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Bibliometric analysis and research trend of sustainable green transportation

Sürdürülebilir yeşil ulaşımın araştırma eğilimi ve bibliyometrik analizi

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Abstract

In recent years, the concept of green transportation has rapidly entered our lives with the increasing awareness of environmental problems such as climate change, air pollution and depletion of natural resources. Green transportation has become a new scientific research area under the umbrella of sustainability due to its benefits to both the economy and the environment. The aim of this study is to provide a common quantitative and qualitative understanding of the overall evolutionary trend, knowledge structure and literature gaps of the sustainable and green transportation (S&GT) research field. For this purpose, the Bibliometrix library provided by R software was used to analyze S&GT-related scientific research in the Web of Science database. In this study, using the science mapping approach, a total of 2018 publications published from 1997 to 2022 were analyzed and synthesized in detail. In addition, visualized statistics on the number of publications, citations, prominent authors, institutions, countries, sources, keywords and research themes in the field of S&GT were analyzed bibliographically. The analysis results show that China is the largest contributing country; Changan University is the most influential institution; Zhang L. is the most influential writer; Sustainability Journal is the primary publishing platform, in the S&GT field. The results are expected to guide researchers interested in S&GT issues to identify research gaps. In conclusion, the findings systematically describe the current state of play, key issues and academic frontiers in the field of S&GT.

Keywords: Bibliometric analysis, Green transportation, Sustainable transportation, Web of science

Öz

Son yıllarda iklim değişikliği, hava kirliliği, doğal kaynakların tükenmesi gibi çevre sorunlarına yönelik farkındalığın artmasıyla yeşil ulaşım kavramı hızlı bir şekilde hayatımıza girmiştir. Yeşil ulaşım, hem ekonomiye hem de çevreye sağladığı faydalar nedeniyle sürdürülebilirlik çatısı altında yeni bir bilimsel araştırma alanı haline gelmiştir. Bu çalışmanın amacı, sürdürülebilir ve yeşil ulaşım (S&GT) araştırma alanının genel evrimsel eğilimi, bilgi yapısı ve literatür boşlukları için ortak bir niceliksel ve niteliksel anlayış sunmaya çalışmaktadır. Bu amaçla, Web of Science veri tabanındaki S&GT ile ilgili bilimsel araştırmaları analiz etmek için R yazılımı tarafından sağlanan Bibliometrix kütüphanesi kullanılmıştır. Bu çalışmada, bilim haritalama yaklaşımı kullanılarak 1997'den 2022'a kadar yayınlanan toplam 2018 yayın ele alınarak ayrıntılı bir şekilde incelenmiş ve sentezlenmiştir. Ayrıca S&GT alanında yayınların sayısı, atıflar, öne çıkan yazarlar, kurumlar, ülkeler, kaynaklar, anahtar kelimeler ve araştırma temalarının zamansal değişimine ilişkin görselleştirilmiş istatistikler bibliyografik olarak analiz edilmiştir. Analiz sonuçları, S&GT alanında Çin'in en fazla katkı sağlayan ülke; Changan Üniversitesi'nin en etkili kurum; Zhang L. en etkili yazar; Sürdürülebilirlik dergisinin birincil yayın platformu olduğunu göstermiştir. Çalışma sonuçlarının, S&GT konularına ilgi duyan araştırmacılara araştırma boşluklarını tespit etmeleri için yol göstermesi beklenmektedir. Sonuç olarak bulgular S&GT alanındaki mevcut durumu, önemli konuları ve akademik sınırları sistematik bir şekilde açıklamaktadır.

Anahtar kelimeler: *Bibliyometrik analiz, Yeşil ulaşım, Sürdürülebilir ulaşım, Web of science*

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1. Introduction

Sustainable transportation involves the use of transport systems and modes that minimize negative environmental, social and economic impacts while meeting the mobility needs of individuals and communities. It aims to create a more environmentally friendly and socially equitable transportation system by focusing on reducing carbon emissions, increasing energy efficiency and minimizing resource consumption. While sustainable transportation represents an approach that meets current needs and considers the needs of future generations, green transportation refers to transportation systems that reduce environmental impacts and use resources more efficiently (Eyüboğlu, 2023). Therefore, green transportation is an approach that supports sustainability goals and is expected to help societies create a more sustainable future in environmental, economic and social terms. The main objective of green transportation is to reduce environmental impacts such as air pollution, greenhouse gas emissions and climate change by reducing the use of fossil fuels originating from transportation. At the same time, green transportation aims to use energy and resources more efficiently, and the transition to less energy-consuming transportation modes supports the sustainable use of natural resources with energy savings. Green transportation provides transportation equality by promoting environmentally friendly and accessible transportation options such as public transportation, cycling and walking.In addition, a cleaner environment and better quality air will be inherited to future generations as a result of the widespread use of green transportation options and the decrease in the use of motor vehicles.In line with its contributions, green transportation has been the focus of attention of countries and researchers in recent years.

The transport sector accounts for about 15% of all greenhouse gas (GHG) emissions and 23% of total CO_2 emissions that the most widespread of all GHG emissions (ITF, 2010). These global CO_2 emissions from the transportation sector increased by 45% from 1990 to 2007 and are expected to continue to increase by around 40% from 2007 to 2030 (ITF, 2010). The increase in these emissions has led countries to develop projects and policies to achieve sustainable development goals. In this context, the BioEthanol for Sustainable Transport (BEST) project was launched in Stockholm in 2005 to promote sustainable transportation. This innovative project aimed to minimize environmental impacts by increasing the use of clean vehicles that run on renewable fuels and have almost zero CO_2 emissions. The objectives were to improve air quality in the city center and reduce greenhouse gas emissions and noise. As part of this innovative project, owners of eco-friendly vehicles were exempted from traffic fees during peak rush hours in the city center and parking fees in the city center were increased. This encouraged people to choose eco-friendly vehicles as a more sustainable transportation option (Bedsworth et al., 2007). The BEST project not only made clean vehicles more widespread, but also raised the awareness of the city's population and emphasized the importance of sustainable transportation.

The Metka-project (Sustainable Building for Metropolitan Area) in Helsinki, Finland, was implemented with the aim of realizing sustainable urban and transportation goals in the metropolitan area. By emphasizing the physical characteristics of the urban fabric and creating pedestrian walkways with site-specific urban design, it has realized a fascinating transformation. In particular, existing constructions were carefully analyzed, various information was collected, and traffic connections were provided in an excellent way (Dymen & Henriksson, 2009). Such innovative projects are an important step in promoting environmentally friendly transportation and preparing cities for a more sustainable future.

Hart stated that the economy exists within society and society exists within the environment together with the economy, and if the environment, society, and economy are considered holistically, the way to achieve sustainability will be paved (Hart, 1999). Sustainable transportation aims to minimize environmental impacts, promote social justice and contribute to economic sustainability.

Figure 1. shows the steps of the A-S-I approach proposed by Shah et al. to achieve sustainable mobility. "Avoid", refers to increasing the efficiency of the transport system and the need to reduce travel demands as much as possible. "Shift" refers to improving travel efficiency by opting for public and non-motorized transportation. "Improve" refers to the optimization of transport infrastructure as well as a focus on improving fuel and vehicle efficiency (Shah et al., 2021). This proposed approach is the focus of the strategies developed by countries to achieve their sustainable development goals. Reducing the use of single-occupancy motor vehicles, increasing the use of environmentally friendly modes of transportation such as walking, cycling and e-scooters for short-distance trips, and encouraging the public to use public transportation will reduce traffic-related emissions. Thus, environmental problems such as air pollution, noise pollution and traffic congestion

are reduced, contributing to a sustainable environment. Finally, it is essential to provide the necessary infrastructure for S&GT. The existing charging station infrastructure needs to be improved to increase the use of electric vehicles, which are one of the environmentally friendly modes of transportation and are trying to replace traditional motor vehicles. In addition, planning and infrastructure improvements should be made for pedestrian and bicycle roads.

