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Sustainable urban street: a bibliometric analysis

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ABSTRACT

This research aims to conduct a bibliometric analysis of various pieces of literature on the "sustainable urban street (SUS)" between 1992 and 2023. This review intends to provide an overall understanding of the evolution and progression of research on the SUS over the past three decades. Our study adheres to the theoretical framework of bibliometric research and uses datasets from the Web of Science and Scopus websites. The diverse literature on the SUS study was compiled using the terms "sustainable" or "green" and "urban street" or "urban road". The datasets include journal articles including early access, proceedings paper articles, book chapters, and review papers with terms mentioned anywhere in their title, abstracts, keyword lists, or bodies. After assembling and analysing the datasets, we got the final dataset of 812 documents on SUS for further analysis. The utilization of the open-source and free statistical and visualization software tools- R and VOS Viewer primarily served the purpose of processing and analysing datasets. The analysis provides the total number of documents that were published per year and the top 10 authors, publications, journals, research organisations, and nations that contributed to publishing papers on this topic. The lexical network analysis reveals that SUS is strongly associated with the two frequently occurring terms "sustainable development" and "air quality". China, the United States of America, and the United Kingdom have conducted most studies on SUS. The top three most influential journals for SUS are "Sustainability", "Building and Environment", and "Sustainable Cities and Society". The main contribution of this bibliometric analysis is to identify future research needs for sustainable urban streets. This dataset, based on an evaluation of 30 years of study in this field, will prove helpful in the future for researchers and policymakers alike. This study also enhances the existing knowledge of sustainable urban streets by offering a comprehensive framework and a systematic understanding of the challenges associated with urban transformation and sustainability that have emerged in recent years.

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Bibliometric analysis; sustainable; urban street; urban area; transport

1. Introduction

The rate at which cities and people are increasingly urbanised worldwide significantly impacts the economy, society, and environment. According to the 2018 Revision of World Urbanisation Prospects, 55% of the world's population lived in cities in 2018 and 68% by 2050 (UN Department of Economic and Social Affairs 2018). Rapid urbanisation worldwide has caused tremendous stress over urban regions (Cook and Lara 2012). It poses many problems, including the urban heat island effect, urban flooding, traffic and transportation stress, congestion, air pollution, urban illness, inappropriate land development, and many more (Wann-Ming 2019). The sustainable development of urban street corridors has essentially been considered the primary balance of possibilities and alternatives for society, the economy, and the environment (Greenberg and Handy 2010). The concept of Sustainable Urban Street (SUS) aims to enhance transportation and supporting facilities in a way that is environmentally friendly and pedestrian-oriented; it includes promoting energy efficiency, minimising environmental impact, maximising the infiltration of rainwater into the ground, improving aesthetics, and increasing the region's economic value (Carlson, Greenberg, and Kanninen 2011; Svensson et al. 2004).

SUS includes three main aspects: mobility, ecology, and community (Greenberg and Handy 2010). Sustainable Streets encompass a variety of transport options, allowing for the efficient movement of people and goods while considering the impact on the environment, ecology, and economy. These rights of way are carefully designed and managed to promote a holistic sustainability approach, focusing on the three E's: environment, ecology, and economy. SUS aims to enhance mobility, preserve natural resources, and foster a sense of community-building places. Mobility encompasses all the many forms of movement comprising the circulation network; this is the primary form of transportation that prioritises efficiency and sustainability. In this situation, the 4C criteria of comfort, convenience, conspicuity, and

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survivability must be considered while determining the circulatory system in a street corridor. Ecology includes the value of landscape resources and natural components on the right of way (also known as green infrastructure). Community elements are connected to the street corridor's visual quality to maximise economic value and optimise street space as a social interaction area. According to authors in (Svensson et al. 2004), the focus of treatment on sustainable streets is highly accessible, used for social and economic activities, enhancing greening, and minimising environmental effects.

According to Allan B. Jacobs (Appleyard 1980), if urban streets are intentionally planned and constructed to create a sense of community and appeal to a diverse range of individuals, they may significantly contribute to the overall quality of a city. In fact, by focusing on the development and design of streets, about one-third of the urban environment can be directly influenced, therefore exerting a substantial influence on the remaining areas. As the foundation of urban infrastructure, streets serve many purposes, such as transportation, leisure, socializing, and breeding (Rui and Othengrafen 2023). The streets within a city are considered to be its vital organs, playing a crucial role in its overall functioning and connectivity (Jacobs 1995).

A SUS, as articulated by Ellen Greenberg et al. (Greenberg and Handy 2010), refers to a thoroughfare within an urban environment that has been designed and developed to prioritise the community's long-term well-being while minimising negative impacts on the environment. Sustainable Streets encompass a variety of transportation options and infrastructure that are strategically planned and managed to promote positive outcomes in terms of mobility, environmental impact, and community well-being. These efforts align with a comprehensive sustainability framework prioritising the interconnected principles of environmental stewardship, ecological preservation, and economic prosperity (Greenberg and Handy 2010).

In line with Etty Agustin's perspective, the notion of a SUS revolves around enhancing transportation options and supporting eco-friendly and people-centric amenities. This includes prioritising pedestrian-friendly infrastructure, promoting energy efficiency, and minimising environmental impact. Additionally, sustainable street design optimises rainwater absorption into the ground, reducing the risk of flooding by implementing green infrastructure (Agustin, Santosa, and Soemardiono 2014). The roadside friction on urban arterial roads has a significant impact on the sustainability of urban streets (Srivastava and Kumar 2023a). In urban street environments, it is common to encounter several frictional activities that can affect transportation efficiency. These activities include on-street parking, pedestrian crossings, and the presence of Non-Motorized Vehicles (NMVs). These factors have an impact on the Level of Service (LOS) and can potentially reduce the effective width of the roadway, consequently affecting road capacity and sustainability (Srivastava and Kumar 2023b).

