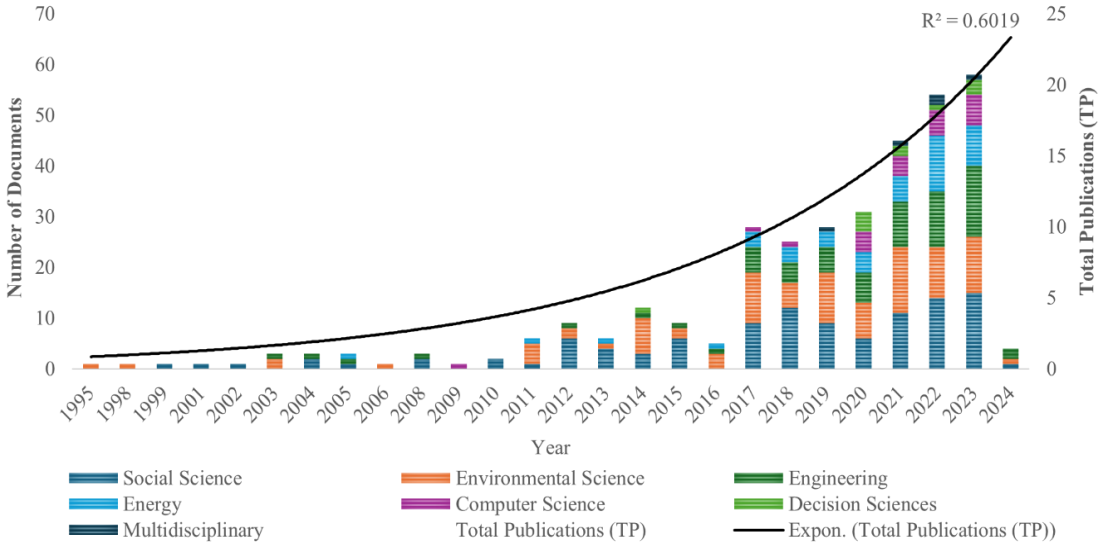

Figure 3 – Subject areas and annual production trends of publications

Top Articles, Countries, and Institutions

For 205 documents, a total of 575 authors from different countries contributed to the research concerning indicators for sustainable urban planning. Table 1 shows the top 10 documents ranked based on the total number of citations. Additionally, the information on year if publication, total citations, citations per year and the publication journal have been given. The paper with highest citations of 508 entitled "The application of urban sustainability indicators - A comparison between various practices" was produced in 2011 and published in an Elsevier based journal. This extensive study investigated nine different urban sustainability approaches and proposed an indicator list to aid information sharing and indicator selection. The discussion was organized

around environmental, economic, social, and governance issues. The fact is also endorsed by the citation network shown in Figure 4 where the node size represents the number of total citations received by a document.

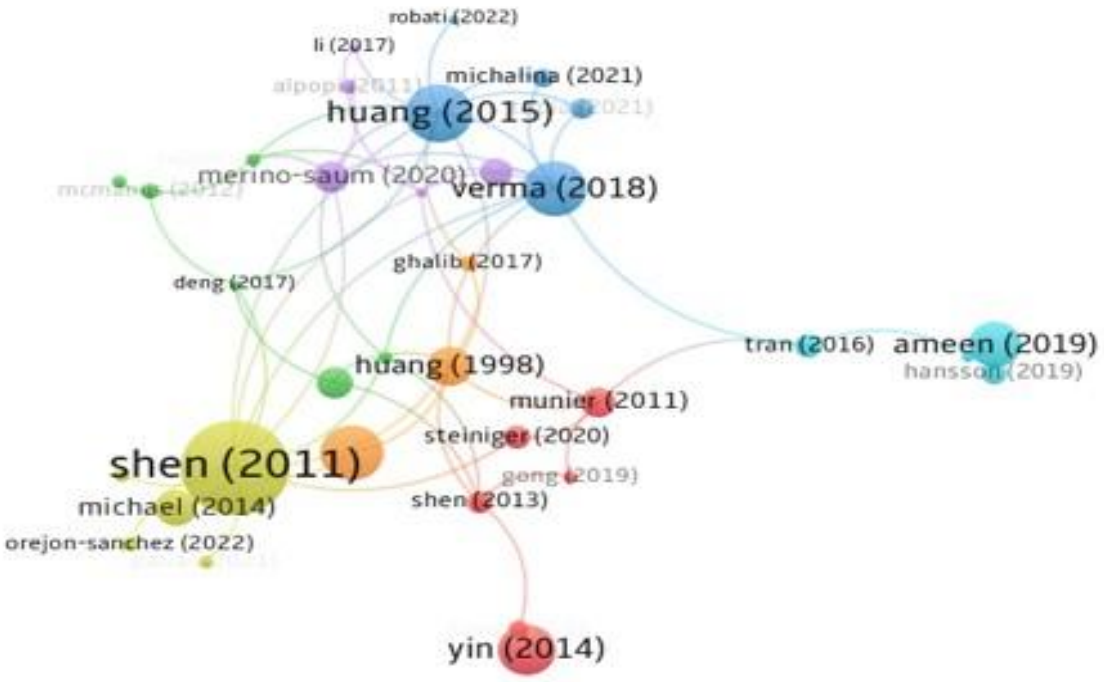

Figure 4 – Citations network of documents

Table 1 - Top 10 documents ranked based on total citations

Rank	Publication Title	Reference	Year	Citation	Citations /year
1	The application of urban sustainability indicators - A comparison between various practices	Liyin Shen, J. Jorge Ochoa, Mona N. Shah	2011	508	39.08
2	Defining and measuring urban sustainability: a review of indicators	Huang, L., Wu, J., Yan, L.	2015	229	25.44
6	Indicator-based urban sustainability-A review	Hiremath, R.B., Balachandra, P., Kumar, B., Bansode, S.S., Murali, J	2013	215	19.55
2	Urban sustainability indicators: Challenges and opportunities	Verma, P., Raghubanshi, A.S.	2018	213	35.5
7	Using eco-efficiency as an indicator for sustainable urban development: A case study of Chinese provincial capital cities	Yin, K., Wang, R., An, Q., Yao, L., Liang, J.	2014	182	18.2
8	Social vulnerability indicators as a sustainable planning tool	Lee, Y.-J.	2014	159	15.9
3	Urban sustainability assessment framework development: The ranking and weighting of sustainability indicators using analytic hierarchy process	Ameen, R.F.M., Mourshed, M.	2019	158	31.6

9	Accessibility to greenspaces: GIS based indicators for sustainable planning in a dense urban context	La Rosa, D.	2014	154	15.4
10	Eco-cities: The mainstreaming of urban sustainability - Key characteristics and driving factors	Joss, S.	2011	153	11.77

Figure 5 shows the details of the top 10 countries ranked based on the number of total publications. Among the 53 countries that contributed to the publications on the topic, China contributed the most with 25 papers, accounting for 12.20%. This was followed by Unites States with 18 publications, accounting for 8.78%, Italy and United Kingdom each with 17 papers, the Spain with 13, Iran with 12 and Australia with 11 publications. The number of publications and collaborations among the 20 most prolific countries are displayed in Figure 6. The number of papers is presented in the figure based on the size of the node where a larger node suggests a higher number of papers (9) . The China and United States were the countries having the most frequent interactions among them, indicating a strong collaboration among these countries.