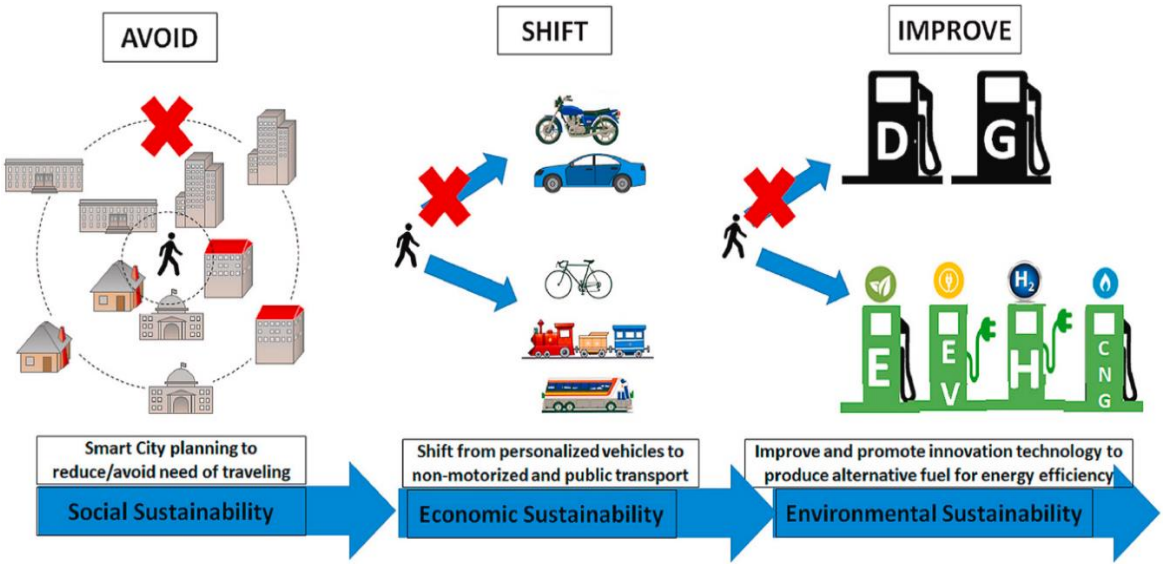

Figure 1. Avoid-shift-improve (A-S-I) approaches (Shah et al., 2021)

It is observed in the literature that green transportation is still an emerging field. However, it is noteworthy that the data sets used in the studies are limited and therefore their contributions are insufficient. The paper contributes to the literature by proposing a bibliometric analysis approach for the field of S&GT for the first time. Furthermore, this study aims to conduct a bibliometric analysis by considering bibliometric characteristics and keywords in order to evaluate the sustainable and green transportation literature and trends in a broader framework. The bibliometric analysis will contribute to sustainable and green transportation researchers on the focused topics. This study focuses on: (i) determining temporal patterns in the quantity of articles and citations released within this field of research; (ii) acknowledging the countries, organizations, sources of publication, and individual researchers with higher prominence and productivity; (iii) exploring co-authorship, most cited articles, co-citation between organizations and individuals worldwide; (iv) discovering patterns within the keywords of these studies. The results of the analysis also help to identify the most appropriate journals for S&GT research.

2. Data collection

Thomson Reuters' Web of Science Core Collection Database (WoS) (http://www.webofknowledge.com/) is widely recognized as the primary database for conducting bibliometric analysis (Van Leeuwen, 2006). Unlike alternative databases, WoS offers greater uniformity and standardization in its records (Bettencourt & Kaur, 2011). Scopus database, which has limited access, was not included in the study, and WoS was used as a source for this study. Publications from 1997 to 2022 were collected from WoS. The keywords "sustainable transportation" and "green transportation" were used for the search. Areas related to S&GT are refined in the web of science categories. Table 1 shows the number and types of publications in this date range.

3. Methodology

Bibliometrics is a set of methods used to quantitatively analyze scientific and technological literature (Nicolaisen, 2010). Bibliometric analysis provides a quick overview of general trends and guidelines that help to understand the research trends of a particular field (Das et al., 2023). The analysis of bibliometric data is a systematic and repeatable process that involves quantitative measures to review scientific publications, evaluate research articles, and identify trends and patterns over a given period (Broadus, 1987). The primary goal of bibliometric analysis is to measure and assess the influence, visibility, and productivity of scientific

research. It provides a way to examine patterns of publication, identify important authors and institutions, track the dissemination of knowledge through citations, and evaluate the impact of individual articles or journals. By employing bibliometric analysis, researchers can uncover patterns, relationships, and trends within scientific literature, enabling them to assess the scientific impact of research, identify potential collaborations, and make evidence-based decisions in academic and research environments.

The information of the publications on S&GT was taken from the Web of Science database electronically and transferred to the R software, all calculations and operations for tables and graphics were carried out through the Rstudio program. Figure 2 shows framework of the study.

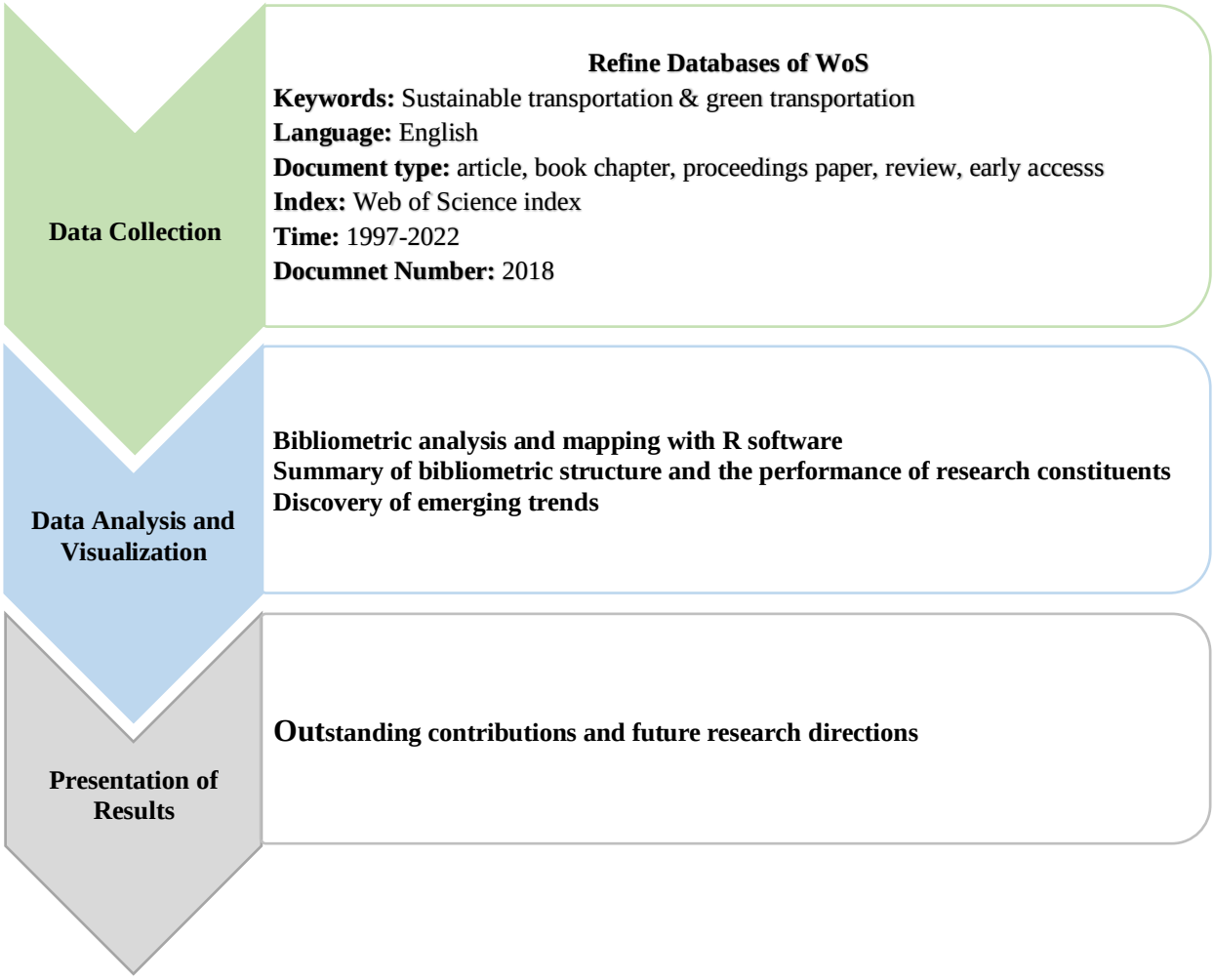

Figure 2. Steps of methodology

4. Results and discussion

Figure 3 illustrates general information about the study. This study includes 2018 documents about S&GT in the Web of Science database between 1997 and 2022. These documents were published in 612 different sources, and 6527 authors contributed to these studies. 176 of them have a single author. The rate of international cooperation between the authors is 28.39 %. The average number of authors per document is 3.81. Authors in 2018 studies defined 6028 keywords and cited 91504 sources. The average life span of the documents is 5.35 years. The average number of citations of these documents was determined as 22.4.