Urban streets are generally considered linear open spaces in urban areas. Urban streets include more than just the road-like linear space between buildings; they also have the people who live and work there and the shops and services they provide. Urban sustainable streets can be broadly characterised as streets that achieve a desirable state by effectively harmonising the three dimensions of environmental, social, and economic sustainability within the urban street environment. These streets play a crucial role in fostering local sustainable development through their thoughtful design, construction, and operation (Bella-Omunagbe 2015). The urban streets are the fundamental public space component and contribute much to the growth of progressive urban culture (Bhagat and Kumar 2023). The residential satisfaction in public housing in urban areas depends on the SUS (Kumari et al. 2023).

Limited studies have been done on SUS to date. This bibliometric analysis has been done to elucidate the evolution of the SUS model as a distinct conceptual framework in architectural literature. Bibliometric analysis is a technique that employs statistical, mathematical, and other measurement methods to evaluate the current state and development trends, as well as to predict the future direction of a research field (Xu and Yu 2019). Bibliometric methods are frequently employed in a variety of academic disciplines to identify their trends (Cuccurullo, Aria, and Sarto 2016). Currently, only a systematic literature review on SUS has been done (Bhagat and Kumar 2024), but there has been no bibliometric review on SUS to date. This work intends to address this research gap by doing bibliometric analysis utilising the prominent citation databases, namely Web of Science (WoS) and Scopus. This study investigates the various aspects of SUS and proposes new areas for future research. Hence, this paper deals with the following research question: What are the key themes and trends in the development of SUS as reflected in academic literature over the past three decades?

To address this paper's research question, the next section starts with the methods of data collection and its analysis. Section three presents the results and bibliometric findings. The last section deals with the discussion and conclusion part of the paper.

2. Methods

2.1. Data sources

A bibliographic study is done with data from WoS, Scopus, PubMed, Computer Science Bibliography (DBLP), and Google Scholar, among other data sources. The DBLP and PubMed databases don't have citation data (Devos and Ménard 2020; Garousi and Mäntylä 2016), but the Google Scholar databases do. For example, a citation from an undergraduate thesis may be added to a paper's citation count. Moreover, there is a lack of clarity in identifying authors and their respective affiliations or organisations. As a result, the research analysis relied solely on two data sources: WoS and Scopus. The WoS citation database was established in Philadelphia in 1956 by Eugene Garfield and the Institute for Scientific Information (ISI). Thomson Reuters Corporation (Mohindra 2015) developed it later. Scopus, which can be found at www.scopus.com, is a database of abstracts and citations made by Elsevier in 2004. The period of 1992 to 2023 is chosen for the analysis, considering this as a comprehensive time frame for evaluating the evolution of SUS. Over the course of three decades, enough data has been collected to draw conclusions to analyse trends, identify key players, and predict future directions. The search encompasses journal articles, book chapters, and research papers containing the terms "sustainable" or "green" and "urban street" or "urban road," as these are the most pertinent terms applicable to SUS, whether they appear in the title, abstract, keyword lists, or body. This bibliometric analysis exclusively considered all publications written in the English language. The primary data was sourced from the WoS and Scopus, listing below is the search parameters and the corresponding Boolean expression.

2.1.1. Scopus

TITLE-ABS-KEY ("sustainable*" OR "green*") AND TITLE-ABS-KEY ("urban* street*" OR "urban* road*") AND LIMIT-TO (LANGUAGE, "English") AND LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "ch") OR LIMIT-TO (DOCTYPE, "re")

2.1.2. Web of science

"Sustainable*" OR "Green*" (Topic) and "urban* street*" OR "Urban* Road*" (Topic) and English (Languages) and Article or Review Article or Early Access (Document Types) and Science Citation Index Expanded (SCI-EXPANDED) or Social Sciences Citation Index (SSCI) or Arts & Humanities Citation Index (A&HCI) (Web of Science Index)

2.2. Data collection and analysis

The data downloaded from both the data sources was further analysed using software R (Version 4.3.1); it helped pretermit the duplicate documents and build the datasets after retrieving them from WoS and Scopus, allowing integration between the two datasets. The period of publication was considered from 1992 to 2023. Duplicated articles and publications unrelated to the topic were deleted manually from the dataset. The bibliometric network analysis constructed a lexical network using keywords/terms extracted from the final number of articles that underwent filtration from the Web of Science and Scopus databases. We use the open-source statistical software R, version 4.3.1, for the descriptive analysis. This allowed us to examine things like most associated keywords with "sustainable urban streets" and their frequency of occurrence. In addition, to generate lexical maps, the VOS viewer visualisation software, version 1.6.19, was used, which may be found at www.vosviewer.com.

3. Results

This section provides an overview of the dataset's general summary statistics, consisting of 812 documents from 1992 to 2023 (Giduthuri 2015). It summarises the top 10 most significant contributors to the field of SUS research, including authors, papers, sources, research organisations, and countries. In the end, it presents the bibliometric networks in the SUS study, including lexical and citation source networks.

3.1. Summary information on the selected documents

Statistics on SUS from published documents are shown in Table 1. According to the findings, between 1992 and 2023, there were 812 journal articles published on the topic of SUS across 380 different sources, including books and journals. The annual growth rate predicted is 15.54%, with 4.87 years as the average age of the

Table 1. Summary of the published documents.

Primary details concerning the data	
Time Range	1992:2023
Sources (Publications, Journals, Books, etc.)	380
Documents (articles, conf. proceedings, etc.)	812
Annual Growth Rate %	15.54
Average Age of Document	4.87
Average citations per doc	20.27
References	7080
Keywords Plus (ID)	4571
Author's Keywords (DE)	2757
Authors	2349
Authors of single-authored docs	67
Single-authored docs	68
Co-Authors per Doc	3.87
International co-authorships %	5.542
article	741
article; early access	2
article; proceedings paper	1
book chapter	43
review	25

Source: WoS and Scopus databases, 2023.

