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A BIBLIOMETRIC ANALYSIS OF SMART CITY FRAMEWORK RESEARCH

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ABSTRACT

Considering the importance of a framework to define and describe any city, this study aims to carry out a bibliometric analysis with the purpose of surveying the applicable state of the art involving the concept of smart city framework and its interrelationships. As a result, a total of 3,848 documents were found between 2015 and 2020, covering 9,625 authors, 1,563 journals, 6,972 institutions, and 126 countries. Through the analysis of bibliographic coupling, eight clusters were identified that are associated with the research fronts involving the theme of study, however the results show that the production specifically oriented on the understanding of the city (notably an ontological model of the city) and the interconnection with the aspects of technological development still need further development.

Keywords: Bibliometric Analysis. Framework. Smart Cities.

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INTRODUCTION

Cities are complex systems, and their complexity is constantly expanding. Therefore, any city model, especially a smart city, must respect the local urban dynamics and the society in which it is inserted. But the reality proves challenging. The search for the ideal city faces many challenges during its development and many urban governments are restricted to blueprints and spreadsheets as their only instruments to provide appropriate infrastructure and services for their residents (EDX, 2020).

On the other hand, the emergence of "smart" instruments, which take advantage of *big data* , and the growing ability of technology to simulate complex systems, are indicators of a new urban reality.

The very term "smart city" inspires us to think about the future. A smart city is said to be an innovative city that uses information and communication technologies and other means to improve the quality of life, the efficiency of urban operation, services, and competitiveness, while ensuring current needs and without compromising future generations with regard to economic, social, social, economic, economic, cultural, cultural environmental and cultural aspects of the city (ITU, 2014).

In this way, the smart city is strongly connected to the development of *Big Data* showing the crucial role of data, information and knowledge in future cities. With the use of information technology, the data collected by different types of sensors are stored, aggregated, and correlated, which results in statistics, trend analysis, and knowledge that will be used for smarter and more assertive decision-making (KITCHIN, 2013; SUN *et al.*, 2016).

In addition, the development of the city model is a precondition for the simulation of urban scenarios. To simulate any system, it is necessary to understand its mechanism. The goal of these models is to simplify the components, properties, functions, and structure of the city to the extent that projections for the future and scenarios become possible with acceptable effort. As an example, considering the territorial scale, simulation is used to represent the growth of city networks, the migration of people or the flows of material and information between continents (EDX, 2020).

However, the importance of a framework to define and describe any city, of any size, in a way that is timeless, culturally comprehensive, scalable and generic, in which it allows the sharing of solutions between cities (ISO, 2019).

In this way, the framework, in addition to presenting the components of the city, allows the organization and personalized exploration of urban data, identifies categories of

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users to share relevant information, and enables a heterogeneous and holistic view of urban indicators at different levels of aggregation, ranging from energy consumption to public safety of citizens.

Thus, through bibliometric analysis, the proposed approach aims to survey the applicable state of the art involving the concept of Smart City Framework and its interrelationships. To this end, the following specific objectives are: (1) presentation of cooperation relations in terms of countries, institutions and authors; (2) identification of the most influential journals, researchers and articles; (3) exposition of the lines of research involving the theme.

From this perspective, the present study is structured in 4 topics, in addition to bibliographic references. The first topic consists of the introductory part with presentation of the characterization of the problem and objectives.

The second topic deals with the method adopted in the research with the indication of the procedures performed. Then, in the third section, we sought to present the results of the bibliometric study organized by group of variables. Finally, in section 4, all the results obtained are systematized, indicating the potential and limitations of the study.

RESEARCH METHOD

The research adopts the bibliometric method, appropriating quantitative statistical approaches, which aim to evaluate and quantify the production and dissemination of scientific knowledge in various topics. According to Quevedo-Silva *Et. Al* (2016) This type of study contributes to the construction of a summarized and systematized view of the theme, which can help mainly young researchers or even experienced researchers who are faced with a new theme.

The variables investigated were divided into categories which are described and related quantitatively, including analysis of geographic distribution, analysis of journals, analysis of authors and co-authorships, analysis of citations and keywords. For this, the *VOSviewer software*[i] was adopted as a tool for bibliometric analysis of the variables.