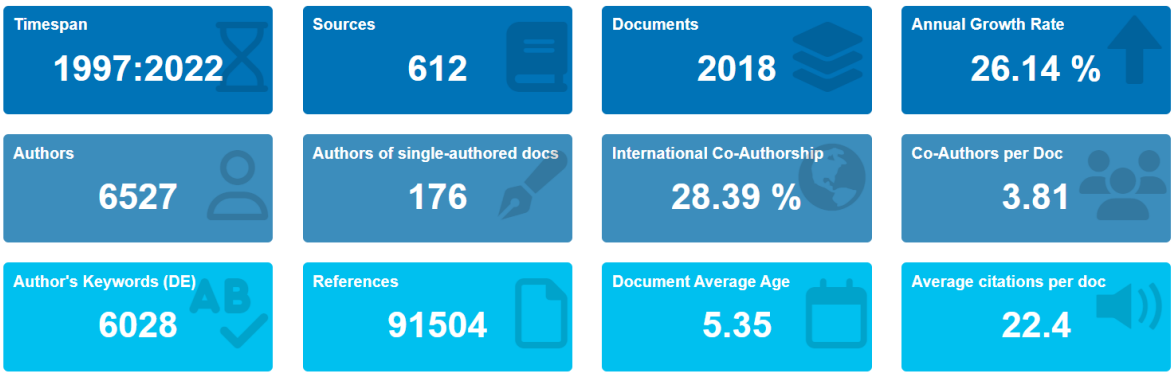

Figure 3. General informations on S&GT studies

Table 1 lists the distribution of publications by document type. In the 2018 documets, 1176 articles, 66 article; book chapter, 23 article; early access, 27 article; proceedings paper, 534 proceedings papers, 187 reviews, 1 review; book chapter, 4 review; early access.

Table 1. Distribution of publications by document types

Document types	No
article	1176
article; book chapter	66
article; early access	23
article; proceedings paper	27
proceedings paper	534
review	187
review; book chapter	1
review; early access	4
Total	**2018**

Figure 4 shows the temporal trend of the number of publications on S&GT. As shown in Figure 4, the number of publications has shown a consistent upward trend from 1997 to 2022. The number of publications in 2013 was 103. Although this number decreased in 2014 and 2015, it started to increase rapidly in the following years. In 2022, this number reached 332 publications on S&GT.

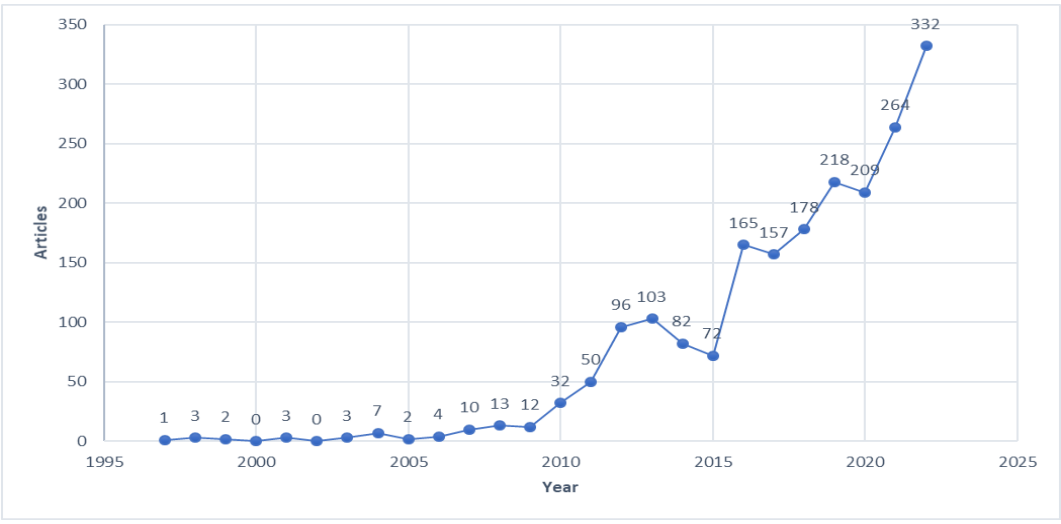

Figure 4. Annual scientific production

Table 2 lists information about the number of publications by year, the average number of citations, the average number of citations per year, and the citation years. Only one study was published in 1997. This study was cited 3 times on average, while the annual citation average was 0.11. Although there was a decrease in the number of articles on S&GT in 2005, 2015, 2017 and 2020 an increase was observed in the average number of citations and the annual average number of citations compared to the previous year. While the highest number of articles was reached in 2022, there was a decrease in the average number of citations and the annual average number of citations.

Table 2. Average citations per year

Year	MeanTCperArt	N	MeanTCperYear	Citable years
1997	3	1	0.11	27
1998	40.67	3	1.56	26
1999	0.5	2	0.02	25
2001	116	3	5.04	23
2003	50.33	3	2.40	21
2004	0	7	0.00	20
2005	29	2	1.53	19
2006	52.25	4	2.90	18
2007	35.1	10	2.06	17
2008	55	13	3.44	16
2009	36.08	12	2.41	15
2010	82.31	32	5.88	14
2011	47	50	3.62	13
2012	12.51	96	1.04	12
2013	19.47	103	1.77	11
2014	39.8	82	3.98	10
2015	44.6	72	4.96	9
2016	25.11	165	3.14	8
2017	31.36	15	4.48	7
2018	19.99	178	3.33	6
2019	21.67	218	4.33	5
2020	24.9	209	6.22	4
2021	14.17	264	4.72	3
2022	5.6	332	2.80	2

Table 3 presents a compilation of the leading 20 nations in terms of their contribution to S&GT research publications. The article count, single-country publications (SCP), denotes the quantity of publications resulting from collaborations within the same country. On the other hand, multiple-country publications (MCP) signify articles that emerged from the collaborative efforts of researchers hailing from multiple countries. Additionally, Table 3 displays the country's publication ratio in relation to the overall publication count, as well as the ratio of multiple-country publications to the total number of publications.

Table 3. Most productive countries and data related to these countries

No	Country	Articles	SCP	MCP	Freq	MCP ratio
1	China	577	440	137	0.286	0.237
2	USA	237	189	48	0.117	0.203
3	India	103	77	26	0.051	0.252
4	Malaysia	76	48	28	0.038	0.368
5	Italy	68	51	17	0.034	0.25
6	Korea	62	37	25	0.031	0.403

Table 3. continues

No	Country	Articles	SCP	MCP	Freq	MCP ratio
7	**Canada**	**56**	**39**	**17**	**0.028**	**0.304**
8	Poland	56	50	6	0.028	0.107
9	United Kingdom	51	20	31	0.025	0.608
10	Germany	42	33	9	0.021	0.214
11	Turkey	36	27	9	0.018	0.25
12	Australia	33	17	16	0.016	0.485
13	Greece	33	27	6	0.016	0.182
14	Sweden	32	22	10	0.016	0.313
15	France	30	16	14	0.015	0.467
16	Brazil	29	15	14	0.014	0.483
17	Spain	29	20	9	0.014	0.31
18	Portugal	26	21	5	0.013	0.192
19	Indonesia	25	20	5	0.012	0.2
20	Japan	25	19	6	0.012	0.24

Table 3 presents data on the effective countries on S&GT. The evaluation of the effective countries is based on citation numbers and average citation numbers. China has the highest number of citations. China is followed by USA, India, Malaysia, Italy, Korea in terms of the number of citations. Some countries (e.g. Cyprus) are ranked in the top 20 in the number of citations, although they are not in the top 20 in the ranking of countries with the most publications. Fort his reason, the average number of citations is also an important indicator of effectiveness.

