Revista Nacional de
Gerenciamento de Cidades
ISSN eletrônico 2318-8472, volume 09, número 74, 2021

Sustainable and Smart Cities: nodes of confluence and research tendencies

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Revista Nacional de
Gerenciamento de Cidades
ISSN eletrônico 2318-8472, volume 09, número 74, 2021

ABSTRACT

With the aim of identifying approximation points and gaps to be filled in efforts to relate research on smart and sustainable cities, this study made use of bibliometrics and scientometrics to materialize information retrieved in searches conducted in academic databases. Starting from the literature in both fields, it was sought to visualize from the quantitative data, the recent state of researches that have this objective, where it was analyzed that: (i) research that relates these fields is still incipient, and is on the rise; and (ii) there is still a technocratic prevalence and a detachment regarding theoretical advances. Both the quantitative results and the literature support these assertions, and in conjunction with the keyword clouds, one can better visualize viable opportunities on different research fronts.

KEYWORDS: Bibliometrics. Scientometrics. Smart cities. Sustainable cities.

1. INTRODUCTION

In essence, the concept of smart cities is a reflection of the complexity and dynamism of urban systems, is a collection of different actors and forces that seek to articulate interpretations against different priorities and goals, as well as being representative of the heterogeneity among cities in terms of scale, urban design, populations, and function. Giffinger *et al.* (2007) suggest six characteristics of a smart city, namely: smart economy; smart people; smart governance; smart environment; smart living; and smart mobility. Smart environment can be understood by: (i) attractive natural conditions; (ii) pollution levels; (iii) environmental protection; and (iv) sustainable resource management. With this as a background, some questions can be raised: what is smart environment? How close is this characteristic and the others to the notion of sustainability and sustainable cities? Is there a concern in the literature to bring sustainability and smartness closer together?

Considerations by Ferreira (2019), Godspeed (2015), Hollands (2015), Luque-Ayala and Marvin (2015), and Lyons (2016), point to a growing concern that smart cities are driven by corporate power and commercial interests at the expense of the disregard for the consequences of social and urban development, issues that are crucial to the sustainability of these "smartified" urban realities. The fear present in the literature has been confirmed by evaluations of smart experiences such as those of Anthopoulos (2017), Grossi and Pianezzi (2017) and Wiig (2015a, 2015b), in which definitions and conceptions of what a smart city is contribute to the perception of it as a utopia, a horizon to be reached, while at the same time they enable the application of a neoliberal agenda in a way that distorts the very essence of what a smart city is. Citizens are transformed into consumers and the city into a product (FERREIRA, 2019; FERREIRA *et al.* 2021).

In this context, making use of bibliometric and scientometric analyzes, this article seeks to draw the current state of academic research that seeks to realize this necessary approximation between sustainability and smartness. This approximation is essential if there is any hope of avoiding an unequal and ecologically predatory socioeconomic development. However, although important, this dialogue does not remedy the concerns of the literature, much less remove the possibility of implementing neoliberal policies, for smart and sustainable cities (and several other qualitative ones, *e.g.*, humane, resilient, disruptive, etc.) are also likely to become hegemonic instruments of a neoliberal urban metabolism. Thus, visualizing and

understanding the current trends and gaps in research related to these issues is indispensable and of utmost importance.

It is necessary to advocate a metabolic rift of the already established urban systems and infrastructures and public policies, as well as to resist against agendas and horizons that advocate the deepening and broadening of the unsustainable neoliberal production of urban space (CLARK; FOSTER, 2009; CROSBY, 2004; FOSTER; CLARK, 2004; FRAME, 2016; QINGZHI, 2017; TOMLINSON, 1997; SAITO, 2021).

2. OBJECTIVES

The aim of this paper is to identify points of confluence and possible gaps to be filled in efforts to bring together smart and sustainable cities research.

3. METHODOLOGY

The methodology of this work is composed of the following stages: (i) bibliographic data collection; (ii) bibliometric analysis of the results; and (iii) identification of points of confluence and research trends.

Bibliometrics and scientometrics allow us to visualize quantitatively the current state of research, as well as to materialize the data in keyword maps and temporal correlation of research and investigations. The bibliographic survey, on the other hand, allows a qualitative analysis of the data and results obtained, as well as guides the initial searches (FERREIRA *et al.*, 2017; GÓMEZ, *et al.*, 2016; SOARES *et al.*, 2016).

