ANALYSIS OF SMART CITY GLOBAL RESEARCH TRENDS WITH NETWORK MAP TECHNIQUE

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Abstract

In the study, it is aimed to systematically analyze and visualize the trends of research on smart cities between 1991 and 2021 on a global scale. The data obtained from the Web of Science Core Collection Database were analyzed with the VOSviewer software. In the database, 1809 articles were accessed in the date range determined by the keyword "smart city" in the title category. A systematic bibliometric analysis was conducted including different variables such as citation numbers, leading authors, organizations, keywords, and countries where the articles were written. According to the findings obtained from the analysis, the three most influential journals for a smart city research are Sustainability, Journal of Urban Technology, and Technological Forecasting and Social. The vast majority of studies have been published in the English language. The three most- cited authors are; Park, Dameri and Kim. The most influential institutions are the universities of Huaqiao, Central South, and College London. The findings will help researchers in the field understand the general trend of global smart city research, the level of relevance and performance of variables, and provide guidelines for further research.

Keywords: Smart City, VOSviewer, Bibliometrics, Network visualization, Web of Science

1. INTRODUCTION

As a result of high rates of urbanization and climate change, the stress on cities is increasing day by day. In cities, problems related to health, transportation, security, energy, education, environmental pollution, resource scarcity, waste management, and infrastructure arise, thus, urban life, urban and economic development are disrupted. The concept of smart city comes to the fore as a solution to the problems that arise in cities. Smart cities are the urban model that offers promising smart solutions to improve the quality of services and the well-being of citizens through operational efficiency, safe communities, efficient resource use and a sustainable environment. The concept of smart city is characterized by sustainable response using innovative technologies to different needs such as industrial and commercial activities, efficient use of resources, economic welfare, public safety, environmental protection, general public and urban services.

Smart city applications; encourages technological solutions in the more effective and efficient management of cities, in the effective and efficient execution of basic services, and in meeting the needs of citizens. With the contribution of developed software and technologies such as big data analytics and artificial intelligence, a transition to automation is achieved in smart cities (Nica, et al, 2020).

Smart city studies are one of the most popular fields of the current century. There are numerous reasons that make smart cities remarkable. Reasons such as meeting the needs of the population that has accumulated in cities in a timely manner, the increasing complexity of urban life, the need for effective management of the city as a large market and living space, increasing and diversifying citizen expectations, and growing and increasing environmental problems can be counted as examples. The quality of life of people depends on the environmental conditions of the environment, the services they can access, the quality and timeliness of these services, etc. shaped accordingly. Therefore, opportunities, facilities, services, technological developments, and problems in a city have a great impact on the lives of those living in that city.

Smart cities have attracted the attention of scientists, global companies, and local and central governments, and the studies carried out in this field have gained momentum in recent years. New technologies have started to play more and more central roles in the management of a city, with the acceptance that they enable the residents and visitors to be included in the city life, meet their demands, and provide unique services by producing solutions.

In this study, the bibliometric analysis method was used to analyze and visualize the smart city literature in a systematic way. This method of analysis is a discipline carried out systematically to evaluate the importance of the subject in the determined field. The bibliometric analysis method helps to interpret the place of the subject in the literature and the distribution of studies according to regions and time (Huang et all, 2016; Xie et al, 2020; Michalopoulos and, Falagas, 2005; Katoch, 2021; Rahman, Haque, and Fukui, 2005) ; Marcucci et all, 2021). Bibliometrics is a statistical technique analyzing a chosen topic quantitatively in academic literature (Zhong et all, 2016). It is also an indispensable statistical tool for identifying key information for various purposes such as mapping the latest state of affairs in a particular field of scientific knowledge, seeking research opportunities, and validating scientific research (de Oliveira et all, 2019). With this analysis method, an overview of research trends in different disciplines is presented by identifying the most contributing publications, journals, countries, institutions, prominent authors, and keywords, intensities and collaborations in important research areas.

The first work on the bibliometric method was published by Henry Armstrong in 1896. In this study, the subject distributions of the publications with the specified criteria were analyzed with a statistical method (Sengupta 1992:75). After Armstrong's work, a lot of research has been done in the field by using different techniques. Articles in different disciplines have been published with the VOSviewer (Visualization of Similarities Viewer) software, which is one of the tool in bibliometric analysis. For example, university–industry cooperation (Mascarenhas, Ferreira, and Marques, 2018), multiple criteria decision making (Yu et al, 2018), safety culture (Van Nunen et al, 2018), social networking (Doleck, and Lajoie, 2018), health inequalities (Cash-Gibson, 2018), digital humanities (Wang, 2018), management information systems (Ozkose, and Gencer, 2017), and policy sciences (Goyal, 2017).

2. METHODOLOGY

VOSviewer software was developed by Nees Jan van Eck and Ludo Waltman in 2010 at Leiden University. VOSviewer is a free program for creating and viewing bibliometric maps of all kinds, such as citation relationships between publications or journals, collaborative relationships between researchers, and co-occurrence relationships between scientific terms. The official website contains learning materials (articles, book chapters, guides and promotional videos) for those who want to use the program (Van Eck, and Waltman, 2010).