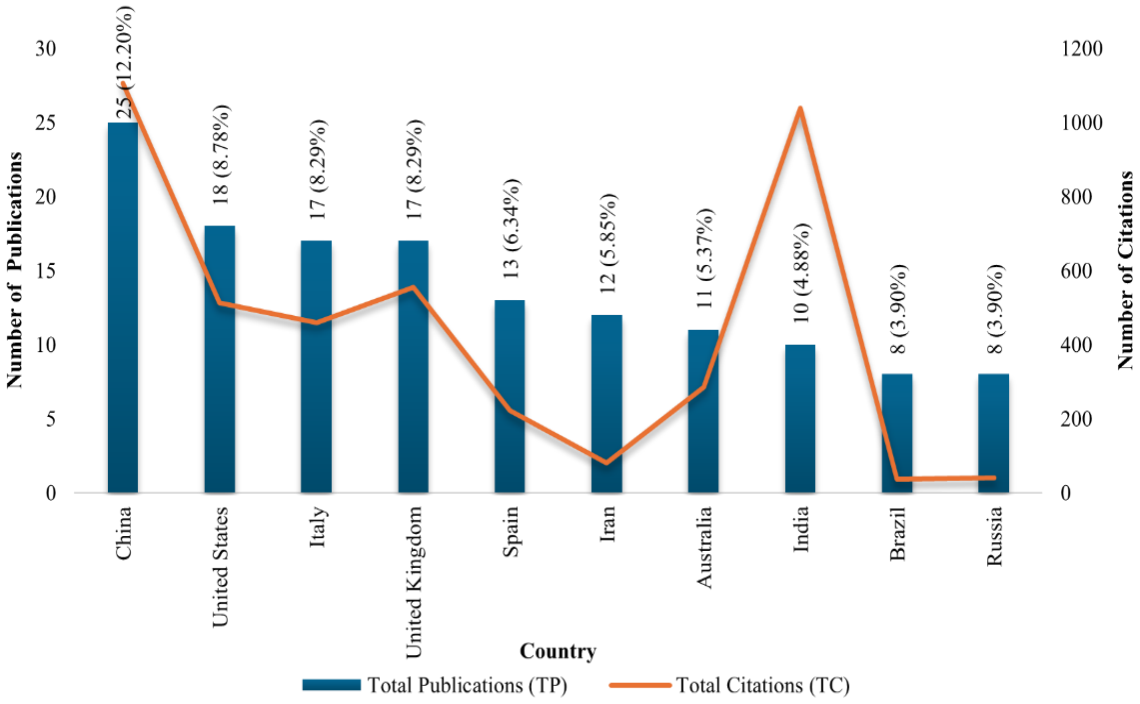

Figure 5 – Top 10 countries, their publications and total citations

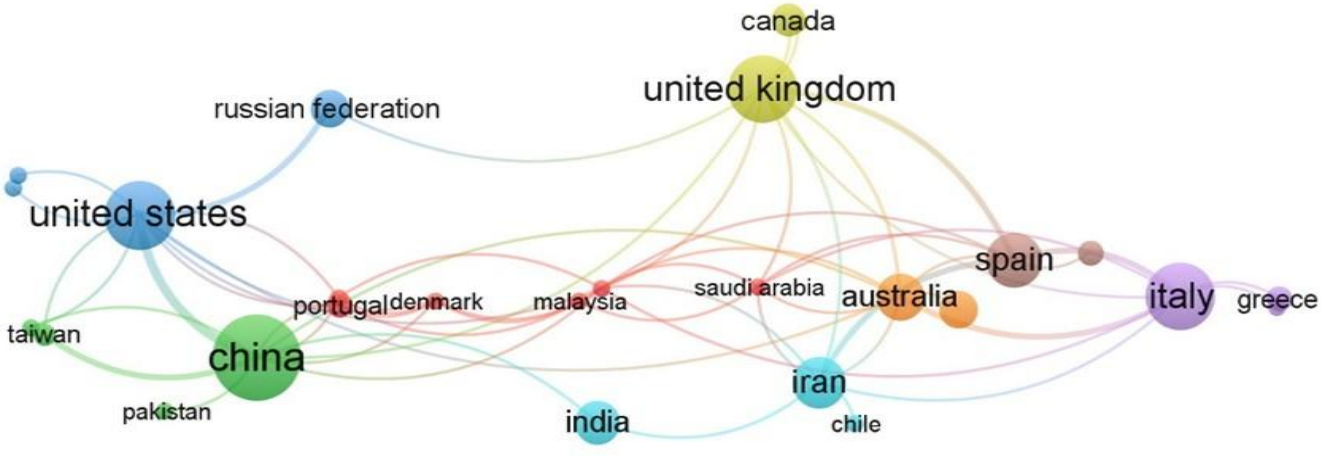

Figure 6 – Top 10 countries, their publications and total citations

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IV April 2025

A total of 385 organizations from around the world were identified contributing to the research on the establishment of indicators for sustainable urban planning. Table 2 summarizes the top three institutions in terms of contributions. The Chinese Academy of Sciences, China is ranked first, accounting for 2.44% of all relevant publications with 5 related papers. Islamic Azad University from Iran comes second with 5 publications, followed by Environment Europe Ltd from United Kingdom, Stellenbosch University from South Africa, and Thammasat University from Thailand, contributing 3 documents each.