In this sense, in order to achieve a representativeness that could reflect the complexity involving the concept of the Smart Cities Framework and its interrelationships, through a simplifying approach, care was taken to follow the methodological procedures and data treatment demonstrated below.

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METHODOLOGICAL PROCEDURES OF THE BIBLIOMETRIC STUDY AND DATA PROCESSING

In this topic, the techniques and operational procedures used based on the methodological strategy of the bibliometric study are presented, aiming to achieve the expected results. To do so, they can be divided into three steps and six steps as follows:

1st stage: bibliographic research

(1) Choice of Database

The database is used as a source of research *Scopus* belonging to Editora *Elsevier*, which was chosen because it is a referential-based platform with the largest database of abstracts and citations of the literature with peer review, covering the areas of Biological Sciences, Health Sciences, Physical Sciences and Social Sciences with a period of access from 1823 to the present (ELSEVIER, 2020).

(2) Search *String* Formulation

The *search string* consists of an expression of characters used in the definition of key terms to search for publications in bibliographic databases, determining which information will be extracted in order to provide a relevant and coherent result with the research object. For this, in addition to the determination of key terms, it is necessary to use operators - Boolean and proximity, to combine different search queries or to locate nearby words within a specified distance between them, respectively.

To search for a specific phrase, you can use the terms enclosed in double quotation marks ("") or use brackets {} to get an exact match. In addition, the asterisk wildcard (*) and question mark (?) are used as proximity operators. In this way, the database interprets the combination of key terms and operators in order to provide a set of documents that best represents the scope of the search.

For this research, the following *strings* were formulated:

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Table 1 – *Strings* search engines used in the database *Scopus*. Source: Prepared by the authors (2020).

String	Key Terms	Operators	Formula	Total Documents Found
S01	Ontology, Complex System, Smart City e SmartCity	OR/AND/ ""/*/()	(("Ontology" OR "Complex System*") AND ("Smart Cit*" OR smartcit*))	280
S02	Ontology e Urban Planning	AND/""/()	("Ontology" AND "Urban Planning")	27
S03	Simulation, Smart Planning e SmartCity	OR/AND/ ""/*/()	(("Simulation" AND ("Smart Cit*" OR "Urban Plan*" OR "SmartCit*"))	1.784
S04	Infrastructure, Smart City	AND/""/*/()	("Infrastructure" AND "Smart Cit*")	1.984

2nd stage: diagnosis

(3) Search in Scientific Literature Banks

By running the four *search strings* in the Scopus *database*, a total of 4,058 documents published with a search period between 2015 and 2020 are found in April 2020. All authors, research areas, publication phase, languages, locality, and type of source were maintained, that is, there were no restrictions in this regard. However, a restriction was applied to the search filter to find results only in summaries.

(4) Initial Database Formation

The results of the *search strings* were exported containing basic information, such as citation information, bibliography and the abstract, in a CSV file, where it was saved in a temporary folder. Blank lines and those that had no authors were removed.

(5) Document Evaluation

In this process, we sought to analyze the results obtained through the reading of titles, abstracts and keywords. The aim was to verify the sufficiency, comprehensiveness and adequacy of the results obtained in relation to the research object for the consolidation of the quality of the documents. For this, *the Mendeley and Microsoft Excel* software were used as support tools.

In addition, in this process, documents that did not have information for analysis were disregarded, such as no connection to any *cluster*, thus resulting in 3,848 documents.

It is noteworthy that several types of documents were included in this research. Conference papers reflect the type with the highest number of publications, 1,910 documents representing about 49% of the total publications, followed by the number of articles (1,645, about 43%). On the other hand, the number of book chapters (184, about

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5%), abstract (82, about 2%), book (18, about 0.5%), editorial (5, about 0.1%) and note (4, about 0.10%) present a considerably lower number of publications.