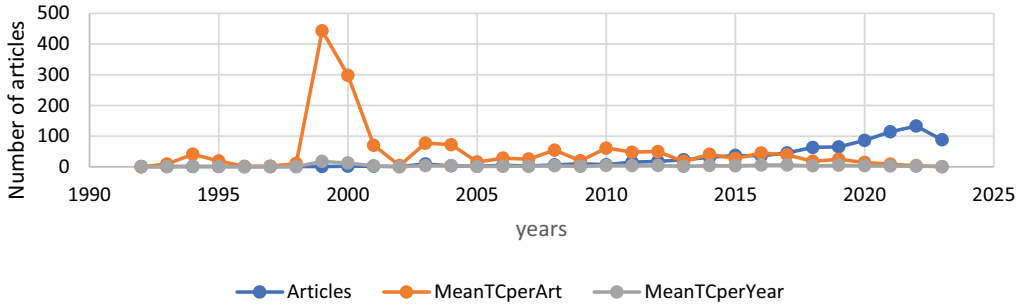


Figure 1. Number of articles per year.

documents. 20.27 is the average citations per doc, with the total number of references being 7080. A total of 2349 authors, including 68 sole authors, contributed to the publication of 812 documents. There are 3.87 co-authors in total for each document. The percentage of international co-authors is 5.542%. The total number of articles is 741, with two early access and one as paper proceedings. The book chapter included 43 and 25 reviews on SUS.

Figure 1 shows the number of scientific papers published each year. The blue line indicates the number of scientific papers published annually, the orange line denotes the mean total citations per article, and the grey line represents the mean total citations per year. The data downloaded from the two data sources reveals a sudden rise in the mean total citations per article published in 1999, followed by a gradual decrease until 2002. There is a gradual rise in the total articles published yearly from 2017, with a drop from 2022 to 2023. This will assist readers in gaining an understanding of the periodic trends in the publication of articles on SUS.

Table 2. Document published.

Row Labels	Sum of Articles
1991–1995	4
1996–2000	6
2001–2005	17
2006–2010	31
2011–2015	124
2016–2020	295
2021–2023	335
Grand Total	812

Table 2 displays the total number of publications that have been done on research about SUS. These publications have been divided into five-year intervals. According to the findings, between 1991 and 2023, there were 812 journal articles published on the topic of SUS, including books and journals.

Tables 3–7 give the top 10 rankings for each of the five criteria (authors, publications, journals, research organisations, and nations) used in the published documents on SUS (Biswas et al. 2021). These rankings are based on the number of citations each document received. The top 10 authors who have produced the most work are listed in Table 3. Each of these authors has written at least nine publications, and some of them have released as many as 15 different publications. The findings reveal that Zhang Y, Li Y, and Zhang J from Henan University of Science and Technology, Luoyang, China; National Taiwan University, Taipei, Taiwan; and Institute of Botany Chinese Academy of Sciences, Beijing, China, respectively, are the top three leading authors in this field. They have published 15, 14, and 14 publications, respectively, and have achieved average citations of 9.33, 21.43, and 11.86, respectively. The top 10 other authors on the list are Wang X, Liu Y, Wang Y, Shashuabar L, Li J, Wang H, and Liu X. It should be noted that there is no single-authored paper on this list. The total number of citations is 1568 for the author Shashuabar L from Tel Aviv University, Tel Aviv-Yafo, Israel, averaging up to 156.80 citations per document.

Figure 2 displays the annual publication record of the top 10 authors, with the size of the circles

Table 3. Top 10 authors (document ≥9).

Rank	Author	SA	CoA	NP	TC	AC	Organisation
1	Zhang Y	0	15	15	140	9.33	Henan University of Science and Technology, Luoyang, China
2	Li Y	0	14	14	300	21.43	National Taiwan University, Taipei, Taiwan
3	Zhang J	0	14	14	166	11.86	Institute of Botany Chinese Academy of Sciences, Beijing, China
4	Wang X	0	11	11	211	19.18	Peking University, Beijing, China
5	Liu Y	0	11	11	99	9.00	Zhejiang Sci-Tech University, Hangzhou, China
6	Wang Y	0	11	11	93	8.45	Peking University, Beijing, China
7	Shashua-Bar L	0	10	10	1568	156.80	Tel Aviv University, Tel Aviv-Yafo, Israel
8	Li J	0	10	10	58	5.80	Li, Junpeng
9	Wang H	0	9	9	132	14.67	Southeast University, Nanjing, China
10	Liu X	0	9	9	84	9.33	Liu, Xiaoming

Source: WoS and Scopus databases, 2023.
*Note: SA = number of single-authored papers; CoA = number of co-authored papers; NP = total number of publications; TC = total citations; AC = average number of citations (TC/NP).