Table 4 presents data on effective countries in the field of S&GT. The evaluation of the effective countries is based on number of citations (TC) and average citation numbers. USA has the highest number of citations. USA is followed by China, Malaysia, India and Korea in terms of the number of citations. While Greece, France, Brazil, Portugal and Indonesia are among the top 20 countries in terms of the number of articles, it is noteworthy that they are not among the top 20 countries in the Number of Citations and Average Number of Citations list.

Table 4. Effective countries, number of citations and average number of citations

No	Country	TC	Average article citations
1	USA	9500	40.08
2	China	8892	15.41
3	Malaysia	3594	47.29
4	India	2424	23.53
5	Korea	1524	24.58
6	Denmark	1293	64.65
7	Cyprus	1254	156.75
8	United Kingdom	1241	24.33
9	Italy	1215	17.87
10	Canada	997	17.80
11	Australia	861	26.09
12	Germany	833	19.83
13	Iran	772	32.17
14	Japan	767	30.68
15	Spain	730	25.17
16	Sweden	687	21.47
17	Poland	598	10.68

Table 4. continues

No	Country	TC	Average article citations
18	Pakistan	547	34.19
19	Turkey	535	14.86
20	Norway	524	23.82

Figure 5 shows the publication information of the 10 most productive institutions in the field of S&GT. The institution that publishes the most in the field of S&GT is Changan University with 49 publications. Beijing Jiaotong University (42) the second institutions that contributes the most to the field. University Technology Malaysia with 33 publications is the third institutions that contributes the most to the field. These university are followed by Tongji University (31), Hong Kong Polytechnic University (29), Tsinghua University (24), Technical University Denmark (22), IOWA State University (21), Maritime University of Szczecin (21), Universiti Teknologi Petronas (21). When the institutions that publish the most in the field of S&GT are examined, it is seen that 5 of the top 10 institutions are universities in China.

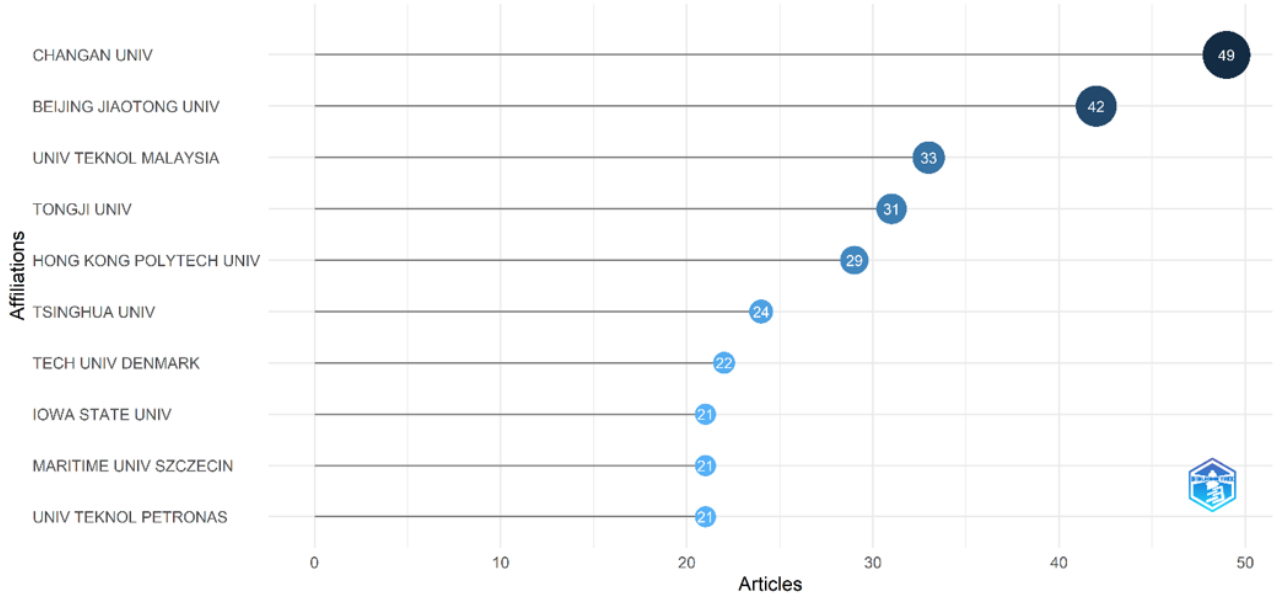

Figure 5. Most productive institutions

Figure 6 illustrates the change in the number of publications of the institutions in Figure 5 over time. This change is given cumulatively. The color of each institution is explained at the bottom of the figure. The contribution to the field of S&GT of Changan University that the institution with the highest number of publications has increased significantly in the last two years. The contribution of other universities also showed an increasing trend from 1997 to 2022 (Figure 6).

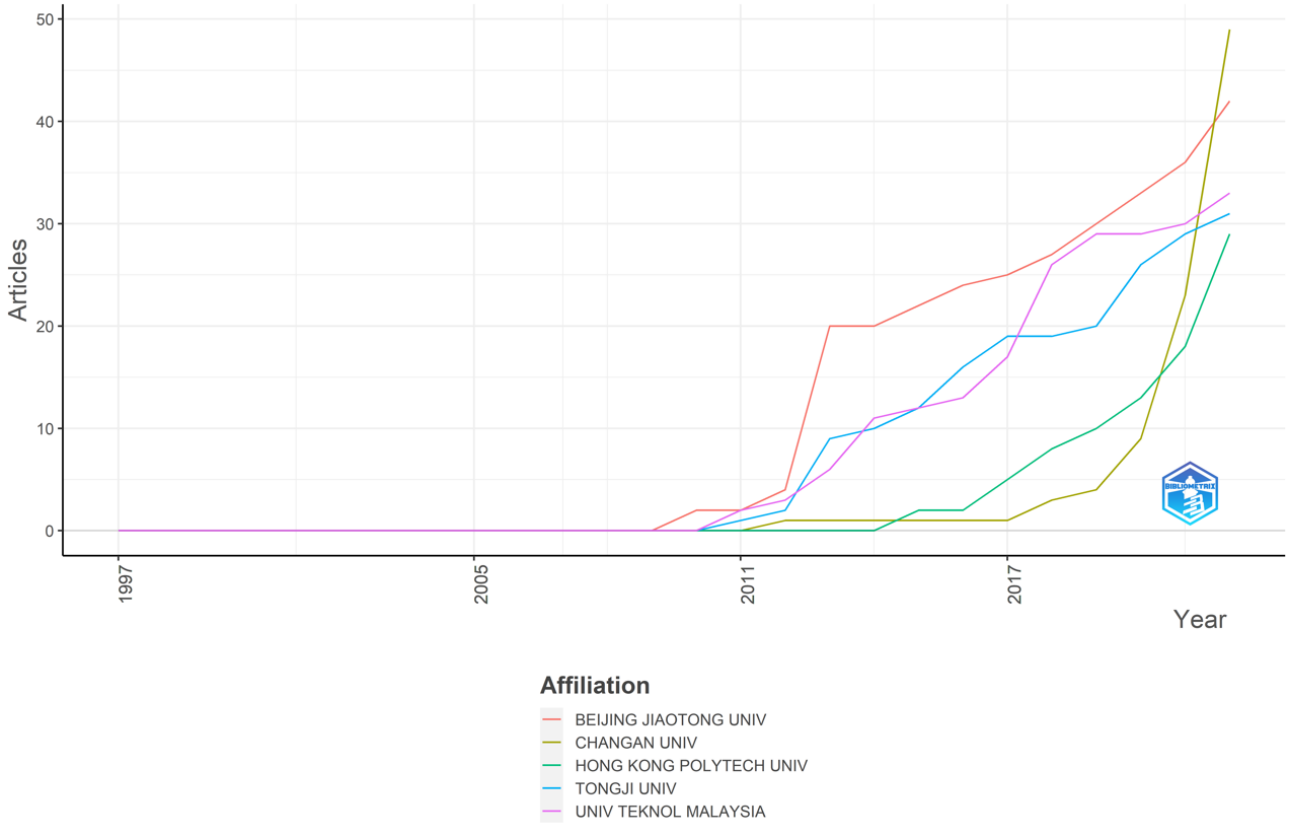

Figure 6. Cumulative representation of publications by the most efficient institutions by time

Figure 7 shows information about the 10 most productive authors in terms of the number of publications in the field of S&GT. The author who published the most is Zhang L with a total of 13 publications. Zhang Y with 12 publications is ranked second. Liu Y and Wang J are in third place with 11 publications. Kijewska K and Wang Y with 10 publications share the fourth rank. Du Q, Li Y and Wu J with 9 publications, ranks fifth. Govindan K with 8 publications ranks sixth.