The metadata used in this study is based on the "Core Collection Database of Web of Science" as it is a peer-reviewed, accessible, comprehensive, and multi-disciplinary database. 1809 articles published between 1991 and 2021 were downloaded from Web of Science in "The Full Record and Cited References" format (Table 1). The search was conducted in the last week of January 2022. "Smart city" was used as a string to search for titles, abstracts and keywords from 1991 to 2021. The data set consists of 4 different "txt" files, as it allows downloading data in "txt" format at most 500 at once from the Web of Science database. The data were analyzed in version 1.6.18 of the VOSviewer program. Only the studies in article type were included in the search.

TABLE 1 - SEARCH FRAME FOR DOCUMENT SCANNING

Search options	Ingredients
Database	Web of Science
Visualization tool	VOSviewer
Version	1.6.18
Search protocol	Subscribed journals
Selection approach	Bibliometric analysis
Search query	"smart city"
Scope	1991–2021
Document type	Articles
Search location	Title
Total number of documents	1809
Indexes	SSCI, SCI-EXPANDED, A&HCI, BKCI-S, BKCI-SSH, CPCI-S, CPCI-SSH, ESCI

3. STATISTICAL RESULTS

In this part of the study, the findings regarding the analyzed articles are included. Statistical analyzes of author, country, keyword, and citation structures of the studies in the last thirty years are presented with the help of graphs, frequency values and maps.

The first article on smart cities was published in 1991. From that date to 2021, 1809 articles were indexed in the Web of Science database. In the last 30 years, smart city document production has grown exponentially and has been stable and continuous over time. While only 8 articles were written until 2013, studies have gained momentum especially after 2017 (Figure 1). Approximately 65% of all publications were made in 2019 (19.6%), 2020 (22.2%) and 2021 (22.7). Articles in the Web of Science database received a total of 16,765 citations.
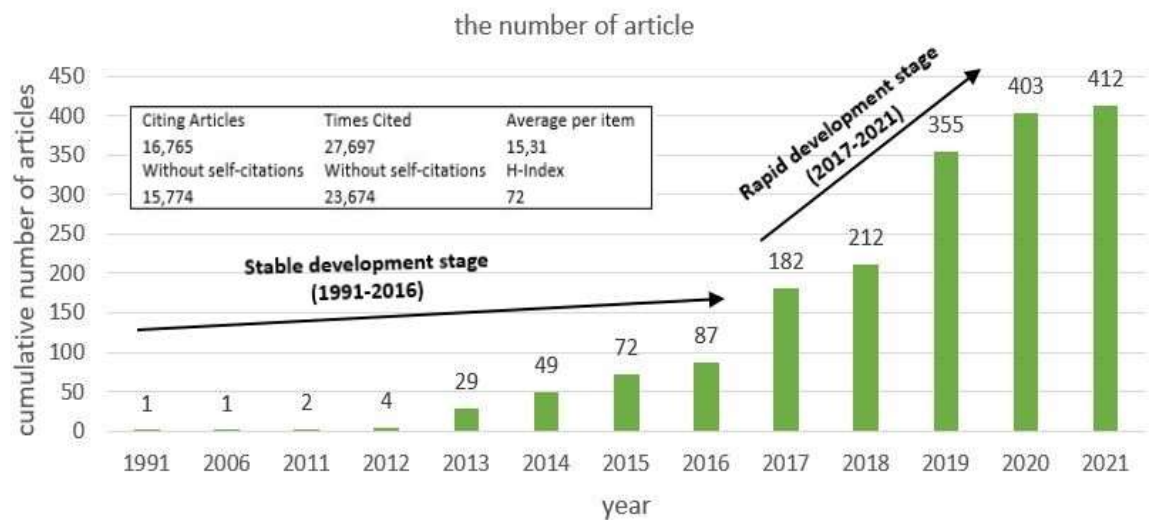

FIGURE 1 - MOST EFFECTIVE YEARS

Network visualization of keywords was made by using VosViewer in 1809 articles filtered with the keyword "smart city" in the Web of Science Core Collection database. In order to create more meaningful maps from the data, a threshold value was given to the data. The minimum number of co-occurrences of a keyword is set to at least 5. In the analysis of keyword co-occurrence, 333 out of 6429 keywords met the threshold. The network of keywords is categorized into 10 clusters presented in Figure 2. These clusters are shown in different colors.

1- Red: Smart city, internet, smart cities, internet of things, blockchain, 5G, sensors, cloud, architecture, networks, things, machine learning,

2- Green: Cities, governance, politics, citizens, policy,

3- Blue: urban, quality, health, pollution, sustainable smart city,

4- Yellow: Model, management, systems, performance,

5- Purple: Desing, security, privacy, algorithm,

6- Light Blue: Framework, safety, ecology, eco- city, urban, sustainability, urban development, social media, science,

7- Orange: Big data, technologies, transport, innovation, knowledge, infrastructure,

8- Brown: Challenges, services, network, urban mobility,

9- Pink: Simulation, evaluation, urban computing,

10- Black: Mobility, open data, ecosystem, public space.