3rd stage: review

(6) Bibliometric Analysis

The VOSViewer software *was used* for bibliometric analysis with the creation of groups of variables, resulting in the identification of a set of publications that are more relevant to the theme of study, grouped by *clusters. Based on this, the respective publications received a file with the analysis of the full text with the discussion of the results. The result of this activity can be found in the next topic of this report.*

RESULTS AND DISCUSSIONS

In this topic, the results of the bibliometric study are presented with the purpose of evaluating the production and dissemination of scientific knowledge with the presentation of information on publications related to the theme under study in a 5-year panorama.

GEOGRAPHICAL DISTRIBUTION ANALYSIS

Based on the authors' affiliations to analyze the geographical distribution of the publications, it was found that the documents originate from 126 countries. Of these, the

Table *2* identifies the ten most productive countries identified by the total number of documents produced, number of citations, and total link strength. China represents the most productive country with the highest number of documents (15.54%), followed by the United States of America (14.57), India (9.40%), Italy (8.49%), the United Kingdom (6.28%), Germany (4.85%), Spain (4.65%), France (3.69%), Canada (3.66%) and Australia (3.22%). Together, they represent approximately 74% of the total publications between 2015 and 2020. Meanwhile, the United States of America has the highest number of citations (5,083) with *CPP* of 9.06, as well as the biggest influence with full strength of the 404 link.

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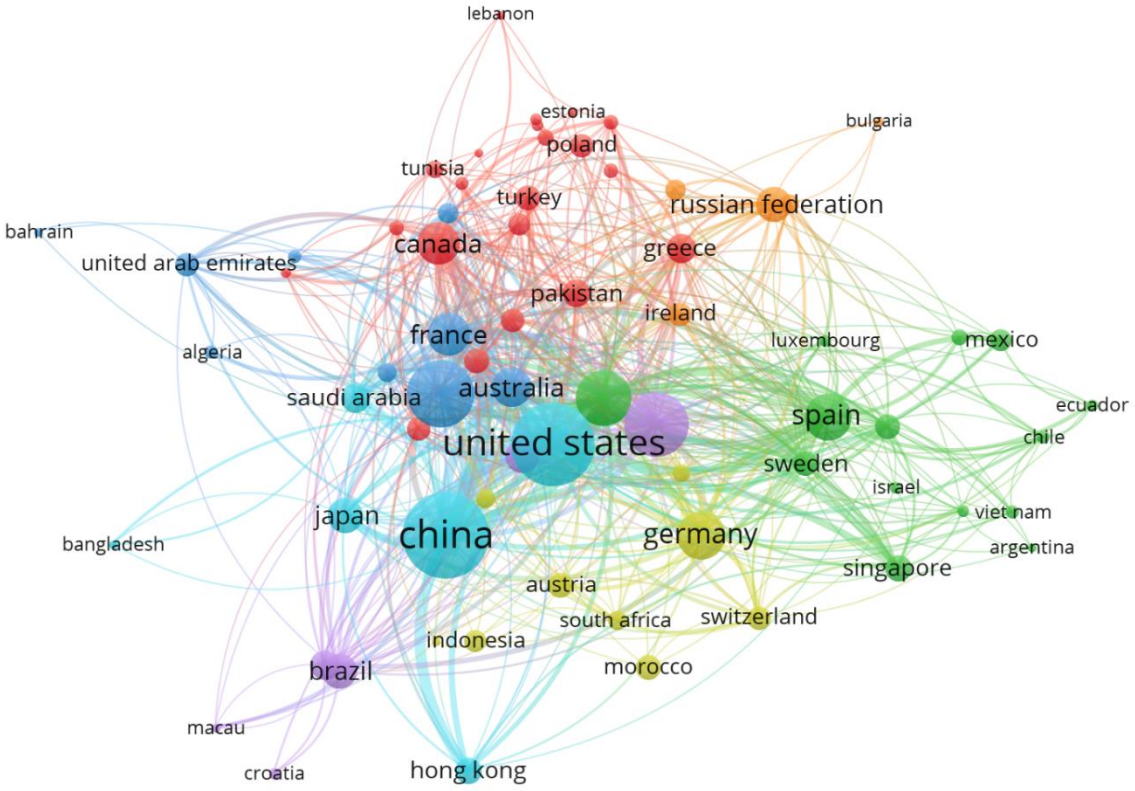
Table 2 – Countries with the most productions during 2015 - 2020. Source: Prepared by the authors (2020).