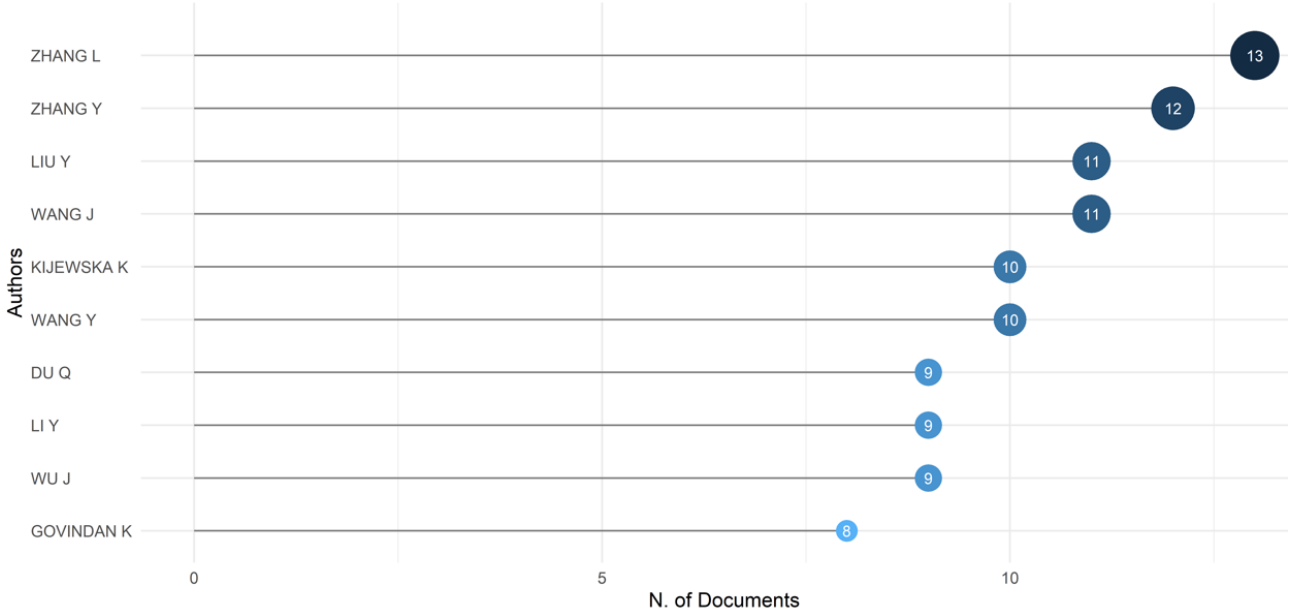

Figure 7. The most productive researchers in the field of S&GT

Table 5 gives information about the effectiveness of the researchers. The table contains information about the h-index, the g-index and m-index values of the respective researchers, the number of citations (TC), the number

of publications (NP), and the first year of their publication in the field (PY_Start). The G-index value, which is considered to be an improved version of the h-index, is the square root of the number of citations and then rounded to the resulting value (Kabakuş et al., 2023). According to Table 5, the author most effective in terms of h-index, g-index and m-index is Liu Y. The h-index value of Zhang Y with the highest number of publications is 6, while the h-index value of Kim H with the least number of publications is 5. It is noteworthy that the h-index value of Wu J which has the highest number of citations is 6.

Table 5. Effective authors in the field of S&GT

Element	H_index	G_index	M_index	TC	NP	PY_start
Liu Y	9	11	0.9	403	11	2014
Govindan K	8	8	0.889	555	8	2015
Li Y	6	9	0.6	193	9	2014
Shi XM	6	8	0.75	156	8	2016
Wu J	6	9	0.462	1180	9	2011
Zhang Y	6	12	0.5	200	12	2012
Zhou XS	6	6	0.462	197	6	2011
Kijewska K	5	10	0.625	122	10	2016
Kim H	5	5	0.385	557	5	2011
Kim S	5	7	0.357	91	7	2010

Figure 8 shows the trend over time of articles published by authors in the field of S&GT. Zhang L's contribution to the field started in 2013 and continued continuously until 2022. It is noteworthy that Kijewska K contributed to the field between 2016-2019, while almost all of the researchers' work continued until recent years. Wang Y is the author who contributed to the field of S&GT for the longest period of time from 2010 until the end of 2022, while Du Q is the author who contributed to the field for the least period between 2020-2022.

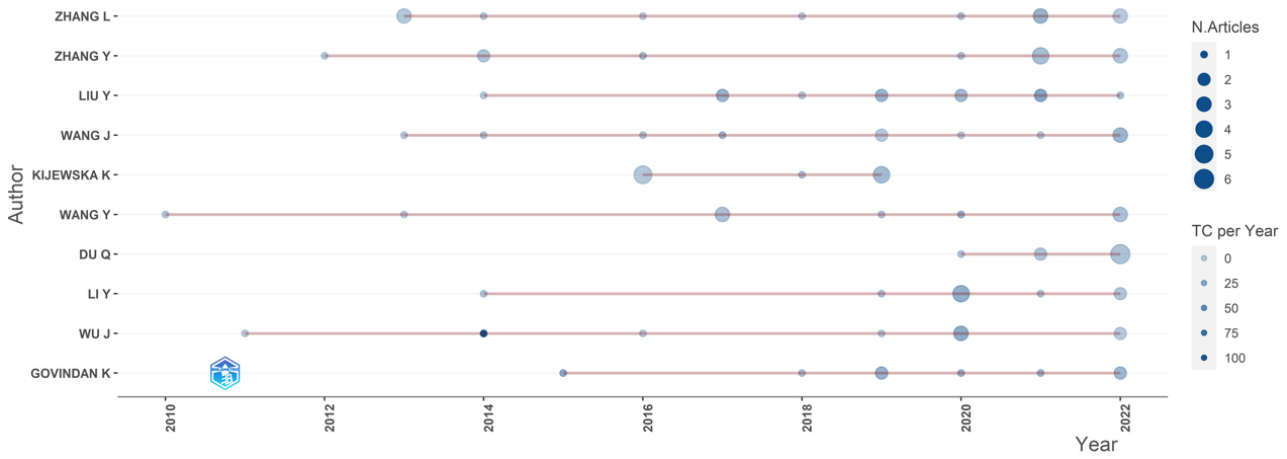

Figure 8. Authors' production over time

Figure 9 illustrates about the number of studies of the 10 most preferred journals in the field of S&GT. The most productive journal is Sustainability, an open-access journal with 148 publications. The most preferred journals after Sustainability are respectively Journal of Cleaner Production, Renewable & Sustaianble Energy Reviews, Transportation Research Part D, International Journal of Sustainable Transportation, Sustainable Cities and Society, Transportation Research Record, Sustainable Environment and Transportation, Transportation Research Part E and ACS Sustainable Chemistry & Engineering.