Each cluster contains a list of 333 keywords covering different dimensions and determinants of the smart city. In the network visualization, each tag is represented by a colored circle. The circle of an item is determined by the frequency of use of the item. The higher the frequency of use of an item is, the larger is the item's tag. Also, between circles and the thickness of the line represent the frequency of keyword co-occurrence. In the image below (Figure 2), the smart city keyword has the largest circle, visualized in red. Smart city has the most remarkable connection power among all keywords and smart cities, cities, internet, IoT, internet of things, etc. and this shows that it is very strongly associated with keywords.

FIGURE 2 - NETWORK VISUALIZATION MAP OF KEYWORDS

Network visualization map of high-frequency keywords (Figure 3). The colors turning from blue to yellow increase the topicality of the publications. The keywords of scheme, trust, sense, data models, place, sustainable development have come to the fore in recent years.

FIGURE 3 - OVERLAY VISUALIZATION MAP OF KEYWORDS

In density visualization maps, the more elements in the neighborhood of a point, the closer the color of the point is to yellow. On the other hand, the fewer elements in the neighborhood of a point, the closer the color of the point to blue. The keyword with the color closest to yellow on the map (Figure 4) is smart city. Smart city keywords respectively; cities, smart cities, internet are the following keywords.

FIGURE 4 - DENSITY VISUALIZATION MAP OF KEYWORDS

When the keywords are sorted according to the frequency of use, smart city, cities, smart cities, internet, internet of things are the most used keywords. The smart city keyword has been used 808 times, cities 458, and smart cities 300 times. It is seen that there is a parallelism between the keywords' occurrences and total link strength.

TABLE 2 - MOST EFFECTIVE KEYWORDS

Rank	Keywords	Occurrences	Link	Total Link Strength	Cluster	Average Publication Year
1.	Smart city	808	323	727	1	2018
2.	Cities	458	293	442	2	2019
3.	Smart cities	300	275	277	1	2019
4.	Internet	206	218	203	1	2019
5.	Internet of things	132	168	131	1	2019
6.	Iot	105	148	101	1	2019
7.	Things	100	145	100	1	2019
8.	Model	100	175	96	4	2019
9.	Management	99	193	96	4	2019
10.	Framework	93	173	92	6	2019
11.	Governance	92	154	92	2	2019
12.	Challenges	89	170	87	8	2020
13.	Big data	75	117	73	7	2019
14.	Innovation	66	145	65	7	2019
15.	Systems	66	135	65	4	2019

The number of publications alone is not enough to measure the productivity of an author. Ideas presented in studies should be read and cited by others. Therefore, one of the most important dimensions in discussing the influence of researchers is the interest of a researcher's ideas by other researchers in that field (Soosaraei et all, 2018). In this section, the minimum number of documents of an author was selected as at least 1 to analyze the citation numbers of the authors. All 5185 authors are listed.
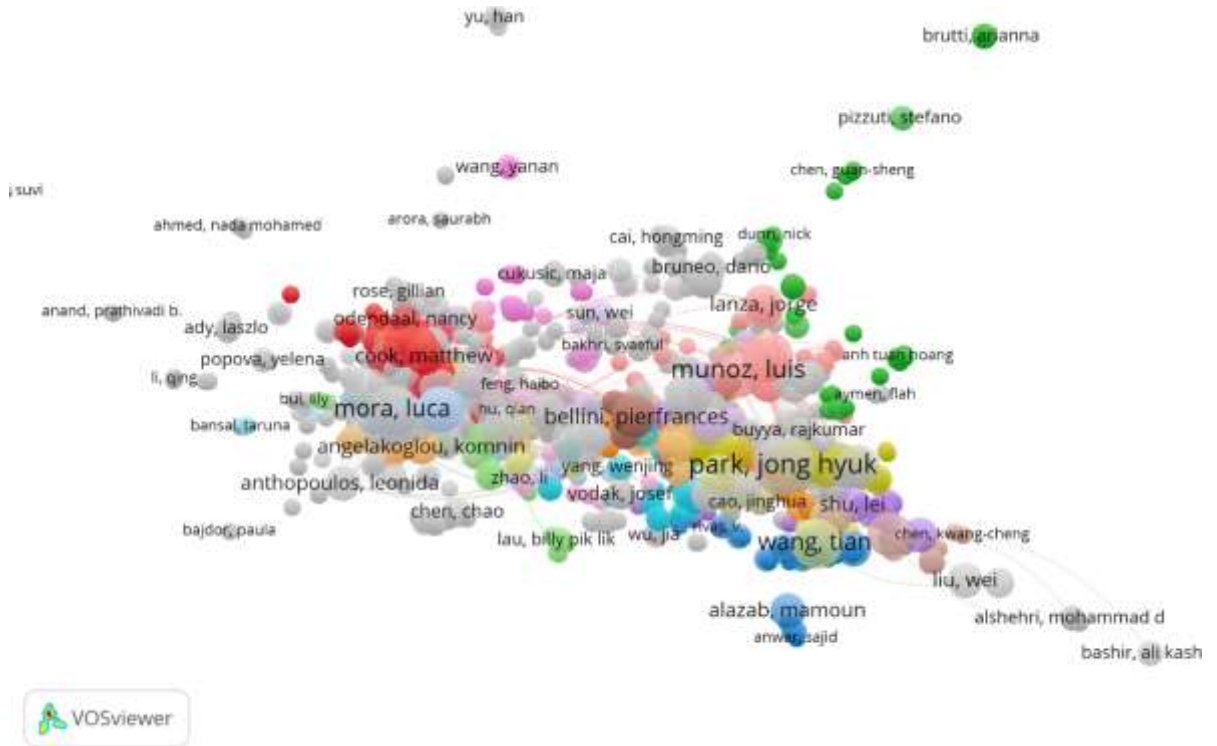