Table 2 - Top 10 documents ranked based on total citations

Rank	Institution	TP (%)	Country
1	Chinese Academy of Sciences	5 (2.44%)	China
2	Islamic Azad University	5 (2.44%)	Iran
3	Environment Europe Ltd	3 (1.46%)	United Kingdom
4	Stellenbosch University	3 (1.46%)	South Africa
5	Thammasat University	3 (1.46%)	Thailand

Current landscape and Research Themes

The current landscape of the research pertaining to indicators for sustainable urban planning has been illustrated in the form of density map shown in Figure 7. The most frequently appearing keywords from the previously published documents on the intended topic were extracted and tabulated. From the density map shown in Figure 7, it is revealed that sustainable development, sustainability, sustainable urban development, indicators, and smart city are the most discussed keywords with the highest density, endorsing the relevancy of the extracted documents with the intended research topic. Aside from that, some tools and analysis techniques have also been highlighted, indicating the use of GIS and spatial analysis as most widely considered for the research on sustainable urban planning. The density map also highlights several emerging concepts in the field of sustainable urban planning, such as smart cities. These concepts have evolved with the emergence of advanced sensing and navigation technologies, and they integrate a variety of digital technologies, such as Internet of Things (IoT) sensors, data analytics, artificial intelligence (AI), and communication networks, to optimize the management of city services and infrastructure(10). Hence, the current landscape of the research on the topic of indicators for the sustainable urban planning indicates presence of some extensively studied together with less explored areas and emerging concepts.

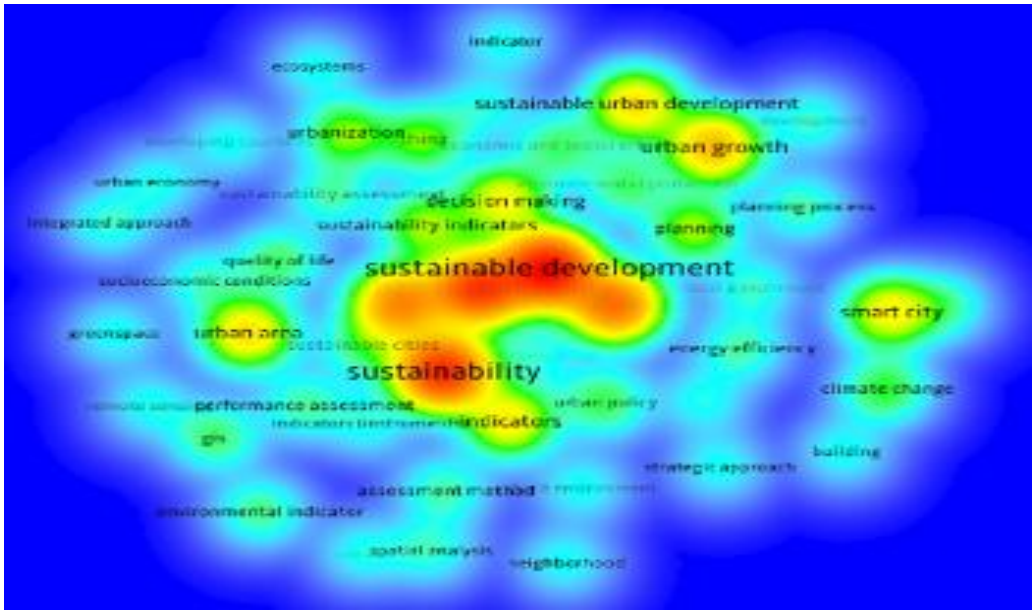

Figure 7 – Density visualization map of most frequently occurring keywords

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IV April 2025

In addition to the keywords, a text analysis was performed by considering the text from article titles and abstracts of the selected documents. A network map created in VOS viewer based on text analysis is shown in Figure 8. As there are multiple clusters, each cluster is represented by a distinct color. The clustering technique in VOS viewer gathers the potential terms having a citation relationship with other terms into one cluster (11). Hence, the terms shown in each cluster have some bond with other terms in the same cluster. The terms present in a cluster represent a thematic area. The details of the most frequently occurring terms in each cluster are given in Table 3.