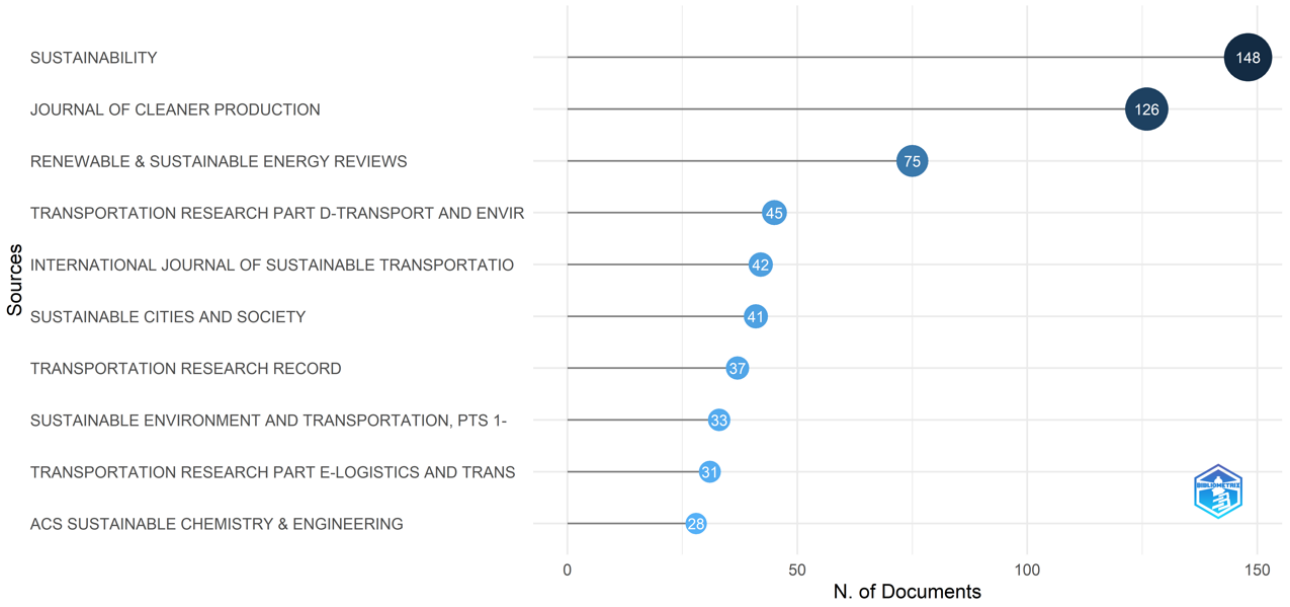

Figure 9. Preferred journals in the field of S&GT

The 25 top cited publications on S&GT between 1997 and 2022 are listed in Table 6. Table 6 presents an overview of highly cited studies within the realm of S&GT. Interested readers can access the articles using the provided DOI numbers. These studies represent pioneering contributions in the field and examining them can greatly benefit individuals seeking to advance their knowledge in this area. Alonso et al., (2010) titled "Catalytic conversion of biomass to biofuels" is the most popular publication in its field with 1746 citations and 124,71 the average annual citation. Nikolidis and Poullikkas (2017) and Hosseini and Wahid (2016) follow this study with 1196 and 1124 citations respectively.

Alonso et al., (2010) conducted a study on the viability of biomass as a sustainable alternative to depleting fossil fuels in energy generation, particularly for the transportation industry. The primary objective of their research is to provide a comprehensive survey of catalytic approaches employed in the production of biofuels from aqueous carbohydrate solutions obtained through biomass pretreatment and hydrolysis.
Nikolidis and Poullikkas (2017) investigated various hydrogen production methodologies through a comparative analysis. The study delved into the technical and economic aspects of 14 distinct production methods, accompanied by detailed process descriptions. The research encompassed both conventional and renewable approaches, offering a comprehensive juxtaposition of their outcomes. Ultimately, the authors contended that advancing technologies, coupled with significant advancements in H_2 storage, transportation, and utilization, would lead to reduced reliance on national fossil fuel imports, with green hydrogen emerging as the predominant energy source. Hosseini and Wahid (2016) presented an extensive overview of the latest hydrogen production technologies utilizing renewable and sustainable energy sources. The objective was to curtail greenhouse gas emissions arising from fossil fuel consumption in the transportation sector and energy-intensive industries.

Table 6. Most cited studies in the field of S&GT

Paper	DOI	Total citations	TC per year	Normalized TC
Alonso, D.M., 2010; Green Chem.	10.1039/c004654j	1746	124.71	21.21
Nikolaidis, P., 2017; Renew.Sust. Energy Rev.	10.1016/j.rser.2016.09.044	1196	170.86	38.13
Hosseini, S.E., 2016; Renew. Sust. Energy Rev.	10.1016/j.rser.2015.12.112	1124	140.50	44.76
Su, X., 2014; Adv. Energy Mater.	10.1002/aenm.201300882	1058	105.80	26.58
Tie, S.F., 2013; Renew. Sust. Energy Rev.	10.1016/j.rser.2012.11.077	825	75.00	42.38

Table 6. continues

Paper	DOI	Total citations	TC per year	Normalized TC
Muradov, N.Z., 2008; Int. J. Hydrogen Energy	10.1016/j.ijhydene.2008.08.054	621	38.81	11.29
Green, R.C., 2011; Renew. Sust. Energy Rev.	10.1016/j.rser.2010.08.015	384	29.54	8.17
Sander, K., 2010; Int. J. Life Cycle Assess	10.1007/s11367-010-0194-1	358	25.57	4.35
Yoshıda, J.I., 2011; Chemsuschem	10.1002/cssc.201000271	349	26.85	7.43
Chum, H.L., 2001; Fuel Process Technology	10.1016/S0378-3820(01)00146-1	346	15.04	2.98
Kumar, S., 2011; Applied Energy	10.1016/j.apenergy.2011.06.035	329	25.31	7.00
Zheng, X.F., 2014; Renew. Sust. Energy Rev.	10.1016/j.rser.2013.12.053	310	31.00	7.79
Rostamzadeh, R., 2015; Ecol Indic	10.1016/j.ecolind.2014.09.045	248	27.56	5.56
Ali, R., 2019; Sustain. Cities Society	10.1016/j.scs.2019.101553	218	43.60	10.06
Esmaeilian, B., 2020; Resour. Conserv. Recy.	10.1016/j.resconrec.2020.105064	212	53.00	8.51
Tang, X., 2014; Renew. Sust. Energy Rev.	10.1016/j.rser.2014.07.209	200	20.00	5.02
Yee, K.F., 2009; Applied Energy	10.1016/j.apenergy.2009.04.014	197	13.13	5.46
Pishvaee, M.S., 2014; Transport Res. E-Log.	10.1016/j.tre.2014.04.001	192	19.20	4.82
Zeng, X.H., 2011; Renew. Sust. Energy Rev.	10.1016/j.rser.2011.04.014	190	14.62	4.04
Ren, G.Z., 2015; Renew. Sust. Energy Rev.	10.1016/j.rser.2014.08.003	190	21.11	4.26
Zhang, L.H., 2015; J. Clean Prod.	10.1016/j.jclepro.2014.04.006	189	21.00	4.24
Holm, M.S., 2012; Green Chem.	10.1039/c2gc16202d	189	15.75	15.11
Van, Fan, Y., 2018; J. Clean Prod.	10.1016/j.jclepro.2018.05.151	183	30.50	9.15
Hafezalkotob, A., 2017; Transport Res. E-Log.	10.1016/j.tre.2016.11.004	180	25.71	5.74
Dev, N.K., 2020; Resour. Conserv. Recy.	10.1016/j.resconrec.2019.104583	179	44.75	7.19

In Figure 10, the trending topics according to the years as a result of the bibliometric analysis are shown. When the figure is examined, while the focus was on transportation fuels in the first years, the studies in the last years (2017-2021) focused on green, energy, performance, choice, model and emissions. Trend topics such as renewable energy, $C0_2$ emissions, carbon emissions and biohydrogen production stand out in 2021-2022.