FIGURE 5 - NETWORK VISUALIZATION MAP OF CITATIONS

The number of citations of the first four most influential articles on the smart city are, in order; 892, 641, 487, 478. Also in Table 3, the number of citations and the time elapsed since the article was published (TC/TS) were formulated in order to provide a more accurate assessment. According to this formula, the order of the most effective article has not changed. The publication, which was in the 3rd rank, rose to the 2nd rank. The article in the last place was in the fourth place.

TABLE 3 - MOST EFFECTIVE ARTICLES

Rank	Title	Author	Total Citations (TC)	Journals	Year	Time Span (TS)	TC/TS	Research Areas
1.	Current trends in Smart City initiatives: Some stylised facts	Neirotti et al.	892	Cities	2014	7	127.71	Urban Studies
2.	An Information Framework for Creating a Smart City Through Internet of Things	Jin, Gubbi, Marusic, and Palaniswami	641	IEEE Internet of Things Journal	2014	7	91.57	Computer Science
3.	Long-range communications in unlicensed bands: The rising stars in the IoT and smart city scenarios	Centenaroet al.	487	IEEE Wireless Co mmunications	2016	5	97.40	Computer Science
4.	Smartmentality: The Smart City as Disciplinary Strategy	Vanolo,	478	Urban Studies	2014	7	68.28	Urban Studies

5.	A Smart City Initiative: the Case of Barcelona	Bakıcı, Almirall, and Wareham	397	Journal of the Knowledge Economy	2013	8	49.62	Business
6.	The role of big data in smart city	Hashem et al.	392	International Journal of Information Management	2016	5	78.40	Information Science
7.	Modelling the smart city performance	Lombardi, Giordano, Farouh, and Yousef	363	Innovation-The European Journal Of Social Science Research	2012	9	40.33	Sociology
8.	SmartSantander: IoT experimentation over a smart city testbed	Sanchez et al.	358	Computer Networks	2014	7	54.14	Computer Science
9.	Smart city policies: A spatial approach	Angelidou,	347	Cities	2014	7	49.57	Urban Studies
10.	UAV-enabled intelligent transportation systems for the smart city: Applications and challenges	Menouar et al.	329	IEEE Communications Magazine	2017	4	82,25	Engineering

The influential journals section will help to address the main trends of smart city research and to evaluate it from a broader perspective. The minimum number of documents published in a source was chosen as "5" the minimum number of citations received by a source was "0", and 67 of 671 references met these threshold values. For each of the 67 sources, the total link strength of the citations with other sources was calculated. The network map was created by selecting the sources with the highest total connection strength. Here, the journals with the highest total connectivity could be listed as Sustainability, Journal of Urban Technology, Technological Forecasting and Social Change, Cities, Smart Cities, and IEEE Access.

FIGURE 6 - NETWORK VISUALIZATION MAP OF JOURNALS

The journal with the most links is Sustainability (1269.34). The second rank is Journal of urban technology (825.57). Technological forecasting and social is the third journal with the highest Total Link Strength. When the journals are evaluated in terms of citations, the journals in the top three are respectively; Cities (1735), Future Generation Computer (1343), Technological Forecasting and Social (1183). When ranking according to impact factor, the dominant journal in this field is Technological Forecasting and Social Change with 8,593 points. This magazine is followed by Sustainable city and society, and Future Generation Computer journals.