The searches were conducted on August 05, 2021 in the Scopus® database, limiting the results to articles in English and published in journals. The sentences used were:

1) *TITLE-ABS-KEY (“smart city" OR "smart cities" AND environment) AND (LIMIT-TO (LANGUAGE, "English”)) AND (LIMIT-TO (SRCTYPE, "j”)) AND (EXCLUDE (PUBYEAR, 2022) OR EXCLUDE (PUBYEAR, 2021));*
2) *TITLE-ABS-KEY (“sustainable cit*” AND “smart cit*”) AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (SRCTYPE, "j")) AND (EXCLUDE (PUBYEAR, 2022) OR EXCLUDE (PUBYEAR, 2021));*
3) *TITLE-ABS-KEY (“sustainable cit*" AND "smart cit*" AND environment) AND (LIMIT-TO (LANGUAGE, "English”)) AND (LIMIT-TO (SRCTYPE, "j")) AND (EXCLUDE (PUBYEAR, 2022) OR EXCLUDE (PUBYEAR, 2021)).*

The choice of the term "environment" in sentences 1 and 3 was made based on Ferreira (2019) and the six characteristics established by Giffinger *et al.* (2007) that define a smart city. Like Ferreira (2019) the qualitative term "Smart" was omitted as it is redundant. This article, following Barrionuevo *et al.* (2012), Lombardi *et al.* (2012), Lyons (2016), Tahir and Malek (2016), and Thuzar (2011), indicate that the point of approach to sustainability is primarily through this characteristic, although sustainability must permeate all the others. The first sentence is intended to visualize smart city research that somehow involves the environment.

ISSN eletrônico 2318-8472, volume 09, número 74, 2021

The second, the researches that relate the terms sustainable cities and smart cities. Finally, the third sentence aims to visualize the intersection of the previous ones.

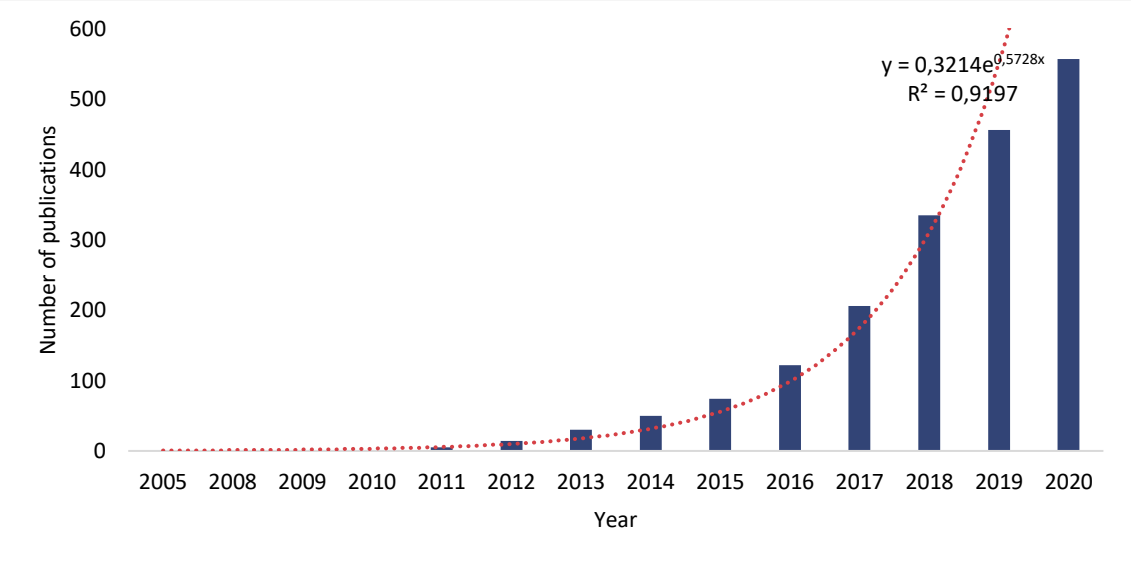
4. RESULTS

The search with the terms "smart city" or "smart cities" and environment returned 1853 publications; the search with the terms "sustainable cit*" and "smart cit*" returned 292 publications; finally, the third search returned only 73 publications. Next, the results are presented in the following structure: (i) historical evolution; (ii) publications by country; (iii) keyword map.