Country	Total Documents	Total em (%)	Total Citations	Document Summons (*CPP*)	Total Link Strength
China	598	15,54	4.906	8,20	357
United States of America	561	14,57	5.083	9,06	404
India	362	9,40	1.416	3,91	102
Italy	327	8,49	2.071	6,33	188
United Kingdom	242	6,28	2.331	9,63	249
Germany	187	4,85	1.053	5,63	130
Spain	179	4,65	1.737	9,70	149
France	142	3,69	819	5,76	117
Canada	141	3,66	1.359	9,64	146
Australia	124	3,22	1.180	9,52	110

In addition, Figure 1 detects 7 *clusters*, identified by color, formed by the 70 countries that meet the minimum of five documents. Clusters represent the co-authorship cooperation relationship and their frequency is represented by the thickness of the line connecting the countries, while their importance is characterized by the size of the circle of the respective country.

Figure 1 – Network of co-authored cooperations between countries during 2015-2020. Source: Prepared by the authors (2020).



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Thus, it is observed that China, the United States of America, Italy and India have the largest cooperation networks with other countries. It is also noted that China collaborates more intensively with Hong Kong, Japan, the United States, and India, while the United States of America interacts more with the United Kingdom, Australia, China, India, and Spain.

JOURNAL ANALYSIS

The analysis showed the existence of 1,563 journals publishing on the topic of study between 2015 and 2020. The *IEEE Access* journal represents the source with the largest number of publications in the period with 96 documents (about 2.5%), followed by the *Lecture Notes in Computer Science* book series (78, about 2%) and *the ACM International Conference Proceeding Series* (77, about 2%). By contrast, the most influential journal with the highest number of citations is *IEEE Internet Of Things* with a total of 1,342 citations, followed by *IEEE Access* with 1,203 and Future *Generation Computer Systems* with 695 citations. This may mean that despite the lower number of documents in the second group, their quality has made these journals references in the subject studied. In addition, the main journals are in computer science, dealing with topics related to technologies, artificial intelligence, and product development. The network of journals can be seen in Table 3.

Table 3 – Journals with the most publications during 2015 - 2020. Source: Prepared by the authors (2020).

No.	Title of the Journal	Total Documents	Percentage (%)	Total Citations	Category
1	IEEE Access	96	2,49%	1.203	Multidisciplinary
2	Lecture Notes in Computer Science	78	2,02%	224	Computer Science
3	ACM International Conference Proceeding Series	77	2,00%	100	Computer Science
4	Sensors Switzerland	66	1,71%	452	Engineering
5	Advances in Intelligent Systems and Computing	52	1,35%	62	Computer Science
6	Future Generation Computer Systems	44	1,14%	695	Computer Science
7	Sustainability Switzerland	43	1,11%	212	Computer Science and Engineering
8	Sustainable Cities And Society	39	1,01%	460	Computer Science and Engineering
9	Communications in Computer and Information Science	38	0,98%	38	Computer Science
10	IEEE Internet Of Things	37	0,96%	1.342	Computer Science

ANALYSIS OF AUTHORS AND CO-AUTHORSHIP

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A total of 9,625 authors were identified producing studies related to search *strings* between 2015 and 2020. Information was collected regarding the total number of documents and the total number of citations, relating to the authors' institution and country of origin. Liu Y., from Wuhan University (China), is the author who contributed the most with 36 publications, followed by Zhang Y. from the Beijing University of Technology (China) with 31 publications and Li X. from the Normal University of East China (China) with 30 publications. It is noteworthy that among the ten most active authors, eight are from institutions located in China, evidencing the mastery of the theme of study.

In addition, regarding the total number of citations, Liu X. of Sun Yat-sen University (China) has the highest number with 354 citations, followed by Liu Y. (Wuhan University, China) with 334 citations and Wu J. (Temple University, United States) with 280 citations, as shown in the table below:

Table 4 – Authors with the most publications during 2015 - 2020. Source: Prepared by the authors (2020).