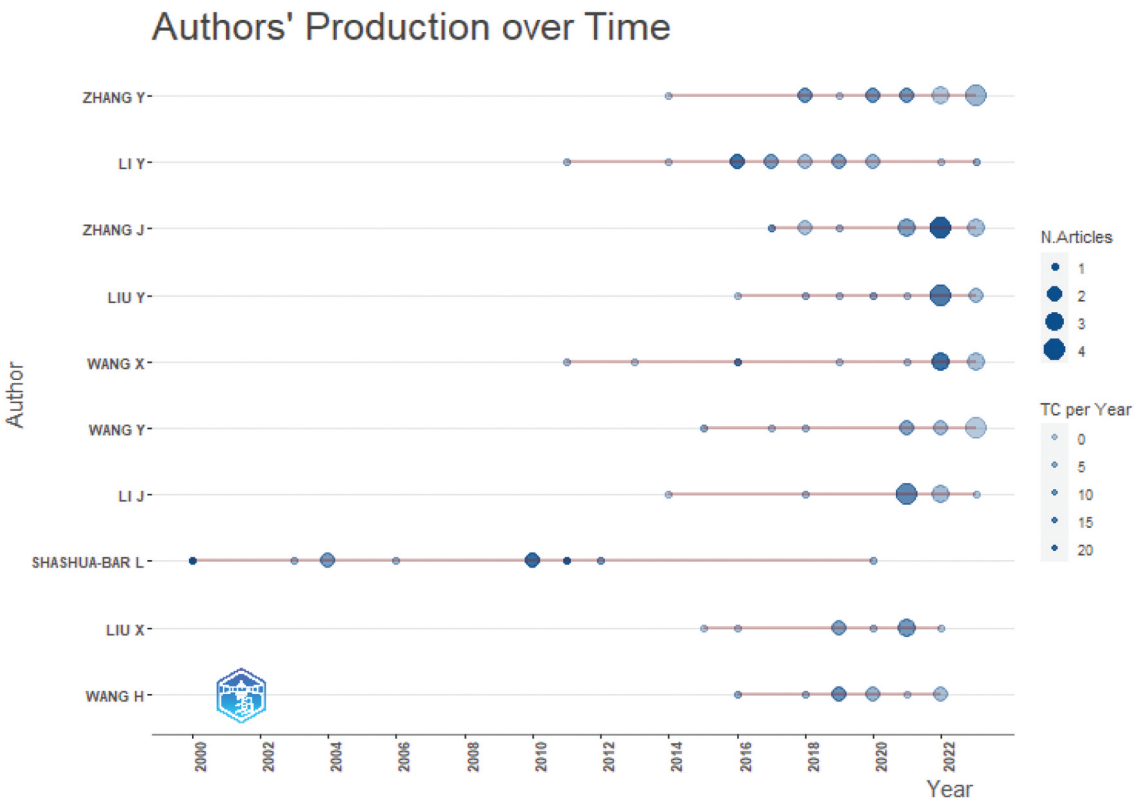


Figure 2. Author production over time and citations per year. Source: WoS and Scopus databases, 2023.

representing the number of publications during that specific timeframe. The number of times the papers have been cited since they were made public is shown by the darker shade of the circles. The figure also demonstrates that the top writer who has produced the most work, Zhang Y, has had their earliest and most recent manuscripts published in 2014 and 2023. The figure also shows that the author, Shashua-Bar L, started publishing his work on this topic in 2000 and his most recent document was published in 2020. The most cited author is Liu Y in the year 2022. Most of the remaining notable authors' scientific output on the subject was published after 2011.

Out of a total of 812 documents that have been published on the subject of SUS, Table 4 provides a chronological listing of the 10 publications that have the greatest amount of influence based on the number of citations they have received and the sources of these articles. The first two columns of the table contain information regarding the documents' ranks as well as the total number of citations received. The information shown in Table 4 reveals that the 10 documents with the greatest combined level of influence have a maximum of 592 and a minimum of 171 citations among them. According to the findings, among the top 10 documents with the most significant impact on SUS, two were released during the years 2014 (Van D B A; Jorgensen A; Wilson E; Skelhorn C; Lindley S; Levermore G) in the Journal of Landscape & Urban Planning with a total number of citations of 234 and 171. The same journal was released again in 2003 (Cheng J; Masser I) with 363 total citations.

Table 5 displays the Top 10 most relevant sources (documents >10). Additionally, the table provides information on the number of published journals on SUS, as well as the TC (total citations) and AC (average number of citations, which is the total citations per total published document) of that said document. As we can see from the table Sustainability is the most relevant source with 69 numbers of total published documents, and Atmospheric Environment has only 10 numbers of published documents with 98.90 average number of citations. Transportation Research Part D: Transport and Environment and Journal of Cleaner Production has published 11 numbers of publications. Urban Forestry & Urban Greening (NP = 35, AC = 27.20), is ranked second, and Building and Environment and Sustainable Cities and Society are ranked third and fourth on the list; both have 23 numbers of total publications with 59.65 and 16.61 average number of citations respectively. These are followed by Transportation Research Record (NP = 19, AC = 13.42), International Journal of Environmental Research and Public Health (NP = 16, AC = 17.81), Landscape & Urban Planning (NP = 14, AC = 86.64), Journal of Cleaner Production (NP = 11, AC = 30.55), and Transportation Research Part D: Transport and Environment (NP = 11, AC = 30.27). It is important to note here that the tenth-ranked source on the list (Atmospheric Environment)

Table 4. Top 10 most cited documents (citations ≥171).