TABLE 4 - MOST EFFECTIVE JOURNALS

Rank	Source	WoS Publications	Citations	Impact Factor (2020)	Total Link Strength
1.	Sustainability	73	701	3.251	1269.34
2.	Journal of Urban Technology	25	770	5.465	825.57
3.	Technological Forecasting and Social Change	28	1183	8.593	816.42
4.	Cities	32	1735	5.835	815.84
5.	Smart Cities	34	271	5.5	720.46
6.	IEEE Access	65	956	3.367	693.52
7.	Sustainable city and society	40	585	7.587	534.55
8.	Future Generation Computer	46	1343	7.187	492.85
9.	Sensors	53	756	3.576	385.41
10.	Energy	19	173	7.147	327.27

When evaluated in the context of co-authorship, 2123 different organizations contribute to smart city studies. These organizations are represented in 63 different clusters.
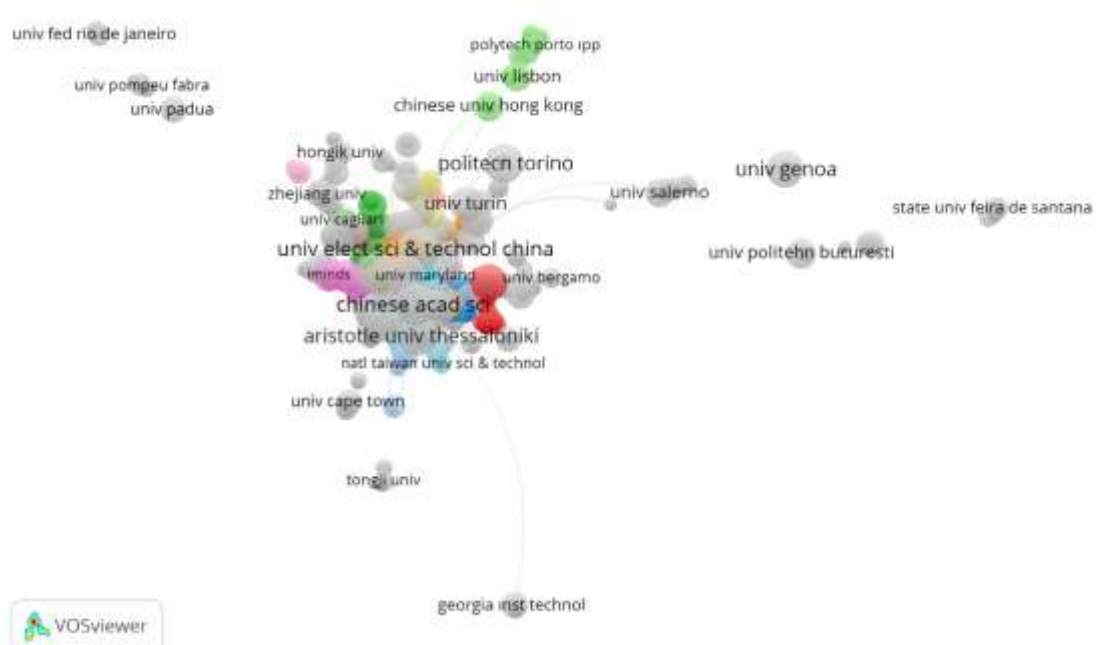
FIGURE 7 - NETWORK VISUALIZATION MAP OF AFFILIATIONS

The distribution of research power, actual contribution and cooperation among institutions in the smart city field is analyzed. According to the network visualization map of Affiliations, Melbourne University has 47 total link

strengths. Melbourne University is followed by Chinese Academy of Sciences, Huaqiao University, King Saud University with 43,37,35 links, respectively.

TABLE 5 - MOST EFFECTIVE AFFILIATIONS

Rank	Affiliations	Country	Link	Documents	Citations
1.	Melbourne University	Australia	47	9	802
2.	Chinese Academy of Sciences	China	43	17	334
3.	Huaqiao University	China	37	11	305
4.	King Saud University	Saudi Arabia	35	17	183
5.	Guangzhou University	China	35	11	320
6.	Central South University	China	33	12	256
7.	Scuola Superiore Sant'Anna di Pisa	Italy	32	4	42
8.	Newcastle University	England	30	10	98
9.	University College London	England	30	9	161
10.	King Abdulaziz University	Saudi Arabia	30	8	97