No.	Author	Total Documents	Total Citations	Institution/Country
1	Liu Y.	36	334	Universidade de Wuhan, China
2	Zhang Y.	31	263	Beijing University of Technology, China
3	Li X.	30	218	East China Normal University, China
4	Liu X.	28	354	Universidade Sun Yat-Sen, China
5	Wu J.	26	280	Temple University, United States
6	Wang X.	22	86	Lewis & Clark College, United States
7	Li Z.	19	124	Zhejiang University, China
8	Li J.	18	77	Universidade de Shanghai Jiao Tong, China
9	Li Y	17	207	Universidade de Wuhan, China
10	Wang S.	17	63	Zhejiang University of Science and Technology, China

From another perspective, the co-authorship network was analyzed in order to identify the cooperative associations among the authors. As illustrated in figure 2, Liu Y. (Link 38), Zhang Y. (Link 35), and Liu X (Link 32) are the authors who have the majority of the papers in cooperation with other authors.

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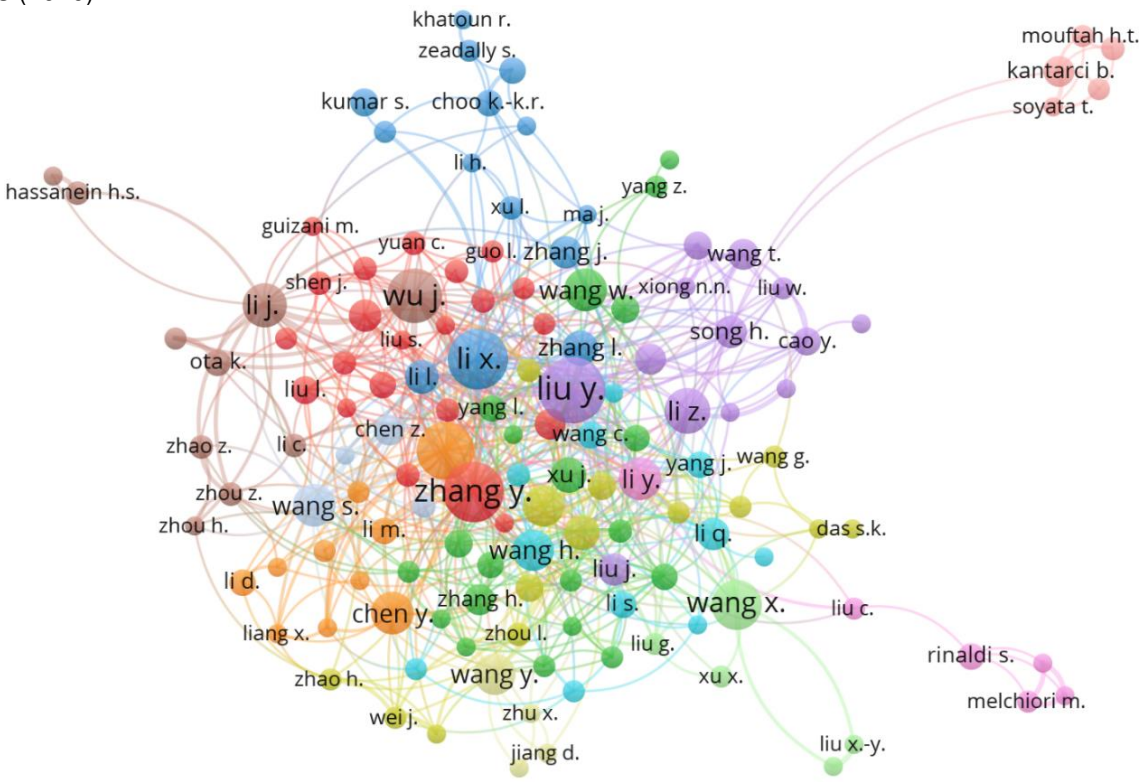
Figure 2 – Network of co-authored cooperations between authors during 2015-2020. Source: Prepared by the authors (2020).



KEYWORD ANALYSIS

Keywords summarize the main themes of a text serving as a reference for searches, while the analysis of keyword co-occurrence evidences keywords cited together in which their frequency maps the main lines of research. In this research, a universe of 19,775 keywords was identified, in which the minimum occurrence of terms was defined as twenty in the *VOSviewer software*, thus generating only 316 keywords.