RANK	TC	Author	DOI	Source	Reference
1	592	Shashua-Bar L; Hoffman M	10.1016/S0378-7788(99)00018-3	Energy and Buildings	Shashua-Bar and Hoffman (2000)
2	443	Fenger J	10.1016/S1352-2310(99)00290-3	Atmospheric Environment	Fenger (1999) Atmos Environ (Sokhi 2008)
3	416	Pugh T; Mackenzie A; Whyatt J; Hewitt C	10.1021/Es300826w	Environmental Science and Technology	Pugh Tam (2012) Environ Sci Technol Pugh et al. (2012)
4	392	Barnett D; Barnett A; Nathan A; Van C J; Cerin E	10.1186/S12966-017-0558-Z	International Journal of Behavioral Nutrition and Physical Activity	Barnett (2017) Int J Behav Nutr Phy Barnett et al. (2017)
5	363	Cheng J; Masser I	10.1016/S0169-2046(02)00150-0	Landscape & Urban Planning	Cheng (2003), Landsc Urban Plann Cheng and Masser (2003)
6	297	Shashua-Bar L; Pearlmutter D; Erell E	10.1002/Joc.2177	International Journal of Climatology	Shashua-Bar (2011), Int J Climatol Shashua-Bar, Pearlmutter, and Erell (2011)
7	286	Lämmer S; Helbing D	10.1088/1742-5468/2008/04/P04019	Journal Of Statistical Mechanics: Theory and Experiment	Lämmer (2008), J Stat Mech Theory Exp Shashua-Bar, Pearlmutter, and Erell (2011)
8	234	Van D B A; Jorgensen A; Wilson E	10.1016/J.Landurbplan.2014.04.012	Landscape & Urban Planning	Van Den Berg Ae (2014), Landsc Urban Plann (Van den Berg, Jorgensen, and Wilson 2014)
9	171	Skelhorn C; Lindley S; Levermore G	10.1016/J.Landurbplan.2013.09.012	Landscape & Urban Planning	Skelhorn C, 2014, Landscape Urban Plan Skelhorn, Lindley, and Levermore (2014)
10	171	Shashua-Bar L; Potchter O; Bitan A; Boltansky D; Yaakov Y	10.1002/Joc.1869	International Journal of Climatology	Shashua-Bar L, 2010, Int J Climatol Shashua-Bar et al. (2010)

Source: WoS and Scopus databases, 2023.
Note: TC = total citations.

having an average number of citations of 98.90 has scored more than the first journal with an average number of citations of 9.30 only; followed by the seventh-ranked source (Landscape and Urban Planning) on the list with an average number of citations of 86.64.

Figure 3 displays the cumulative frequency line graph depicting the publications related to SUS from the top five journals, as listed in Table 5. As shown in the figure the most significant journal Sustainability (Switzerland), first began publishing on the subject in 2016, and the number of articles published on the topic gradually climbed up until the recent year 2023. The second-ranking journal Building and Environment started publishing from the year 2003 and gradually increasing to date. The third-ranking journal Sustainable Cities and Society started publishing in 2013 and has gradually increased since then. The fourth in the ranking list is Transportation Research Record, which started publishing in the early years of 1993 with a gradual increase in output starting in 2002. The fifth-ranking journal Urban Forestry & Urban Greening is the first journal to start publishing in the year 1992, with a gradual rise in the graph from the year 2013 onwards.

Table 6 presents a comprehensive overview of the 10 leading institutions that have contributed significantly by producing the journal on SUS. The table showcases various indicators such as NP (total number of publications), TC (total citations), and AC (average number of citations TC/NP). Additionally, the data presented illustrates the number of publications produced by the leading 10 organisations over various time intervals. Nanjing Forestry University, China is the top-ranked university with 17 total publications starting from the year 2020 until date. With an average citation of 1.35, this university has contributed over 14% of publications produced in this field. Tongji University and the Chinese Academy of Sciences, both from China, ranked second and third respectively. Tongji University has produced 16 journals since 2012, with 13% of publications produced in this field having a comparatively high average citation of 23.38 per document. It is important to note that the top five universities are from China with the first publication in the field of SUS from the year 2012. Shanghai Jiao Tong University is in the fifth position with a contribution of 10%, producing 12 journals and 17.33 average citations per document.

Table 7 presents a comprehensive overview of the top five countries that have high productivity in the field of SUS research. The table further delineates various attributes of the publications, including NP (total number of publications), TC (total citations), and AC (average citation per publication = TC/NP). Additionally, it facilitates the dispersion of publication counts among the top five countries over various

Table 5. Top 10 most relevant sources (documents ≥10).

Rank	Sources	NP	TC	%	AC
1	Sustainability	69	642	30%	9.30
2	Urban Forestry & Urban Greening	35	952	15%	27.20
3	Building and Environment	23	1372	10%	59.65
4	Sustainable Cities and Society	23	382	10%	16.61
5	Transportation Research Record	19	255	8%	13.42
6	International Journal of Environmental Research and Public Health	16	285	7%	17.81
7	Landscape and Urban Planning	14	1213	6%	86.64
8	Journal of Cleaner Production	11	336	5%	30.55
9	Transportation Research Part D: Transport and Environment	11	333	5%	30.27
10	Atmospheric Environment	10	989	4%	98.90

Source: WoS and Scopus databases, 2023.
Note: NP = total number of publications; TC = total citations; AC = average number of citations (TC/NP).