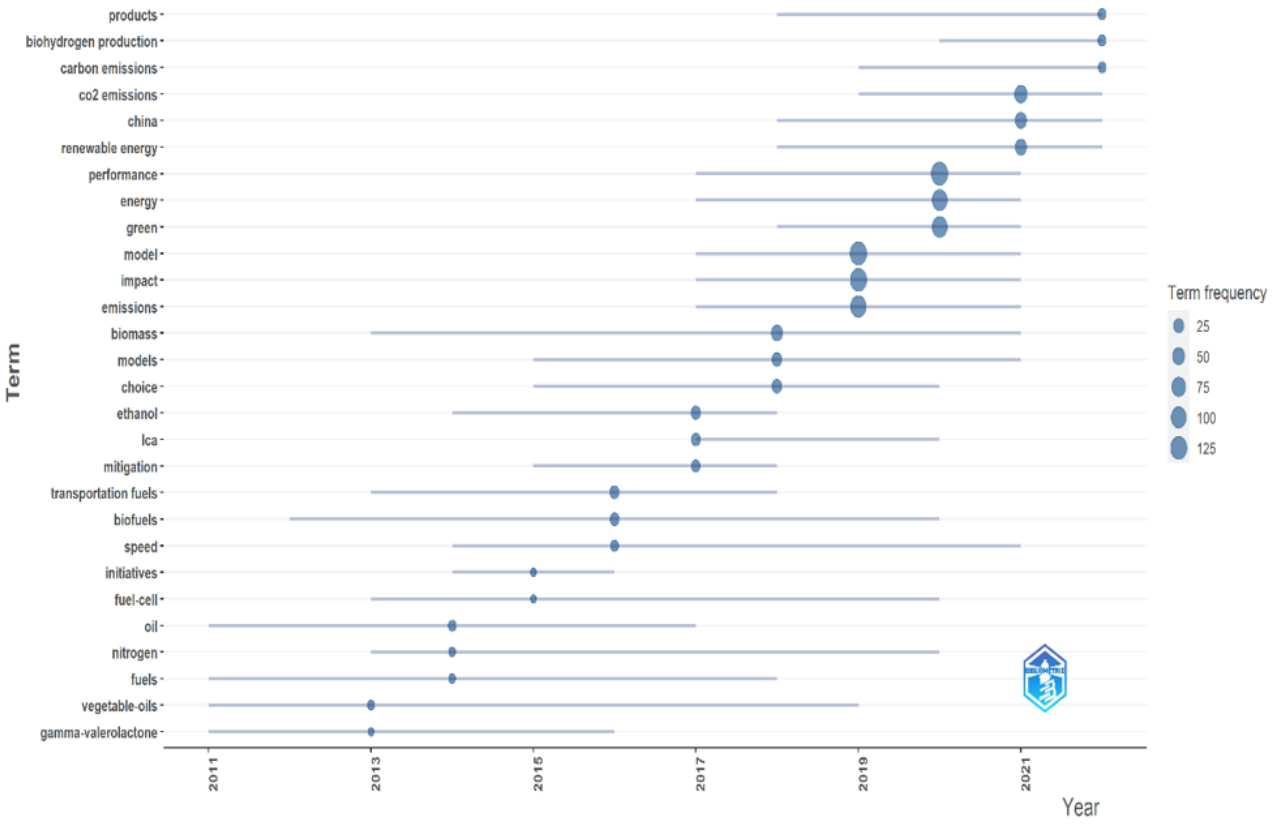

Figure 10. Trend topics

The thematic map of the keywords in S&GT studies is presented in Figure 11. In this map, centeredness is expressed on the vertical axis and density is expressed on the horizontal axis. When Figure 11 is examined, 3 niche themes that are used less frequently in the field in the upper left, 1 emerging and declining themes in the lower left part, 2 motor themes in the upper right part that determine the level of progress of the field, and finally 3 main themes that can be called the foundation of the field in the lower right is located.

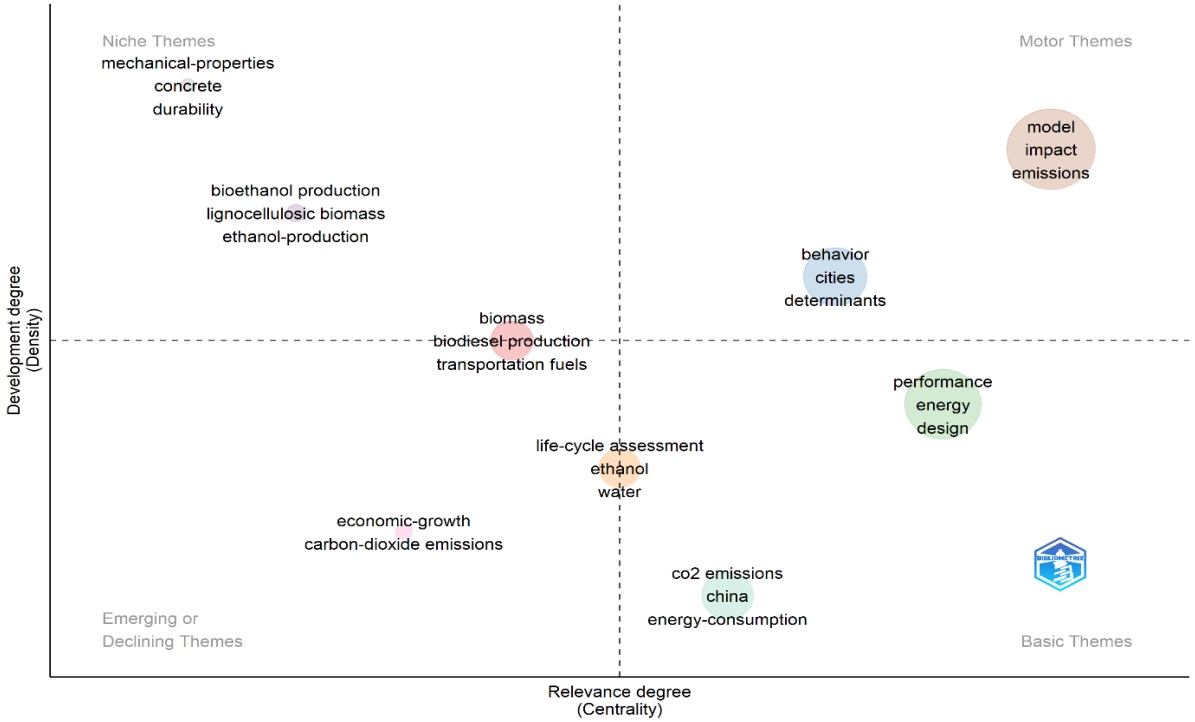

Figure 11. Strategic diagram

The main themes on which the studies focused the most were determined as: performance, energy, design, and CO_2 emissions. Life-cycle assessment, ethanol and water, on the other hand, are candidates for becoming the main theme, leaving the developing or regressing themes. Although the niche themes of mechanical properties, concrete, durability, bioethanol production, lignocellulosic biomass, ethanol-production are not covered frequently, they are still influential on the field. Biomass, biodiesel production and transportation fuels themes are candidates for developing themes. Model, impact, emissions, behavior, cities themes can be expressed as motor themes.

Figure 12 presents a knowledge map derived from the co-occurrence analysis of keywords in S&GT research articles from R software. The predominant cluster, denoted by the color green, encompasses the keyword "model" and exhibits the largest size. The number of papers in which each keyword was identified is indicated in parentheses alongside the respective keywords. This cluster also contains keywords impact, management, transportation, optimization and design. The red cluster, which is the second largest cluster of keywords, comprises terms such as "performans", "energy", "emissions", "life-cycle assessment" and "system". The blue cluster includes CO_2 emissions, climate change, energy, biodiesel production, renewable energy and cities. The purple cluster includes behavior, travel, attitudes and determinants.