While the most influential countries were selected in the program, the number of publications per country was determined as at least 5. In total, 66 countries from 96 countries meet this condition. As can be clearly seen in the image, China ranks first with 409 publications, America ranks second with 210 publications, and Italy ranks third with 161 publications. The three most cited countries are as follows: Italy, China, and England. When evaluated in terms of total link strength, China's strongest links are the USA (36.06), Australia (18.92), England (14.98), Italy's are Russia (6.67), USA (5.58) and Romania (4), and USA's are China (36.06), South Korea (13.42), and France (5.41).
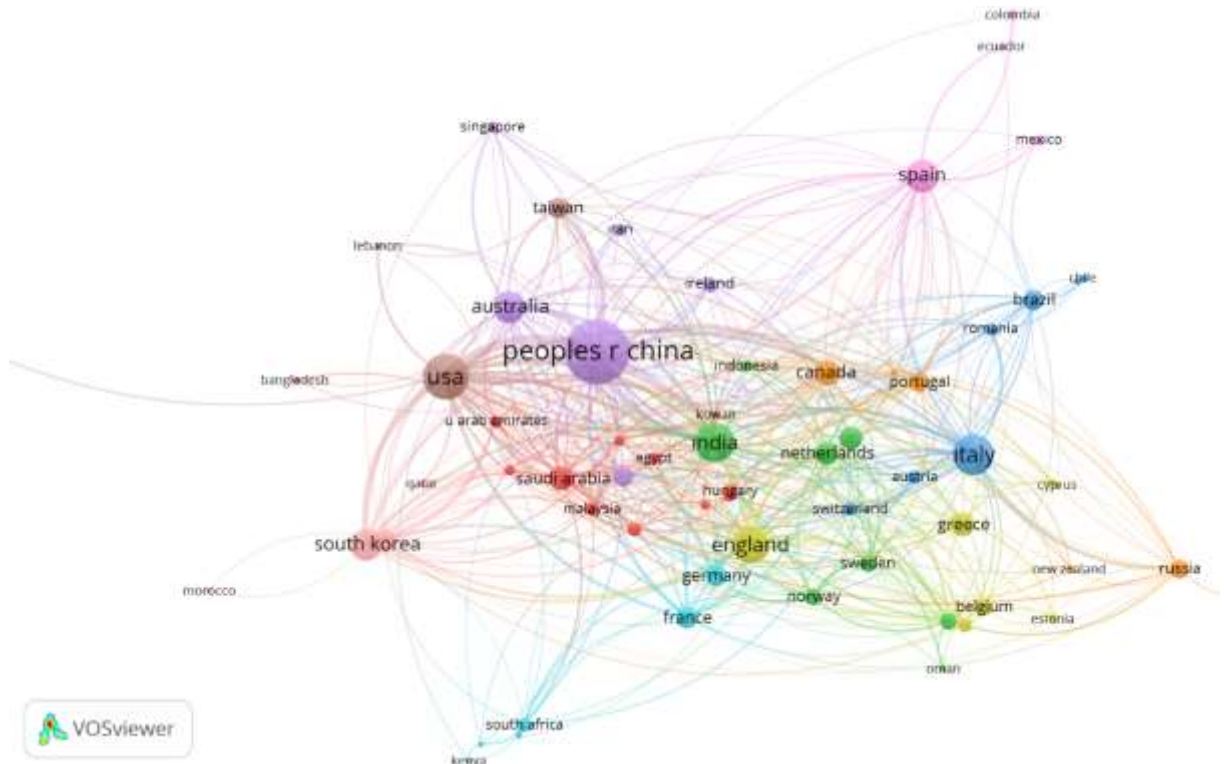
FIGURE 8 - NETWORK VISUALIZATION MAP OF COUNTRIES

While creating the density map of the countries, the total number of publications was taken as a basis. The countries closest to the yellow color are the countries with the highest number of publications. On the map (Figure 9) of China is the country closest to the yellow color. America comes after China.
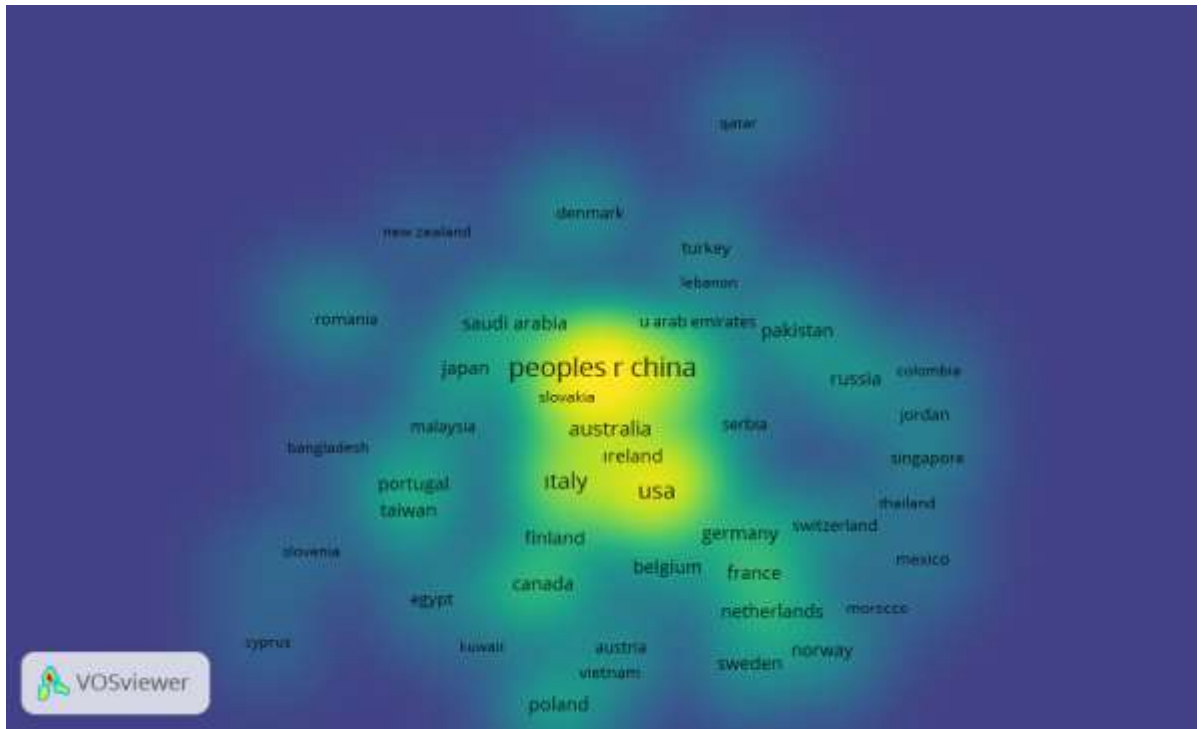
FIGURE 9 - DENSITY VISUALIZATION MAP OF COUNTRIES