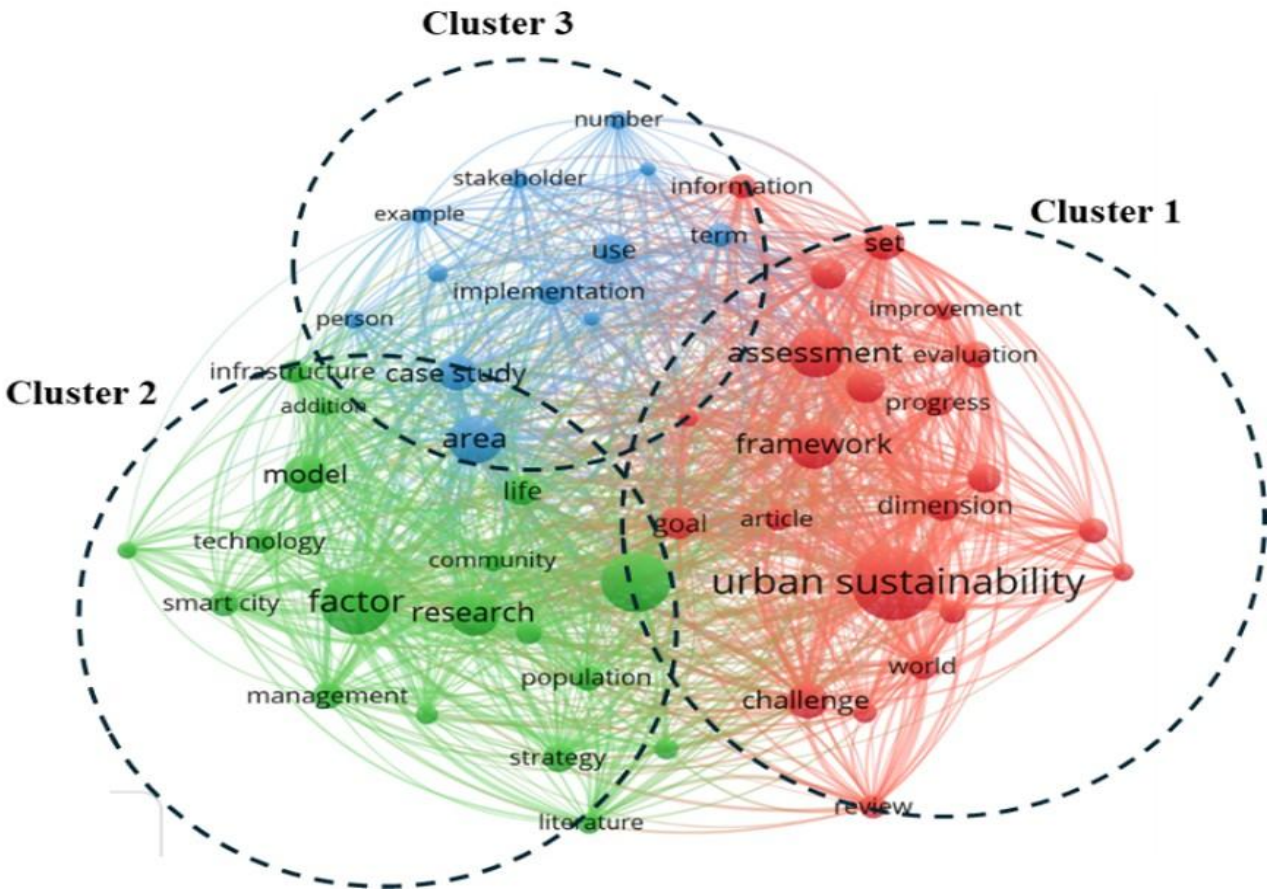

Figure 8 – Clusters developed based on the text analysis

Table 3 – Notable keywords in clusters and research themes

Cluster	Terms	Research Theme
Cluster 1 (Red)	Urban sustainability, assessment, framework	Framework for urban sustainability assessment
Cluster 2 (Green)	Factor, urban development, model, research, smart city	Research and models for smart city
Cluster 3 (Blue)	Area, case study, implementation, use, stakeholder	Stakeholder Engagement and Implementation Strategies

Framework for urban sustainability assessment

A framework for sustainable city assessment is a structured technique considered for the evaluation of urban areas. These frameworks include several indicators that address environmental, social, economic, and governance aspects of sustainability. Measures of biodiversity, energy use, waste management, and the quality of the air and water are considered as environmental indicators (11). Social indicators frequently include things like social equity, affordable housing, healthcare, and education(12). Economic indicators can be used to track

things like job openings, GDP growth, income inequality, and company innovation(13). Governance indicators assess how well public engagement programs, urban governance frameworks, and policy coherence work (14). Based on multidimensional indicators, a robust framework for assessing sustainable urban development provides comprehensive guidance for understanding a city's sustainability profile, allowing policymakers, planners, and stakeholders to identify areas for improvement, track progress over time, and make informed decisions to promote long-term urban sustainability.

A review of the literature on frameworks for urban sustainability evaluation reveals a number of noteworthy findings. Earlier attempts proposed the criteria and sub-criteria of indicators for urban infrastructure sustainability(15). (16)provided a conceptual framework for urban sustainability that includes urban and community planning. (17)underlined the importance of focusing on place-related concerns in urban social sustainability, while (18) endorsed the importance of developing a synthesis framework for sustainable urban development. Similarly, (19) proposed for a unifying framework and universal sustainability principles in urban sustainability evaluation. The systematic review discussed the role of considering the sustainability aspects in rapidly urbanizing settings and need for the assessment of progress towards sustainable urban development (20), revealed the challenges of urbanization and the significance of sustainability assessment in urban design. The study, however, highlighted the limitation of existing assessment methods for not taking the urban scale into account for assessment of urban sustainability. (21)emphasized the importance of context customization, regulatory body involvement, and consideration of socioeconomic issues in urban sustainability evaluation systems. However, according to the study, assessment procedures continue to be heavily focused on environmental effects. (13)discussed the need for a framework to measure sustainability, and the goal of transforming cities into sustainable smart cities and provided some indicators for the assessment of current processes of urban infrastructures. However, the study lacks a common criterion among diverse frameworks, evolving nature of proposed indicators, and inability of key indicators to cover interconnected issues. (22)also endorsed the urban sustainability assessment frameworks as an effective tool for the urban regeneration process. These findings together highlight the need for a more comprehensive and context-specific approach to urban sustainability.

In literature, the frameworks for the assessment of urban sustainability are based on certain indicators which provide a standardized and systematic way for the measurement and monitoring progress towards sustainable developments. Assessing sustainability using indicators has been suggested as an effective method for managing sustainable urban development (19). The frameworks include multidimensional indicators in order to integrate the various components of urban settings into the development process. Indicators chosen carefully thus serve to comprehend the entire concept of sustainable development(23).

The literature offers numerous studies discussing the theoretical and methodological aspects of identifying potential indicator frameworks and their application in the intended sustainability process (24) (25) . These studies have contributed to the topic by reviewing the available frameworks for the assessment of sustainability. Some other studies have contributed by identifying indicators for methodological frameworks of urban sustainable assessment along with their practical application (7, 10, 21, 26).

Existing research has indicated numerous issues related to the urban sustainability evaluation framework that require additional investigations. The studies have supported the necessity for quantitative-based performance assessments, a lack of complete analytical frameworks, indicators based on substantial data, and consideration of regional differences (7, 27) . These gaps highlight the necessity for further research to address evolving sustainability issues, incorporate health-based dynamics, consider climate justice, and bridge the sustainability gaps in urban areas to support decision-making and policy development. Also, exiting frameworks have considered the use of environmental, social, economic, and institutional themes for the assessment of urban sustainability, however, little considerations have been witnessed on using master plan as a tool to facilitate the urban sustainability assessment process. Provided the limitations on the availability of adequate data, size of city and administrative divisions, a general framework based on established sustainability themes would be less effective for diverse nature of cities. However, an approach considering the master plan as tool would be equally effective for any city. Hence, there is a need of taking city’s master plan into account for the assessment of urban sustainability.

Research and models for smart city

In the next two decades, by 2050, it is estimated that almost 70% of the world's population will migrate to cities, creating a need of sustainable solutions to cater such large populations(28). To accomplish this, various concepts of smart city are to be considered. The concept of smart city entails the use of information and communication technologies (ICT) to manage various city activities in order to boost the effectiveness of city operations (29) . A broad overview of smart city concept includes the six components such as smart economy, smart people, smart governance, smart mobility, smart environment, and smart living(30).

The smart city concept has grown significantly over time. Originally focused on ICT technologies, smart cities have evolved beyond simply technological applications to emphasize human and social engagement as important components (31). Smart cities have shifted from focusing solely on ICT solutions to tackling governance, environmental, and urbanization concerns. Today, the concept includes ICT to improve urban infrastructure efficiency, create awareness of societal concerns such as energy efficiency and decarbonization, and promote sustainable development practices(32). Furthermore, the emergence of the "smart energy city" concept has added a sector-specific dimension to smart cities, merging ICT-led advancements with low-carbon and sustainable energy projects(33). This progression represents a change toward a more holistic and interdisciplinary approach to developing smart cities.