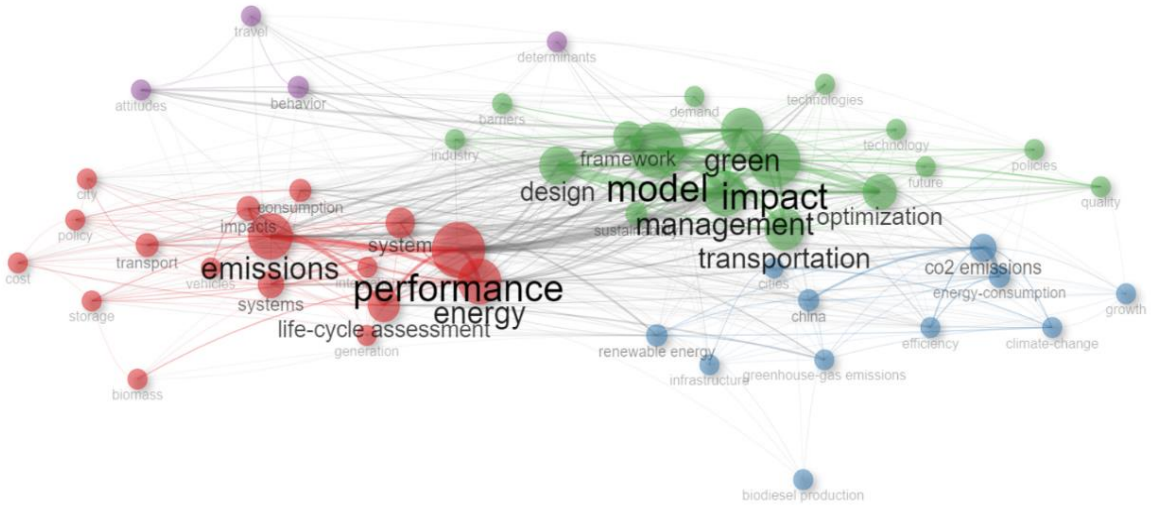

Figure 12. Mapping of co-occurrence keywords in S&GT researchs

Figure 13 shows conceptual structure map. When the figure is examined, the red area shows a large number of related words. There are words listed in many publications in this field. It can be said that there has been a great deal of interest lately on topics that include keywords such as transportation, emissions, impact, energy, policy and sustainability approaching the red central point. There are 6 terms in blue cluster. The keywords closest to the center point in the blue area are renewable energy and integration. The narrower points at the edges of the blue area contain less researched keywords. These keywords (generation, storage, climate change and greenhouse gas emissions) have the potential to guide future research and form the basis of the research topic.

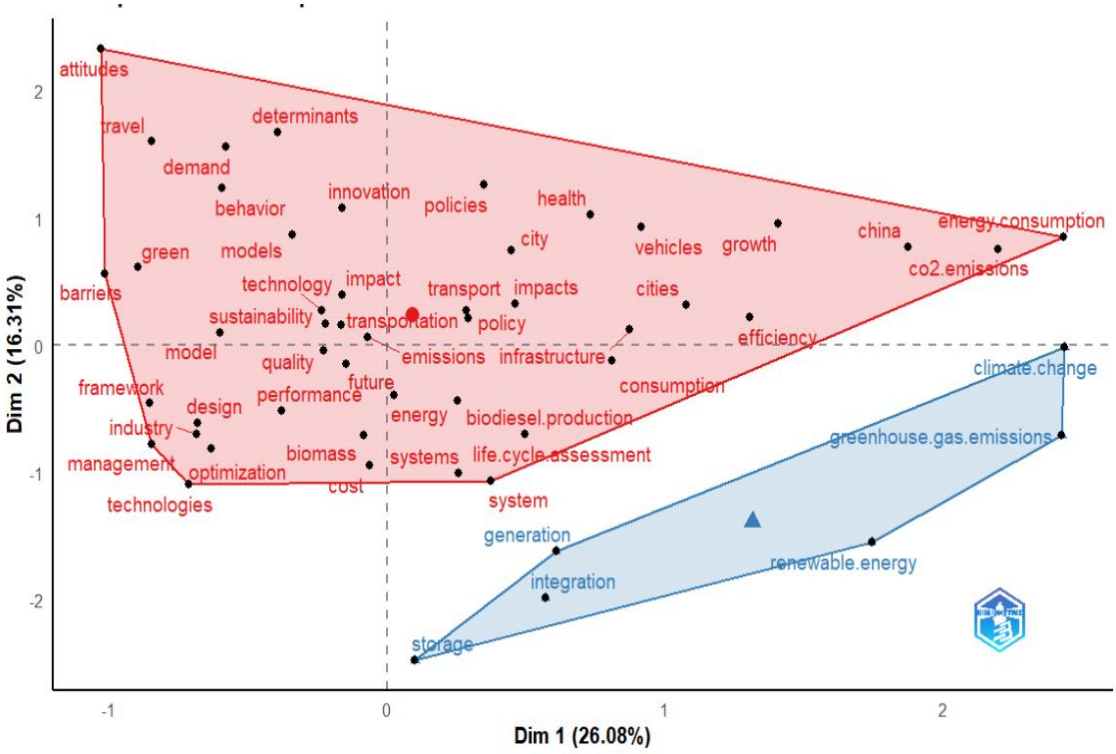

Figure 13. Conceptual structure map of S&GT researchs

In this study, various analyzes were conducted focusing on keywords to explore the S&GT research trend. The 50 keywords that stand out in scientific research in the field of S&GT are presented in Figure 14. These keywords provide an idea of the focus of the S&GT field. Performance (134), model (130), impact (124), emissions (106), energy (99), green (96), management (95), transportation (90), design (86) and life-cycle assessment (76) stand out as the top trend words in studies in the field of S&GT.

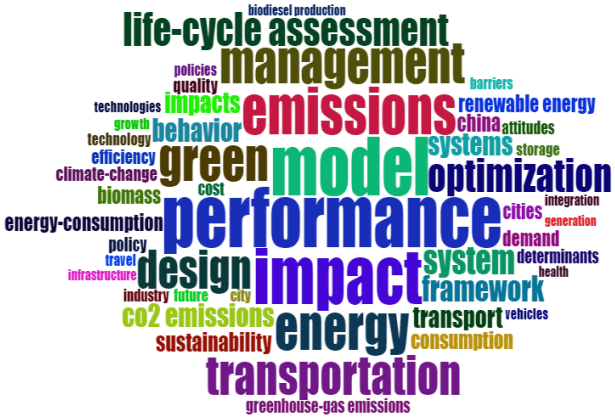

Figure 14. Word cloud

5. Conclusions

This paper presents a bibliometric analysis to investigate studies in the field of S&GT. This analysis is based on a dataset of 2018 documents published in journals indexed in WoS. Before 2010, there were fewer than 20 publications each year in S&GT field. After 2018, there has been a significant increase in the number of

publications. According to the analysis, while the country that contributes the most to scientific research in the field of S&GT is China, the institution that contributes the most is Changan university. The author who contributed the most to this field is Zhang L. The findings suggest that Sustainability has emerged as the primary publication organ and serves as an effective platform for researchers to disseminate their studies in the field of S&GT. According to the findings, when the frequency of keywords used in the 2018 study is analyzed, it is seen that there are three dominant clusters. The first of these clusters is the green cluster consisting of model, impact and green. The second is the red cluster consisting of performance, energy, and emissions. The last one is the blue cluster consisting of CO_2 emissions, climate change and energy-consumption.

There are a very few bibliometric analysis studies on S&GT in the literature. The contribution of this study to the literature is to summarize what researchers have done in the field of S&GT research and to provide information that will help researchers interested in this field better understand the past and explore the future of this research field.

The limitations of this study are that the original data used can only be obtained from the WoS core collection database and the space limitation. In future studies, these limitations can be improved by adding different databases and expanding the field filters.

The results of this study can provide important guidance to the planning and design processes of future research. Furthermore, expanding future studies to include important topics such as sustainability, intelligent systems, and integration of transportation systems may allow the results to be examined in a broader perspective. Furthermore, in-depth examination of the themes in the S&GT field will contribute to multidisciplinary integration. The bibliometric analysis conducted in this study helps us to understand the current research trends in the S&GT field, which topics are prominent and what is important. Thus, it will guide researchers in identifying potential areas to focus on in future studies. The analysis identifies gaps in the existing literature and highlights topics that require further research in the S&GT field. This is expected to provide opportunities for researchers to develop and contribute to new projects. As we have identified key themes and concepts in the sustainable green transportation literature through this analysis, it will help to understand the topics and interesting perspectives to focus on in future studies. Furthermore, by identifying important journals and platforms in the S&GT field through this analysis, this study is expected to guide researchers in finding appropriate places to publish their work.

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Author contribution

Nuriye Kabakuş: Research, Data collection Methodology, Software, Verification, Analysis, Investigation, Writing - original draft, Writing - review and editing, Visualization.

Declaration of ethical code

The author of this article declare that the materials and methods used in this study do not require ethical committee approval and/or legal-specific permission.

Conflicts of interest

The author declares that there is no conflict of interest.

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