4.1 Historical Evolution

As seen in Figure 1, the publications returned by the first search sentence gain traction in the year 2012, with 14 publications. Similar to the studies of Machado and Leta (2016) and Ferreira *et al.* (2017), a non-linear regression model represented by the dotted curve was applied, which obtained a coefficient of determination R^2 = 0.9197, showing that scientific production will continue to rise.

Figure 1 - Historical evolution of publications with the terms "smart city" or "smart cities" and environment, and trend curve.



Source: Created by the authors, 2021.

The result that can be observed in Figure 2 represents the publications referring to the second sentence of the searches and demonstrates a distinct reality from the previous one. Among the 292 publications returned, the years 2017, 2018, and 2019 show a significant increase, however, in 2020, the number of publications shows a stagnation, putting in doubt a possibility of an increase in 2021 and subsequent years. Figure 3, on the other hand, shows a significant surpassing of the expectation of publications in the year 2020, which may represent an increase in the interest of research relating these terms.

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Gerenciamento de Cidades
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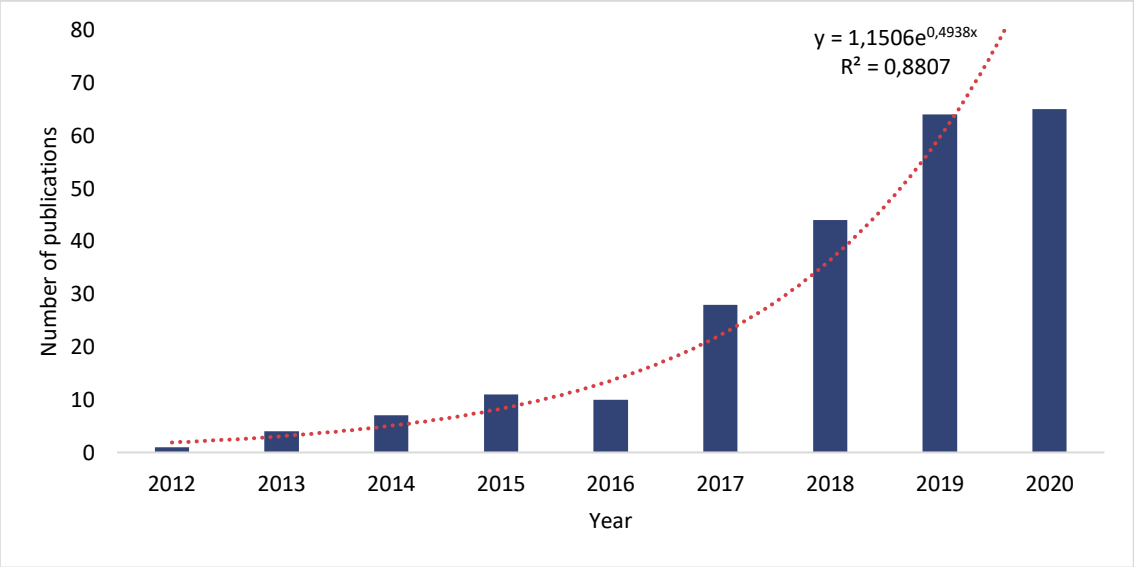
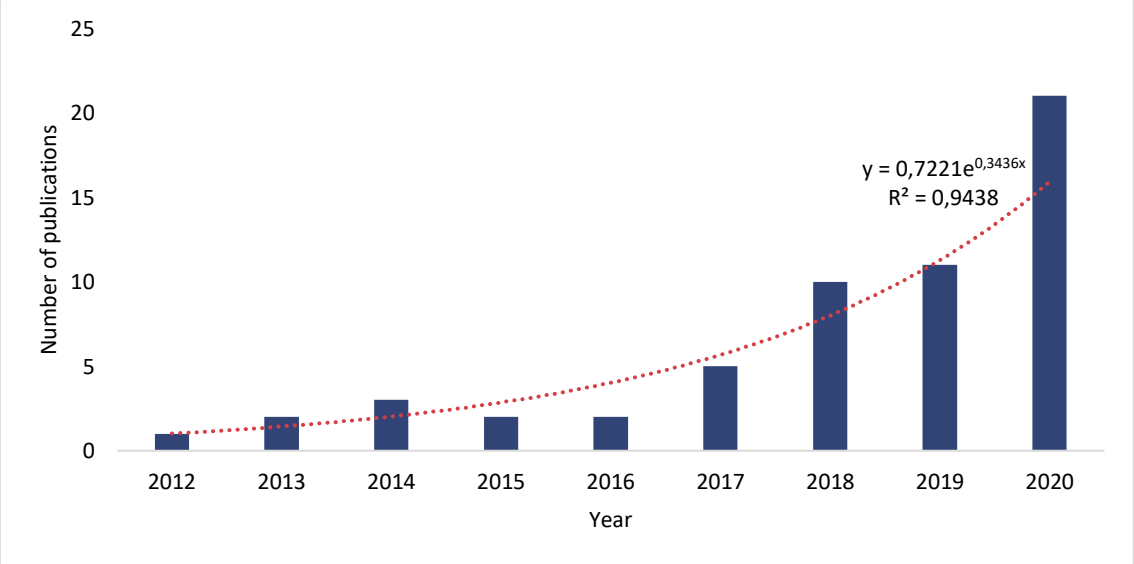
Figure 2 - Historical evolution of publications with the terms "sustainable cit*" and "smart cit*" and trend curve.