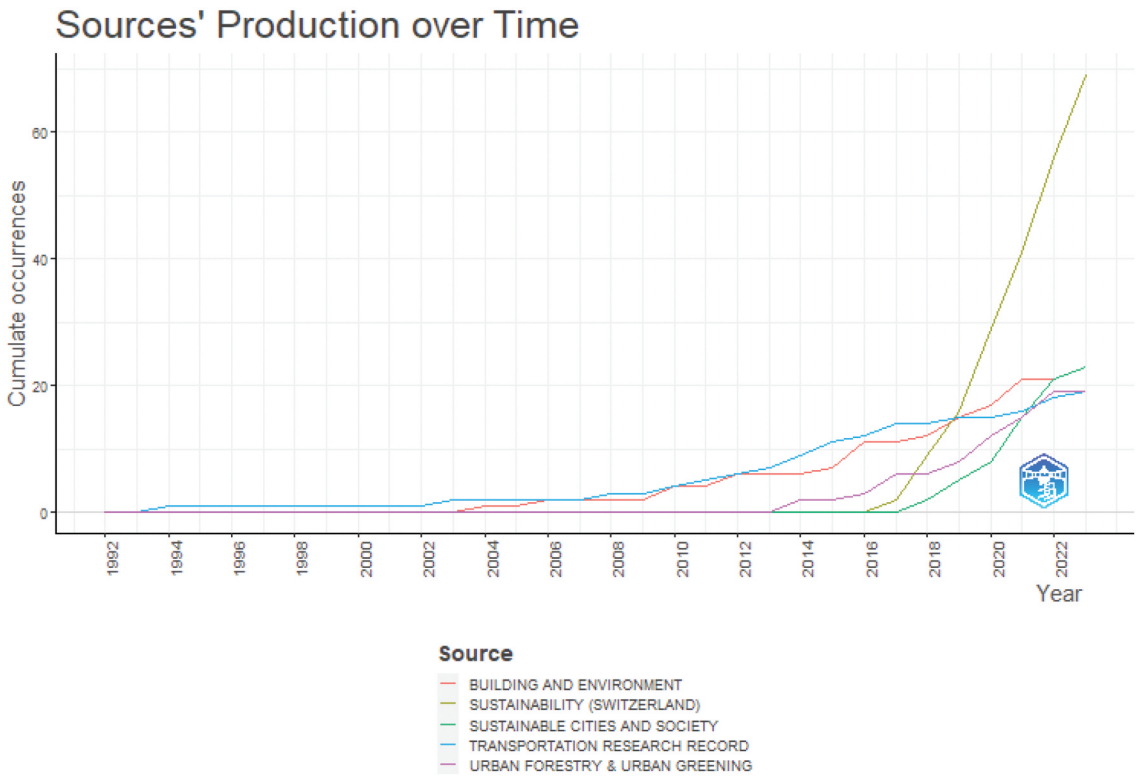


Figure 3. Source production over time for the top five journals. Source: WoS and Scopus databases, 2023.

Table 6. Top five most relevant affiliations (documents ≥12).

Affiliation	NP	%	TC	AC	1992–2000	2001–2010	2011–2020	2021–2023	First	Last
Nanjing Forestry University	17	14%	23	1.35	0	0	1	16	2020	2023
Tongji University	16	13%	374	23.38	0	0	11	5	2012	2023
Chinese Academy of Sciences	14	12%	292	20.86	0	0	9	5	2013	2023
Nanjing University	13	11%	260	20.00	0	0	10	3	2016	2023
Shanghai Jiao Tong University	12	10%	208	17.33	0	0	8	4	2014	2023

Source: WoS and Scopus databases, 2023.
Note: NP = total number of publications; TC = total citations; AC = average number of citations (TC/NP).

Table 7. Top five countries (documents ≥27).

Country	NP	%	TC	AC	1993–2000	2001–2010	2011–2020	2021–2023	First	Last
China	302	51%	3183	10.54	0	5	133	164	2006	2023
USA	130	22%	838	6.45	3	8	72	47	1993	2023
UK	68	11%	1570	23.09	0	4	48	16	2003	2022
Italy	52	9%	567	10.90	0	0	25	27	2012	2023
Spain	42	7%	706	16.81	0	4	32	6	2006	2023

Source: WoS and Scopus databases, 2023. Country production over time.

periods, including the year of first and last publication in that particular country. According to the following data, China has contributed 51% of the documents published in the field of sustainable urban streets, with a total of 302 publications starting in 2006 and an average citation count of 10.54 per document. The second-leading country is the USA, with 130 published documents contributing up to 22% with 6.48 citations per document, starting early from 1993, followed by the UK, Italy and, Spain with contributions of 11%, 9%, and 7%, respectively. The same (Table 7) has been illustrated in Figure 4, where the top five countries' production has been depicted over time. It's very clear from the graph that China has contributed the most in the field of SUS. Figure 4 illustrates the countries with the highest publication output globally. The figure clearly illustrates that China had an upward graph, starting with a steep rise from 2015.

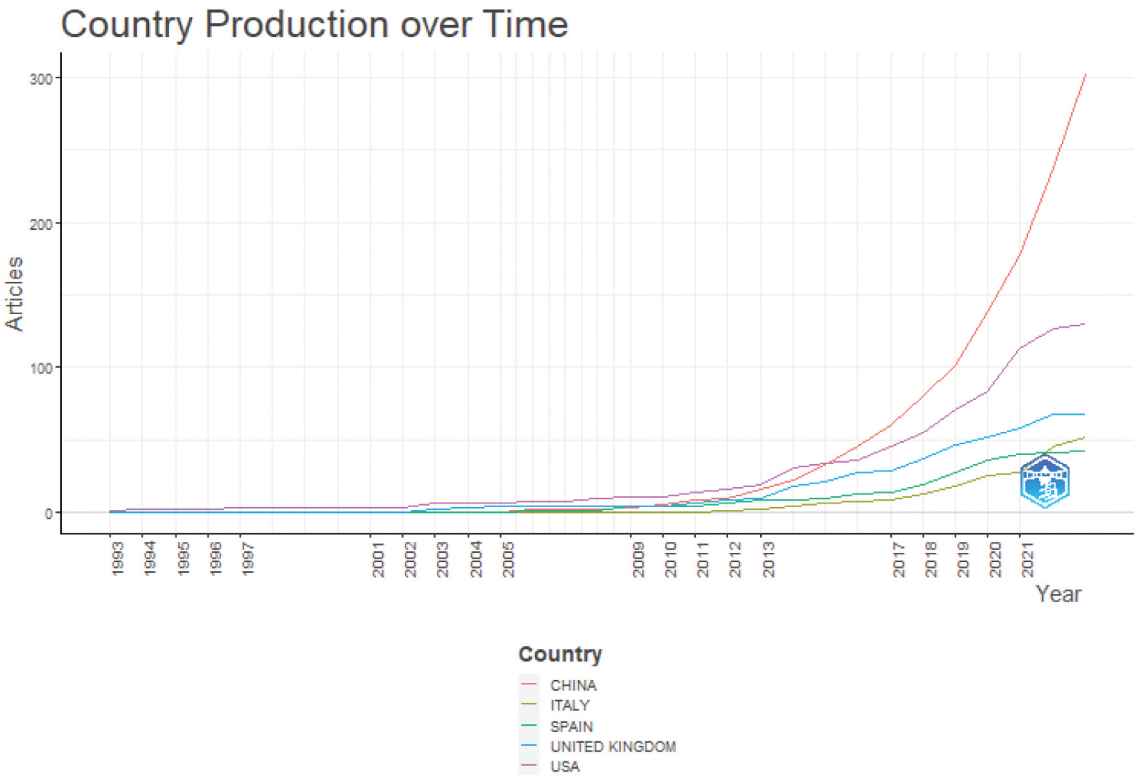


Figure 4. Country production over time. Source: WoS and Scopus databases, 2023.