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Figure 3 – Co-occurrence of Keywords. Source: Prepared by the authors (2020).

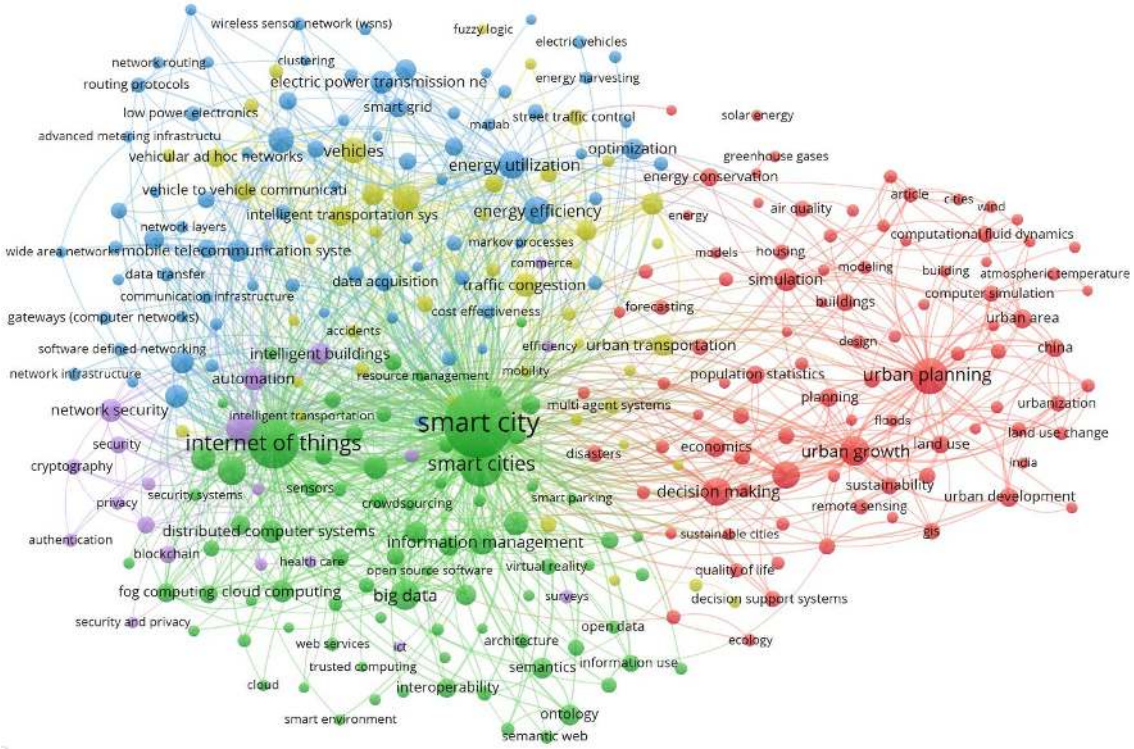

Figure 3 represents the network of co-occurrence of keywords, in which it is possible to verify that the words "*Smart City*" and "*Internet of Things*" are central points of the searches linked to the five research *clusters*. It is noteworthy, however, the existence of repeated keywords, differentiated in writing by grammatical inflections for number indicative (singular and plural), in which the *VOSviewer software* did not join the terms.

Despite this, the analysis was satisfactory with the identification of five distinct *clusters* of research fronts, which are presented in the table below:

Table 5 – Clusters for co-occurrence of keywords. Source: Prepared by the authors (2020).