Recently, many countries have started implementing cutting-edge methods and technologies to improve management and city affairs in order to gain from smart governance and management(34). The deployment of advanced technologies together with the fulfilment of essential aspects of management and governance are required to effectively introduce the concept of smart city. Making a city genuinely smart requires a redesign at the design level, which is a major primary effort with beneficial social, economic, human, and environmental effects. A number of cities in the developed countries have already implemented the smart city concept. Examples of such cities include London, Dubai, New York, Hong Kong, Amsterdam, Singapore, Tokyo, Paris, and Copenhagen (35) . Some recent standards have also been established and added to the standard library of the International Organization for Standardization (ISO). This offers the essential benchmarking and guidance to effectively realize the concept in the other parts of the world.

The major advantages of implementing smart city concept include the enhanced quality of life, improvement in infrastructure efficiency, and assistance to long-term economic growth (36). The integration across various domains like transportation, energy, health, and governance help to create interconnected urban environments(37). However, there exist some challenges pertaining to data privacy concerns, unequal access to technology, and the need for collaboration among different sectors (38). Furthermore, the introduction of smart city technology can lead to concerns like inequality, discrimination, and monitoring, especially in decision-making processes that lack clear-cut answers (39). The studies have also shown concern over the long term sustainability implications of this concept(40), unequal emphasis on social and cultural aspects, centering mostly on technical aspects rather than political, social and economic dimensions(10), lack of transparency and reporting of results as output of smart city concept(10), and inadequacy of portability and resource sharing between different sectors of high impact smart city system(10). Despite the potential benefits, the practical implementation of smart cities confronts challenges due to the complexity of managing numerous parties with varying interests and goals in urban environments. Hence, more research is expected to address these hurdles and provide a long-term solution to urban problems.

Stakeholder engagement and implementation strategies

The engagement of stakeholders in the urban planning process has always been considered crucial owing to its effectiveness in bridging the diverse backgrounds and enhanced project success (41). The strategy for sustainable urban planning comprises of numerous factors, including scenario planning, public participation, and energy-intensive planning, to ensure active stakeholder involvement in decision-making processes (42). Additionally, the use of geospatial technologies can aid in the implementation of sustainable urban planning methodologies. Overall, effective stakeholder engagement and implementation strategies are vital for successful and sustainable urban development.

The literature pertaining to the stakeholder engagement and implementation strategies for sustainable urban planning is divided into multiple research themes covering multidisciplinary approach of urban planning, insights from urban studies, implications on environmental and social aspects, and public administration. Studies emphasize the need of incorporating multiple stakeholders, such as government institutions, corporate sector partners, community organizations, and people, to achieve complete and inclusive planning processes(41). The literature has highlighted several strategies including the workshops, and the application of digital platforms for better reach and feedback. The current research landscape emphasizes that successful implementation of sustainable urban planning projects frequently depends on open communication, collaborative decision-making, and the ability to adapt to changing circumstances and stakeholder needs (43) . Furthermore, experts have identified important barriers such as competing interests, resource limits, and institutional inertia, implying that addressing these issues will necessitate strong governance frameworks, capacity building, and the development of a shared vision for sustainability. Recent research has revealed several emerging themes, including the need for more empirical studies to assess the efficacy of various engagement and implementation strategies across a range of urban contexts and the role of smart technologies and data analytics in boosting stakeholder engagement and tracking the impact of sustainability measures.

Thematic Evolution and Trending Topics

Over the years, the research in the area of urban sustainability assessment has seen various transitions and emergence of new topics. With the emergence of new technologies and allied concepts, several topics of the last decades have embraced the new definitions. Figure X shows the temporal trends and frequencies of several terms pertaining to urban studies and sustainability from 2006 to the present. The node size represents the frequency of terms, where larger node sizes indicate higher frequencies.