When the distribution of articles in research areas is analyzed, the Computer Science category (611 publications) has a quantitative advantage. Engineering is in the second place with 497 broadcasts, while the telecommunications category has 319 broadcasts. The ratio of the Computer Science category in all publications is 33%, the Engineering category's is 27%, and the telecommunications category's is 17%.
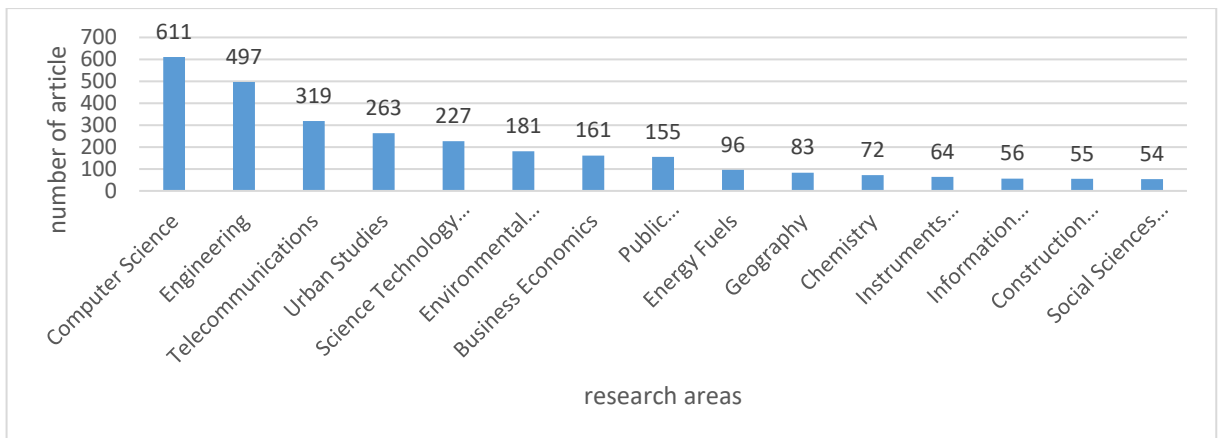

FIGURE 10 - MOST EFFECTIVE RESEARCH AREAS

The articles were published in 12 different languages. The difference between ratios are more obvious here with 1775 articles (97,5%) in English. English was followed by Spanish (9 articles), Italian (8), Portuguese (8), Hungarian (5), Russian (4), French (3), and Polish (3), respectively. The number of articles published in Croatian, Dutch, Korean, and Turkish is only one for each. Since English is accepted as an international language, it is the language in which most articles are produced.

The top ten publishers indexing the most articles on smart city are shown in Table 6. The share of Elsevier company among publishers is about 19%. Among a total of 208 publishers, the total weights of the first four journals (Elsevier, Springer, MDPI, and IEEE) are also quite high (58%).