Cluster	Total Items	Item with the Highest Occurrence	Total Occurrences	Total Link Strength
1 - Red	93	Urban Planning	371	1.908
2 - Green	80	Smart City	1.739	9.168
3 - Blue	78	Internet of Things (iot)	849	5.555
4 - Yellow	45	Intelligent Systems	194	1.499
5 - Roxo	20	Automation	142	1.077

ANALYSIS OF BIBLIOGRAPHIC CITATIONS

The analysis of bibliographic citations allows us to identify which publications are frequently cited and, thus, which are more relevant in the scientific environment. Table 5 7 shows this panorama with the 20 most frequently cited publications with the identification of

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the author along with the total number of citations and journal in which it was published. It was found that the most cited article is the one entitled "*A Survey on Internet of Things: Architecture, Enabling Technologies, Security and Privacy, and Applications*" authored by Lin *et al.* (2017) published in the *IEEE Internet of Things Journal* and cited 615 times. In second place is the article by Diaz *et al.* (2016) called "*State-of-the-art, challenges, and open issues in the integration of Internet of things and cloud computing*" published in the *Journal of Network and Computer Applications* with a total of 283 citations and, thirdly, the article called "*Urban planning and building smart cities based on the Internet of Things using Big Data analytics*" published in *Rathore's Computer Networks magazineEt. Al.* (2016) with 270 citations. Considering the 20 publications, the IEEE organization is best represented with nine relevant articles, followed by the ACM association.

Table 6 – Publications with the most citations during 2015 - 2020. Source: Prepared by the authors (2020).

No.	Author	Total Citations	Title	Newspaper
1	Lin J. *et. al.* (2017)	615	A Survey on Internet of Things: Architecture, Enabling Technologies, Security and Privacy, and Applications	IEEE Internet of Things Journal
2	Diaz M. *et. al.* (2016)	283	State-of-the-art, challenges, and open issues in the integration of Internet of things and cloud computing	Journal of Network and Computer Applications
3	Rathore M. M. *et. al.* (2016)	270	Urban planning and building smart cities based on the Internet of Things using Big Data analytics	Computer Networks
4	Yu W. (2017)	209	A Survey on the Edge Computing for the Internet of Things	IEEE Access
5	Bor M. *et. al.* (2016)	196	Do LoRa Low-Power Wide-Area Networks Scale?	ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems
6	Minoli D. (2017)	157	IoT Considerations, Requirements, and Architectures for Smart Buildings—Energy Optimization and Next-Generation Building Management Systems	IEEE Internet of Things Journal
7	Calvillo C. F. (2016)	153	Energy management and planning in smart cities	Renewable and Sustainable Energy Reviews
8	Zhang K. (2017)	148	Security and Privacy in Smart City Applications: Challenges and Solutions	IEEE Communications Magazine
9	Ejaz W. (2017)	140	Efficient Energy Management for the Internet of Things in Smart Cities	IEE Communications Magazine

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10	Sharma P. K. *et. al.* (2017)	131	Block-VN: A Distributed Blockchain Based Vehicular Network Architecture in Smart City	Journal of Information Processing Systems
11	Wang Y. *et. al.* (2016)	128	Comparing the effects of urban heat island mitigation strategies for Toronto, Canadá	Energy and Buildings
12	Mehmood Y. *et. al* (2017)	124	Internet-of-Things-Based Smart Cities: Recent Advances and Challenges	IEEE Communications Magazine
13	Talari S. (2017)	115	A Review of Smart Cities Based on the Internet of Things Concept	Energies
14	Tang B. *et. al* (2017)	112	Incorporating Intelligence in Fog Computing for Big Data Analysis in Smart Cities	IEEE Transactions on Industrial Informatics
15	Perera C. *et. al.* (2017)	112	Fog Computing for Sustainable Smart Cities: A Survey	ACM Computing Surveys
16	Gil-Garcia Jr. (2016)	102	Conceptualizing smartness in government: An integrative and multi-dimensional view	Government Information Quarterly
17	Tong Z. *et. al.* (2016)	99	Roadside vegetation barrier designs to mitigate near-road air pollution impacts	Science of The Total Environment
18	Khatoun R. *et. al.* (2016)	96	Smart cities: concepts, architectures, research opportunities	ACM Computing Surveys
19	El-Sayed H. *et. al.* (2017)	94	Edge of Things: The Big Picture on the Integration of Edge, IoT and the Cloud in a Distributed Computing Environment	IEEE Access
20	He Y. *et. al.* (2017)	91	Software-Defined Networks with Mobile Edge Computing and Caching for Smart Cities: A Big Data Deep Reinforcement Learning Approach	IEEE Communications Magazine

In addition, the bibliographic coupling analysis was carried out (Figure 5), which consists of the measure of association between cited publications, bringing a perspective of the research fronts. The coupling force of published documents is determined by the amount of overlap between their bibliographies. Therefore, the results of the bibliographic coupling are independent of the point in time at which the analysis is conducted and are based on the premise that articles that cite the same works have similarity (VOGEL; GÜTTEL, 2013).