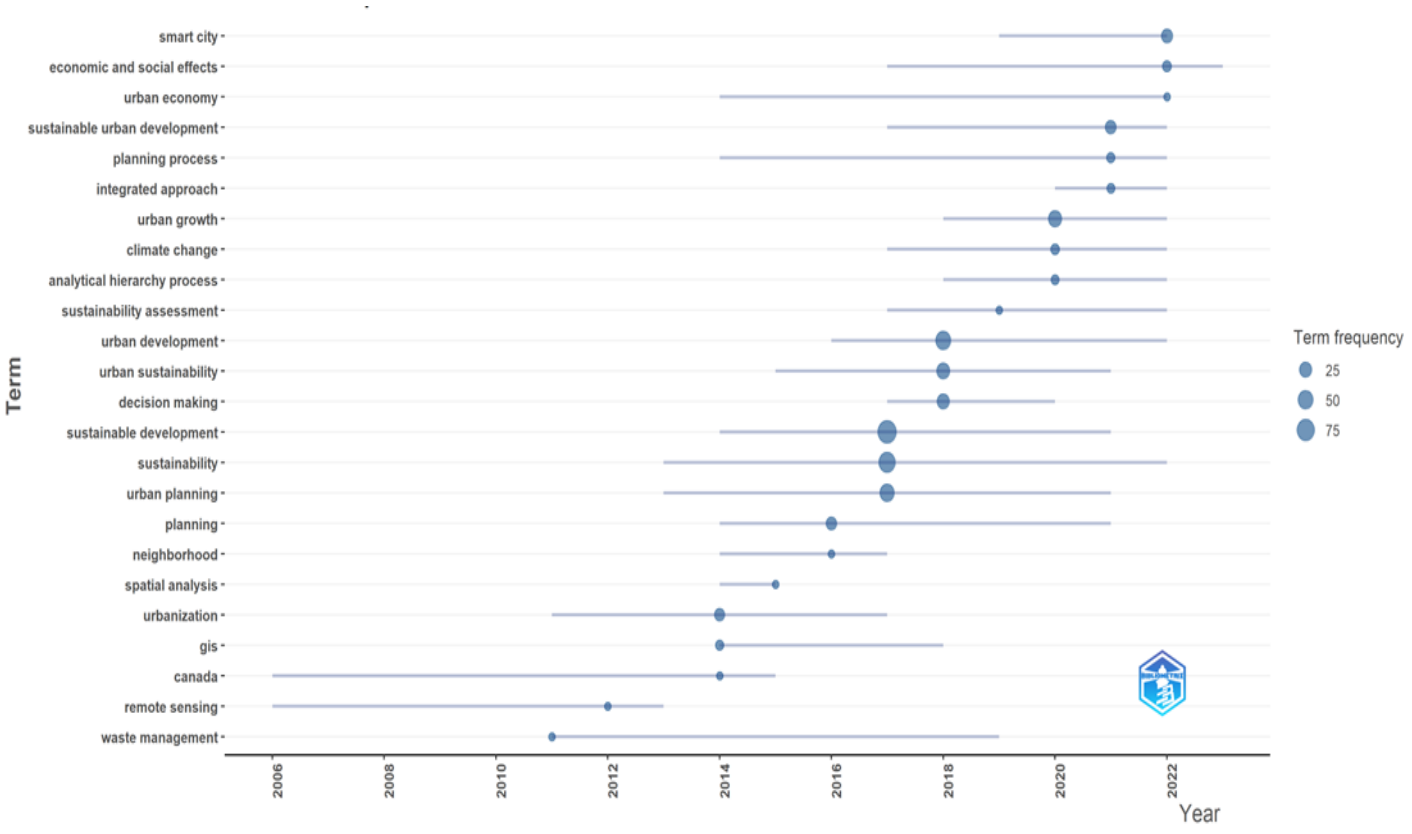

Figure 9 – Thematic evolution and trending topics

The terms can be broadly classified into themes including technology integration, sustainability, urban planning, and spatial analysis. Notably, over time, the terms "sustainability" and "sustainable development" have continuously surfaced, underscoring their fundamental significance in the area. Significant increases in frequency are observed for these terms, especially starting in 2014, which suggests that sustainable practices in urban contexts are continuously becoming important. Terms like "remote sensing" and "GIS" (Geographic

Information Systems) are more common early in the timeline, indicating the early emphasis on spatial analysis methods in urban studies. However, their relative frequency diminishes over time as the discourse broadens to include more diverse aspects of urban sustainability. Additionally, since 2012, the term "climate change" shows a steady increase in frequency, highlighting the importance of environmental considerations while designing urban spaces. Similarly, the terms "urban growth," "integrated approach," and "decision making" see a rising trend, signifying a comprehensive method of urban planning that considers a variety of interdisciplinary aspects.

The terms "urban economy" and "smart city" have gained popularity recently, starting about 2018. This indicates a shift towards integrating cutting-edge technologies and economic factors into the urban development process. The term "smart city," in particular, is bearing a notable rise, indicating the growing interest in leveraging technology to improve urban living.

The network of keyword co-occurrence, shown in Figure Y, illustrates the central themes and temporal trends in the area of urban sustainability. The nodes with different colors and sizes represent the years and term frequency in the literature. The nodes with blue colors represent the terms that have been investigated earlier and greater sizes indicate the volume of studies published in that research area Terms like "smart city" and "smart cities" are highlighted in red and orange, indicating a recent rise in their popularity (between 2018 and 2020). This suggests that there is increased interest in using cutting-edge technologies and smart solutions in urban planning contexts. Moreover, terms “sustainable assessment”, “integrated approach”, and “local government”, with nodes in red color, suggest the need of further investigations in these areas.

Overall, a dynamic evolution in the field of urban studies has been observed over the years, with a clear trend towards sustainability, technological integration, and comprehensive planning approaches. The increasing frequency of these terms over time underscores the growing complexity and interconnectivity of issues faced in urban development and the corresponding need for multifaceted strategies. Moreover, focus on smart city concept has been a prominent topic these years indicating extensive research for the integration of multidimensional aspects of cities into urban planning.

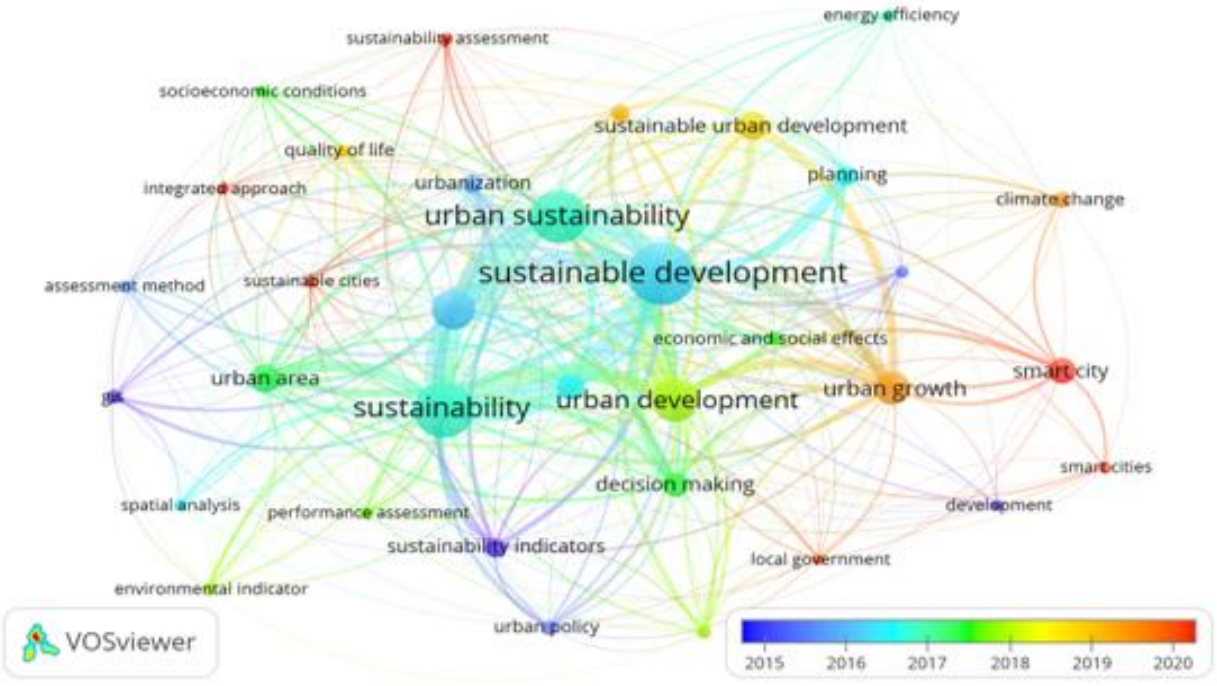

Figure 10 – Keywords occurrence network and research hotspots

INDICATORS FOR URBAN SUSTAINABILITY ASSESSMENT

In literature, the studies pertaining to the frameworks for urban sustainability assessment have identified the key thematic dimensions where each of the dimensions encompass a variety of indicators. Most of the studies merely focused on arranging the indicators within a thematic category without considering their relationship to the main