Source: Created by the authors, 2021.

Figure 3 - Historical evolution of publications with the terms "sustainable cit*" and "smart cit*" and environment and trend curve.



Source: Created by the authors, 2021.

The behavior of the historical series shows a peculiarity, although there is an increase of publications in Figure 1, which represents a broader search on smart cities, Figure 2 shows a stagnation of researches that relate smart cities and sustainable cities, but Figure 3 shows an increase for more specific researches related to "sustainable cit*" and "smart cit*" and environment. This peculiarity may occur because, as Ferreira (2019) shows, there is an overlap of terms regarding environment, since in the literature this term is used both to refer to virtual environments and to the environment. Therefore, based on these results one can deduce a behavior where, although there is an increase in the term's use as environment, and consequent interest for this aspect in smart cities, there is still a stagnation in publications that relate

ISSN eletrônico 2318-8472, volume 09, número 74, 2021

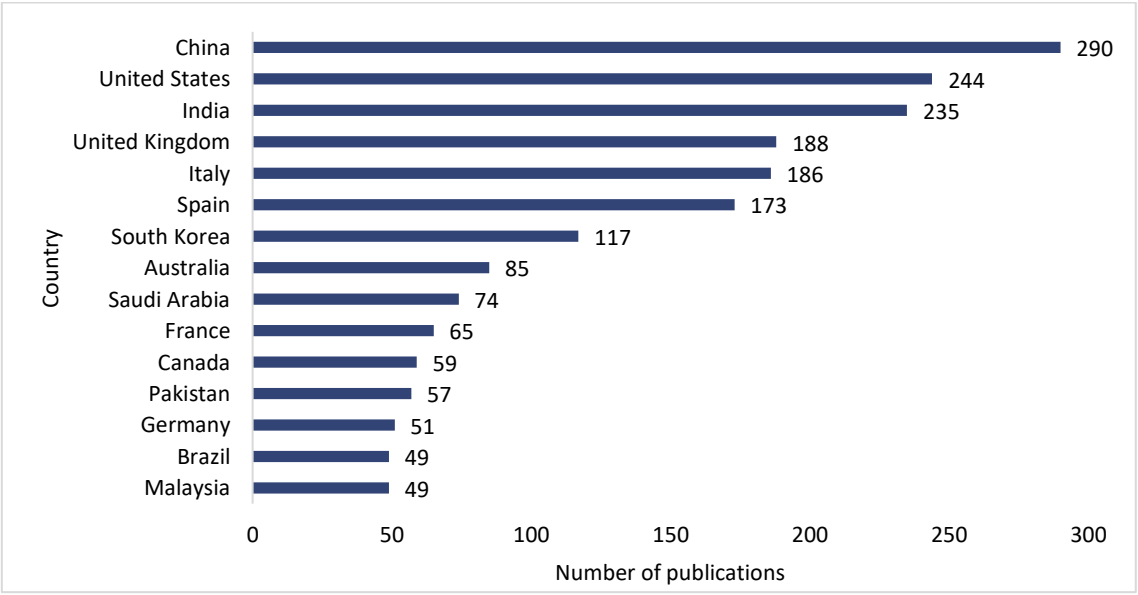
sustainable and smart. What this may suggest is, as advocated by Lyons (2016), the understanding in smart city research that for a city to be smart it must necessarily be sustainable, thus removing the need to use both qualifiers.