TABLE 6 - MOST EFFECTIVE RESEARCH PUBLISHER
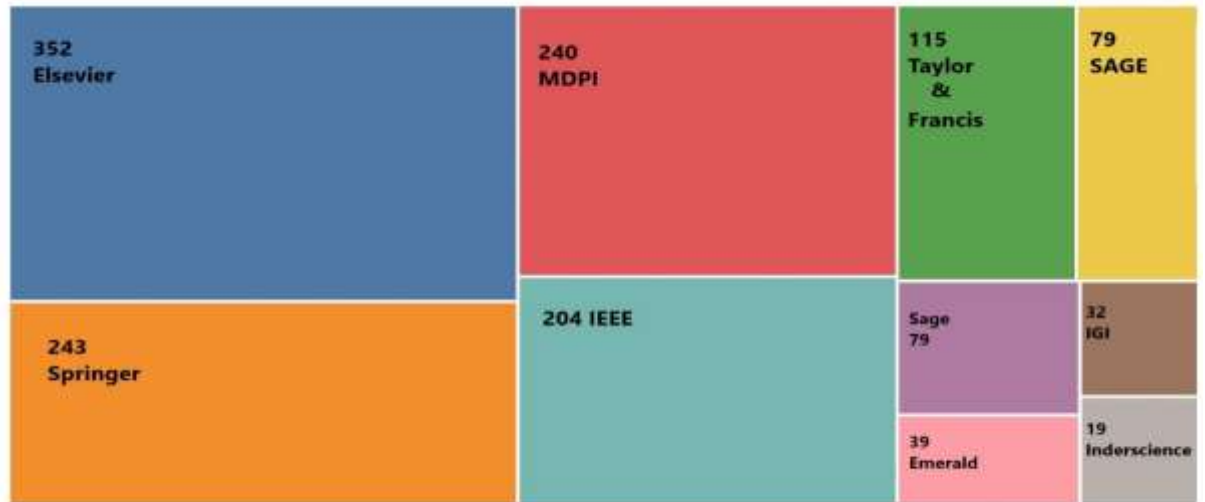
In order to frame the findings in the study, the most influential journals, affiliations, research areas, years, authors, countries, keywords, and languages in the selected categories are given in Table 7. Findings are as follows; the most influential journal is "Sustainability"; affiliation is "Melbourne University"; research area is "computer science"; publication year is "2021"; author is"Park JH"; country is "China"; keyword is "smart city"; and publisher is "Elsevier".

TABLE 7 - MOST EFFECTIVE JOURNALS, AFFILIATIONS, RESEARCH AREAS, YEARS, AUTHORS, COUNTRIES, KEYWORDS, AND PUBLISHERS

Rank	Journals	Publishers	Universities	Research Areas	Publication Years	Authors	Countries	Keywords
1	Sustainability	Elsevier	Melbourne	Computer Science	2021	Park JH.	China	Smart city
2	Journal of urban technology	Springer	Central South	Engineering	2020	Dameri RP.	USA	Cities
3	Technological forecasting and social	MDPI	College London	Telecommunications	2019	Kim J.	Italy	Smart cities
4	Cities	IEEE	Hunan	Urban Studies	2018	Munoz L.	India	Internet
5	Smart Cities	Taylor & Francis	Delft	Science Technology	2017	Wang T.	England	Internet of things
6	IEEE Access	SAGE	Chinese Academy of Sciences	Environmental Sciences Ecology	2016	Zhang Y.	Spain	Iot
7	Sustainable city and society	Wiley	Beihang	Business Economics	2015	Lv ZH.	South Korea	Things
8	Future generation computer	Emerald	Erasmus	Public Administration	2014	Mora L.	Australia	Model
9	Sensors	IGI	Guangzhou	Energy Fuels	2013	Sanchez L.	Canada	Management
10	Energy	Inderscience	King Saud	Geography	2012	Angelidou M.	Greece	Framework

4. CONCLUSIONS AND DISCUSSIONS

Considering how important the research on the smart city is for solving economic, social, political and spatial problems, increasing the quality of life of the citizens, providing effective and efficient service, and optimum use of resources, to form a comprehensive view and to draw a framework for the researches in this field is necessary. Therefore, the aim of the study is to provide information about the general trend of smart city article publications, to identify and visualize their dynamic aspects in order to help researchers make new studies on the subject.

The Web of Science Core Collection database was used, as it is the leading source for indexing articles and allows the collection of different types of data from a large number of journals. Version 1.6.17 of the VOSviewer software, a freely available tool for creating bibliometric maps, has been used. As a result of the study, some important points were obtained about the global smart city research trends and performances during the period from 1991 to 2021. Looking at the results as a whole;

- Studies in the smart city field have shown rapid development since 2016. This shows that smart city research is a more current discipline. The top three journals with the highest total link strength in this field are Sustainability, Journal of urban technology and Technological forecasting and social.

- Smart city, cities, smart cities, internet, internet of things are the most used keywords. The most recent keywords are; scheme, trust, sense, data models, place, sustainable development.

- Jong Hyuk Park (Seoul National University of Science & Technology), Renata Paola Dameri (University of Genoa), and JungHoon Kim (Korea Institute of Civil Engineering & Building Technology) are the most prolific scientists. The publication language preference of the authors was more than 95% English.

- Academics in China, America, and Italy are prolific when it comes to the authors' country or region. Melbourne University, Huaqiao University, and Huaqiao University are the most active institutions.

- When publishers are ordered by a number of publications, the most active publisher is Elsevier (352). Springer, MDPI, and IEEE companies have also published over 200 articles.

The study is based on Web of Science Core Collection data only. The bibliometric analysis method was applied by using the Web of Science Core Collection database. In addition, Proceedings papers, books, book reviews, book chapters, editorial materials, early access, news items and meeting abstracts are excluded. Therefore, a more comprehensive study can be done by including both academic databases such as Scopus and PubMed and all document types.

Finally, this article provides a holistic view of past, present and future research trends in the smart city topic. It will be a useful reference for those who will do research in this field.

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