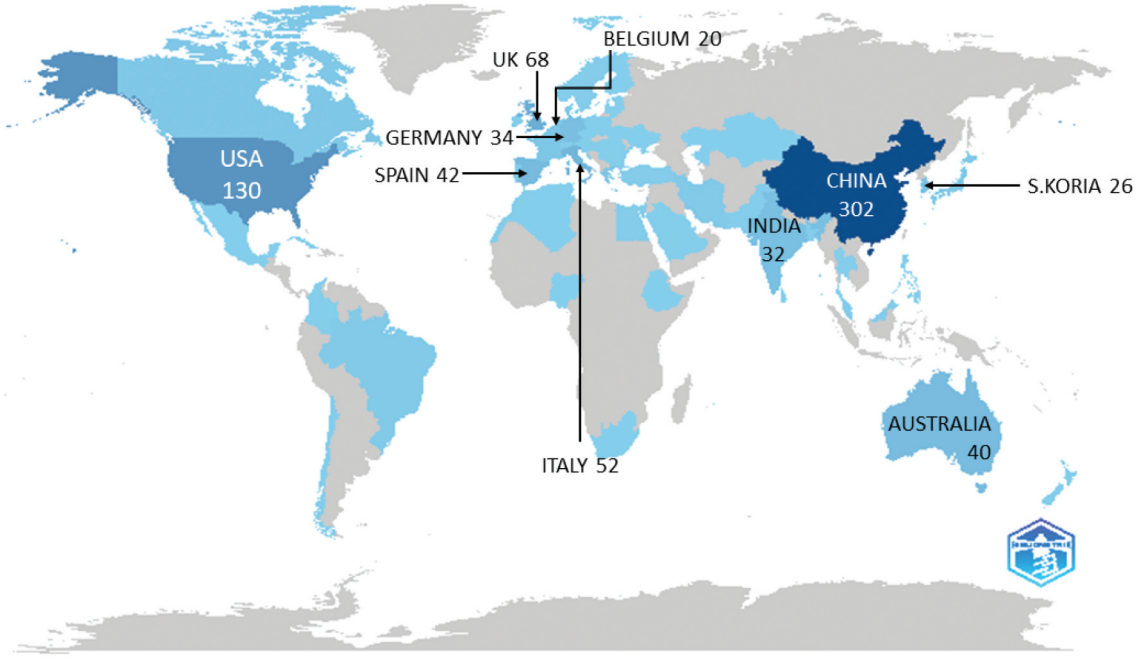


Figure 5. Top 10 countries with the total number of publications. Source: WoS and Scopus databases, 2023.

Figure 5 shows the top 10 countries with their total number of publications. China is leading with 302 publications, while Belgium is ranked tenth with only 20 publications.

After filtering 812 articles from Web of Science and Scopus databases, we used the keywords and terms to build a lexical network. In the examination of keyword co-occurrence, it was found that 134 out of a total of 4116 keywords satisfied the threshold requirement, which stipulated that a keyword must have a minimum co-occurrence of 10 or more.

Figure 6 shows the network of field-specific keyword co-occurrences. When looking at the lexical network of the keywords, the network size shows how often the keywords are used (Shaukat et al. 2020). The study's keywords summarise what's in the research papers and show the research's main idea and content (Lina, Wei, and Chen 2020; Zhang et al. 2019). As a result, the proximity of related terms can indicate emerging themes and trends in a specific field of study (Lina, Wei, and Chen 2020).

Table 8 compiles the 25 most-used keywords that have appeared at least 33 times. The keywords are determined by analysing the document's title and description and how often they appear in the document's text. Table 8 shows that the three terms that come up most often in research on SUS are urban area (138 occurrences), China (119 occurrences), and roads and streets (114 occurrences). SUS encompasses many factors, including physical elements such as roads and streets, green space, urban transport, etc. Additionally, non-physical attributes such as urban planning, traffic congestion, environmental monitoring, and decision-making also contribute to the overall experience of the SUS. Figure 7 illustrates the compilation of frequently occurring keywords in the research on SUS with a minimum occurrence of 25 times contributing to 1% of the share. The number of occurrences and the percentage have been marked for each word in the figure. It clearly states that "urban area" had a maximum occurrence of 138 times, and the word "greenhouse gas" had the least occurrence of 25 times, contributing to 6% and 1%, respectively. According to (Mehta and Bosson 2010) the streets are defined as "a third place" where people can regularly visit and commune with friends, neighbours, co-workers, and even strangers to support sociability and place attachment. Roads, on the other hand, are open, usually surfaced with asphalt or concrete, providing a passage from one place to another (Mehta 2008). Hence, we can conclude that keywords such as "urban area," "China," and "roads and streets" have the highest frequency of occurrence. The thematic emphasis includes sustainable development, air quality, and urban planning, which are crucial areas of study

Table 8. Frequency of occurrence of keywords associated with "sustainable urban street".