dimensions of sustainability. However, some of them organized the indicators into three (environmental, social, and economic) or four (environmental, social, economic, and institutional) sustainability dimensions. Urban sustainability assessment includes a wide range of indicators that cover environmental, social, and economic factors. Studies have identified significant indicators from multiple sustainability assessment methodologies such as BREEAM-C, LEED-ND, SNTool, and SBToolPT Urban, with the purpose of establishing a comprehensive set of sustainability priorities(33, 44). Moreover, the researchers have established multiple frameworks to ensure the reliable measurement of cities' progress towards long-term sustainable development(45, 46). Overall, combining these diverse indicators allows for a more comprehensive assessment of urban sustainability, considering environmental effects, social equality, economic viability, and institutional efficiency. From the review of existing frameworks, the most frequently adopted thematic categories were identified for sustainability assessment frameworks, shown in Figure Z.

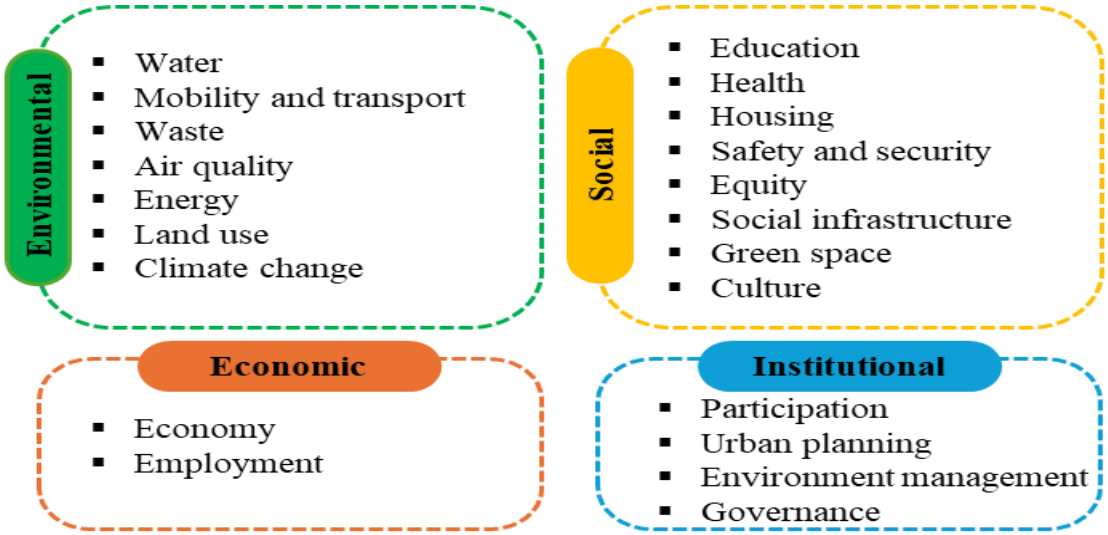

Figure 11 – Most frequently adopted thematic areas for sustainability assessment frameworks

The environmental dimension of sustainability is divided into seven major themes: water, mobility and transportation, waste, air quality, energy, land use, and climate change. Within the theme of "water", most of the frameworks considered the water consumption, water quality and water sanitation. For mobility and transport, the most frequently monitored indicators were daily traffic volumes, private vehicle ownership, modal split, traffic flow, and public transport affordability. Regarding the "waste" most of the frameworks focused on production, separation, and recycling. For air quality, the annual mean concentration of NO_2 PM_{10} and $PM_{2.5}$ and their frequency of exceeding the allowed limits were considered. For energy, the key focus was given to the consumption and considerations on renewable sources. The "land use" category involves several further categories using the city's territory, while "climate change" involves indicators pertaining to the assessment of the amounts of CO_2 emissions.

Within the dimension of the economic dimension of sustainability, there exists two main thematic categories: economy and employment. The "economy" category considers the financial power of a city, whereas "employment" category involves both employment and unemployment in the city. However, the classification was not clear enough because these indicators existed in both categories of the economic dimension of sustainability.

The social dimension of sustainability is divided into eight major theme categories: education, health, housing, safety and security, equity (social and economic), social infrastructure, green space, and culture. In the "education" category, the content of the topic's monitoring differs significantly between the global and European indicator frameworks. Global frameworks focus on indicators relevant to developing cities (literacy rate, school enrollment), whereas indicator frameworks in Europe or developed countries focus on educational quality. The indicators in the "health" category explicitly track the quality and availability of medical services. In the "housing" category, enough space and the cost of living are monitored. The "safety and security" category is primarily evaluated by indicators that measure the amount of crimes and traffic accidents in the city. The final

mentioned indication is also commonly found in the "mobility and transport" and "health" categories. The "equity (social or economic)" category monitors income distribution and equitable opportunity for all groups of population. Several indicators in the "social infrastructure" category measure household saturation and access to basic services. The "green space" category is largely assessed using measures that track green spaces and their accessibility to city residents. In the "culture" category, public spending on culture is tracked.

The institutional dimension of sustainability is divided into four major thematic categories: participation, urban planning, environmental management, and governance. Within the "participation" category, voter turnout and the number of civic associations in the city are the most frequently examined. The "urban planning" and "environmental management" categories are monitored by similar indicators, which most typically examine the availability of documents promoting sustainable and strategic urban growth and the adoption of an environmental management plan. In the final category, "governance," the handling of public funds is carefully evaluated, most typically using the total debt per inhabitant of a municipality.

Despite comprehensive supply of frameworks, there exist some challenges that limit the applicability of existing frameworks to different cities of world. The primary challenge in identifying sustainability indicators is the heterogeneity of terminologies and category names, even when they analyze the same domain(19). Consequently, numerous authors argue for standardizing the terminology of sustainability assessment to highlight these concerns(47). Secondly, there are some prime indicators that exist in every established framework for the assessment of urban sustainability. Such indicators must be identified as the key indicators so that they will always be present in each framework(1). The third and most critical challenge with the existing framework is the representation of indicators between frameworks of developing countries and those of developed countries. The priorities of developed and developing countries vary significantly, creating a difference of relevancy of categories and indicators in the cities. In developed countries, environmental categories and indicators are prominent, whereas, in developing countries, the prime focus is on social and economic categories and indicators. Hence, the relevance of geographical space must be taken into consideration while making the selection.