The publications resulting from this process were grouped into 8 *clusters* - identified by color, considering only documents with a minimum of 50 citations or more. Table 7 shows the respective clusters with the corresponding publications, identified by the authors in a reduced form.

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Table 7 - Publications organized in Smart Cities Framework Clusters during 2015-2020. Source: Prepared by the authors (2020).

Cluster 1 (9 itens)	Cluster 2 (8 itens)	Cluster 3 (6 itens)	Cluster 4 (6 itens)
Abdel-Basset M. (2018)	Cicirelli F. (2017)	Ejaz W. (2017)	Brundu F. G. (2017)
Bibri S. E. (2018)	Latre S. (2016)	El-Sayed H. (2017)	Calvillo C. F. (2016)
Gil-Garcia Jr. (2016)	Mehmood Y. (2017)	The Y. (2017)	Diaz M. (2016)
Khatoun R. (2016)	Montori F. (2018)	Minoli D. (2017)	Lu W. (2018)
Lioret J. (2016)	Naranjo P. G. V. (2019)	Yu W. (2017)	Tang B. (2017)
VisVizi A. (2018)	Ning Z. (2017)	Zhu C. (2017)	Vijayakumar P. (2018)
Yang C. (2017)	Pouryazdan M. (2016)		
Zhang K. (2017)	Rathore M. M. (2016)		
Zhuhadar L. (2017)			
Cluster 5 (5 itens)	**Cluster 6 (4 itens)**	**Cluster 7 (4 itens)**	**Cluster 8 (2 itens)**
Guan Z. (2018)	Chaudhari K. (2018)	Bagula A. (2015)	Sharma P. K. (2017)
Lin J. (2017)	Javaid N. (2017)	Bawany N. Z. (2017)	Sharma P. K. (2018)
Lom M. (2016)	Khanna A. (2016)	Days (2018)	
Perera C. (2017)	Talari S. (2017)	Petrolo R. (2017)	
Wen Z. (2017)			

CONCLUSION

In this study, a bibliometric profile on the concept of the Smart City Framework and its interrelations was conducted by VOSviewer with the objective of surveying the applicable state of the art based on 3,848 documents from the *Scopus database*.

It was found that the documents originate from 126 countries, in which China represents the most productive country with the largest number of documents, followed by the United States of America, India, Italy and the United Kingdom. Thus, these countries have the largest cooperation networks with other countries. Likewise, considering the network of collaboration between institutions, institutions in China are producers of a significant number of publications, in which they represent six of the eight most influential in this research.

A total of 9,625 authors were identified producing studies related to search strings, with Liu Y. of Wuhan University (China) being the author who contributed the most, followed by Zhang Y. of Beijing University of Technology (China) and Li X. of East China Normal University (China). These three authors are also the authors who have the most documents in cooperation with other authors.

There are 1,563 journals publishing on the topic of study, with three journals being the most active, the *IEEE Access journal,* the Lecture Notes in Computer Science *book series,* and the *ACM International Conference Proceeding Series*. By contrast, the most influential journals with the highest number of citations are *IEEE Internet Of Things*, *IEEE,* and *Future Generation Computer Systems*. This may mean that despite the lower number

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of documents in the second group, their quality has made these journals references in the subject studied.

At another point, through the analysis of bibliographic coupling, eight *clusters were identified* that are associated with the research fronts involving the theme of study. The results show a strong pace of increase in international production related to different aspects of the theme, notably the technology-oriented part, sensors, IoT. On the other hand, production specifically oriented towards the understanding of the city (notably an ontological model of the city) and the interconnection with aspects of technological development still need further development.

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[i] The *VOSviewer software* allows you to create maps and various analyses of bibliometric networks from information extracted from databases such as *Scopus* and *Web of Science*.