Rank	Sources	Frequency	%
1	Urban area	138	6
2	China	119	5
3	Roads and streets	114	5
4	Sustainable development	97	4
5	Air quality	71	3
6	Urban planning	67	3
7	Motor transportation	64	3
8	Green space	61	3
9	Particulate matter	61	3
10	Traffic congestion	61	3
11	Article	60	3
12	Urban Transport	55	2
13	Air pollution	51	2
14	Urban Transportation	49	2
15	Transportation	44	2
16	City	43	2
17	Cities	42	2
18	Environmental monitoring	41	2
19	Human	41	2
20	Urban Road	41	2
21	Decision making	36	2
22	Sustainability	35	2
23	Urban growth	35	2
24	Pollution	33	1
25	Traffic control	33	1

Source: WoS and Scopus database, 2023.



Figure 6. Most associated keywords. Source: WoS and Scopus databases, 2023.



Figure 7. Frequency of occurrence of keywords associated with "sustainable urban street". Source: WoS and Scopus databases, 2023.

related to SUS. The most frequently discussed themes revolve around sustainability in urban environments, with a focus on transportation, green infrastructure, and ecological preservation.

4. Discussions and conclusions

This study offers a comprehensive analysis of the emergence and future research needs related to SUS through the application of bibliometric research tools. A total of 812 publications on SUS were identified across 380 sources from 1992 to 2023. Among the 812 documents, 68 were authored by a single individual. Annually, an average of 25.37 documents is published across various sources, with a growth rate of approximately 15.14%. The volume of works and publications on SUS globally has been increasing rapidly. This finding suggests that SUS needs have become increasingly significant concerns, accompanied by a rise in conflict issues in this domain. Consequently, it has emerged as a focal point of interest among global scholars, particularly in countries such as China, the USA, and the UK, as illustrated in Table 7, over recent years.

The three most prolific writers in SUS research are Zhang Y from Henan University of Science and Technology in Luoyang, China, Li Y from National Taiwan University in Taipei, Taiwan, and Zhang J from the Institute of Botany of the Chinese Academy of Sciences in Beijing, China. The three most frequently referenced manuscripts are Shashua-Bar L, 2000 (Shashua-Bar and Hoffman 2000), published in Energy and Buildings, Fenger J, 1999 (Sokhi 2008), published in Atmospheric Environment, and Pugh Tam, 2012 (Pugh et al. 2012), published in Environmental Science and Technology.

The main sources of "SUS" are "Sustainability", "Urban Forestry and Greening", and "Building and Environment". China's Nanjing Forestry University produces the most research, followed by Shanghai's Tongji University and Beijing's Chinese Academy of Sciences. Finally, China is the leading publisher, followed by the United States and the United Kingdom. The three most significant keywords for co-occurrence in "SUS" research are "urban area", China, and "roads and streets". The outcomes of our research may differ if data from Google Scholar or PubMed is utilised instead. Some literature lacks essential terms, potentially impacting the lexical network analysis.

Due to the scarcity of bibliometric studies on SUS in the literature, this study is expected to expand knowledge and guide researchers. This study can help authors who are researching sustainable urban streets understand the relevant material. This study presents certain limitations as well. The primary limitation of this research is the analysis of articles indexed in SSCI, SCI, ESCI, and A&HCI, which were accessed through the WoS and Scopus databases. Future studies should incorporate additional indices alongside the current indices and utilise other databases. The VOSviewer visual mapping method applies to various databases, including SCOPUS, JSTOR, EBSCO Host, and the WoS database. Future studies may involve analyses and comparisons

utilising various visual mapping programs, including Citespace, Pajek, and RStudio. Additionally, deficiencies may occur during the data retrieval process. This paper utilises bibliometric analysis to enable scholars to identify trends in sustainable urban street research and uncover potential research gaps that may facilitate further studies on the subject.

The results of this investigation are subject to certain constraints. The research was restricted to studies written in English from the WoS and Scopus databases. Consequently, it is advisable to incorporate additional scientific databases and studies that have been written in other languages in order to assess the subject in a broader context for future research. Another limitation of the study is the exclusion of alternative search terms related to SUS and the use of specific search criteria. To gain a more comprehensive perspective, it is imperative that future research expand the number of studies that explore broader search strategies that incorporate a variety of keywords and their variations.

The studies have identified several critical issues that hold significant relevance. Initially, emerging nations must prioritize sustainability in urban areas to conform to global trends. Secondly, including environmental, green space, and air quality considerations within the framework of urban streets and sustainability is essential. Moreover, the study emphasizes that urban planning and transportation are not ancillary but essential elements of SUS. SUS plays a critical role in enhancing the quality of urban life, promoting environmental health, and fostering social equity. Sustainable urban streets contribute to enhanced health, equity, and resilience within urban environments, ultimately improving the overall liveability of all residents.

This study enhances academic understanding while offering practical insights for decision-makers and professionals aiming for SUS. This study enhances our comprehension of the complex relationship between urban streets and sustainability from a scientific perspective. This work not only highlights the essential themes and challenges but also lays the groundwork for subsequent research avenues. This study holds considerable importance for those involved in policy-making, urban planning, and practical implementation. The highlighted challenges underscore the pressing necessity for intervention in swiftly urbanising developing nations. Collaborative initiatives that include a variety of stakeholders highlight the necessity of involving communities, experts, and policy-makers in developing strategies for SUS. Informed decision-making is essential for enhancing environmental and economic sustainability in the face of urban challenges, particularly through design considerations and collaborations with relevant experts (Bhagat and Kumar 2024).

In conclusion, this research establishes a strong foundation for future research that will explore the complex interplay between sustainability and urban streets. It provides policymakers and practitioners with practical suggestions to effectively address the multifaceted challenges of SUS. In the end, it is anticipated that this research will advance urban planning strategies that are consistent with global sustainability objectives, thereby promoting the development of SUS for future generations.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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