DISCUSSION AND IMPLICATIONS FOR URBAN PLANNING PRACTICE

This study presented a bibliometric overview of urban sustainability indicator research, revealing evolving scholarly trends across thematic domains. However, a deeper reflection on the findings suggests that while the academic discourse has matured in scope, its translation into actionable urban planning strategies remains limited. The three principal thematic cluster frameworks for sustainability assessment, smart city paradigms, and stakeholder engagement reflect a diverse and expanding body of knowledge. Nonetheless, these strands often lack contextual adaptability, particularly for cities in data-constrained and institutionally diverse environments. For instance, while numerous frameworks propose comprehensive indicator sets, they rarely offer mechanisms for local customization or alignment with existing governance instruments. Similarly, the emphasis on smart cities tends to prioritize technological and infrastructural solutions, often at the expense of governance integration and social inclusivity, which are critical dimensions for long-term urban resilience.

The practical implications of these limitations are substantial. Urban planners, particularly in developing contexts, face the dual challenge of interpreting complex indicator systems and operationalizing them within constrained planning regimes. The integration of sustainability indicators into statutory master plans emerges as a pragmatic strategy, offering an institutionalized platform for sustainability monitoring without necessitating parallel frameworks. Moreover, governance and participatory mechanisms—frequently referenced but less frequently embedded—should be reconceptualized as core components of sustainability indicators, rather than supplementary themes. Planners must not only consider infrastructure and environmental benchmarks but also institutional transparency, public participation, and inter-sectoral coordination, especially as these elements influence both policy efficacy and public legitimacy.

In terms of methodological scope, this review relied exclusively on the Scopus database. While Scopus offers robust coverage of international literature, it inherently excludes significant contributions from regional journals, grey literature, and non-English publications. As a result, the review may inadvertently marginalize region-

specific knowledge systems, particularly from the Global South, where urban sustainability issues are often compounded by socio-economic vulnerabilities. Future reviews should expand their bibliographic scope to include databases such as Web of Science, SciELO, and CNKI, while also considering multilingual literature. Such inclusiveness would help mitigate selection bias and enrich the global applicability of findings.

Additionally, the visual representations used in this study—particularly co-occurrence networks and thematic evolution maps—are informative, but their analytical potential depends on critical contextual interpretation. For example, the increasing prevalence of terms such as "smart city" and "urban economy" since 2018 points to a shifting focus toward technological and economic dimensions of sustainability. At the same time, the declining emphasis on foundational tools like GIS suggests the need for renewed attention to spatial analysis in contemporary planning research. Emerging terms such as "integrated approach" and "local government" warrant further empirical investigation, as they bridge conceptual research with institutional practice. By linking bibliometric trends with policy-relevant interpretations, scholars can better inform the development of context-sensitive sustainability strategies.

Overall, this analysis underscores the importance of advancing bibliometric reviews beyond descriptive trends by integrating practical implications, methodological reflection, and critical interpretation. Such an approach not only strengthens the academic contribution of sustainability studies but also enhances their relevance for urban planners, policymakers, and institutions seeking to operationalize sustainable development in complex urban systems.

CONCLUSION

The objective of this bibliometric study is to provide a landscape of existing research in the area of sustainable urban planning. The documents on the topic were extracted from the Scopus database by using a valid search query. After screening and filtering based on language and subject area and considering all the documents published before the search date, a total of 205 documents were extracted for analysis. The retrieved data were utilized to conduct a systematic bibliometric analysis and a visual examination to identify prospective components and research hotspots. The annual publication trend showed an exponential trend, delineating an immense scholarly attention since 2020. The most prominent document with highest number of citations is written by Shen *et al.* (2011) entitled "The application of urban sustainability indicators - A comparison between various practices", followed by publication by Huang *et al.* (2015), with 229 citations. The most productive countries and institutions publishing frequently are China and "Chinese Academy of Sciences", respectively. This reflects China's dominance in this research area. From the density map developed based keywords occurrence frequency, it was revealed that sustainable development, sustainability, sustainable urban development, indicators, and smart city are the most discussed keywords with the highest density. The thematic evolution of the terms showed the focus of researchers over the years based on the notable keywords.

The text analysis carried out in VOS viewer identified three thematic areas: framework for urban sustainability assessment, research and models for smart city, and Stakeholder Engagement and Implementation Strategies. Within each thematic area, the existing research was discussed, and future research hotspots were identified. Pertaining to framework for urban sustainability assessment, the review highlighted the need for a quantitative-based performance assessments, a lack of complete analytical frameworks, indicators based on substantial data, and consideration of regional differences. Furthermore, the studies endorsed the development of a unifying framework that could be applied to cities with diverse sizes, culture, and administrative divisions. Regarding the concept of smart cities, studies show concern over its long-terms implications, demand equal emphasis on social and economic aspects, and suggest portability and sharing of resources between different sectors of high impact smart city system. The studies also highlighted the importance of stakeholders' engagement and implementation strategies. However, competing interests, resource limits, and institutional inertia might influence the effectiveness of employed framework, necessitating the strong governance frameworks, capacity building, and the development of a shared vision for sustainability.

The study also highlighted the most frequently adopted indicators pertaining to key thematic dimensions of sustainability: environmental, social, economic, and institutional. For each of the indicators, the most frequently

measured categories were also identified from the literature. Furthermore, the limitations of existing frameworks were also discussed. These limitations included the heterogeneity of terminologies and category names within frameworks, absence of a set of key indicators potentially applicable to various areas, and representation of indicators between frameworks of developing countries and those of developed countries. In addition to presenting the landscape of existing research and highlighting the challenges of existing frameworks, this study identified the potential research hotspots and trending topics with the help of thematic evolution in Biblioshiny tool and keywords analysis in VOS viewer. It was revealed that the concept of smart city together with some integrated concepts such as urban economy and social implications are being researched as the most trending topics. The term "smart city" is bearing a notable rise, indicating the growing interest in leveraging technology to improve urban living. The current state of publications endorsed further investigations in these areas, focusing more on the integration of social, cultural and assessment approaches of smart city. Hence, the future studies pertaining to assessment of sustainable urban planning should consider the aspects of smart city, level of integration of different sectors and deployment status of cutting-edge technologies.

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