2.2 Geographical division of the publications

Next, we present the data regarding the geographical origins of the publications. While China comes first in the number of publications found by the use of the first sentence, as seen in Figure 4, it falls to eighth and sixth place, respectively, in the results of searches for the second and third sentences. Similar behavior can be observed with the United States and South Korea which show significant drops in the sentences incorporating the term "sustainable cit*". The UK, on the other hand, takes the top position in both Figures 5 and 6. Similarly, Spain, Italy, the Netherlands and Norway perform better. Brazil has its best performance in research that relates to smart and sustainable cities by obtaining the ninth position, as presented in Figure 5. However, it occupies the fourteenth position in research on the environment in smart cities and presents the return of only one article in the third search sentence, thus leaving it out of the countries with the highest number of publications.

The differences in country performance may indicate the prevalence of one research focus over the other. Countries that did better in the sentence that excludes the term "sustainable citi*" may have research that focuses not only on smart cities as a whole but also on the technical and technological aspects, with a low influence of sustainability concerns. This assumption can be argued in the specific case of the United States, where techno-political agendas and corporate interests have promoted more technical research, with little or no room for consideration of socioeconomic and political consequences (FERREIRA, 2019; WIIG, 2015a, 2015b).

Figure 4 - Publications per country indexed in the Scopus database. Search keywords: "smart city" or "smart cities" and environment.



Source: Created by the authors, 2021.

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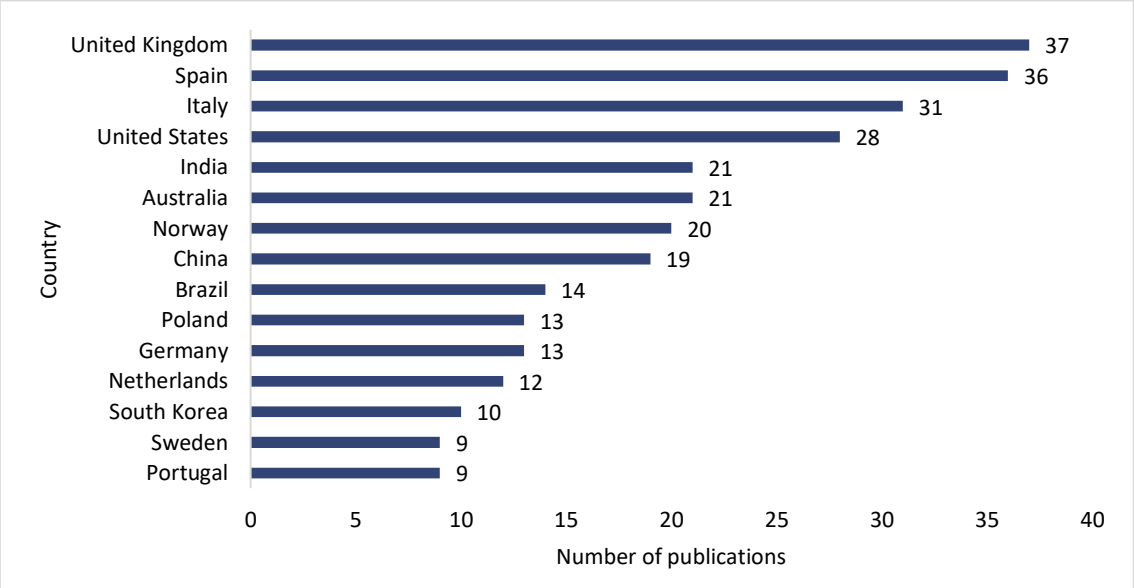
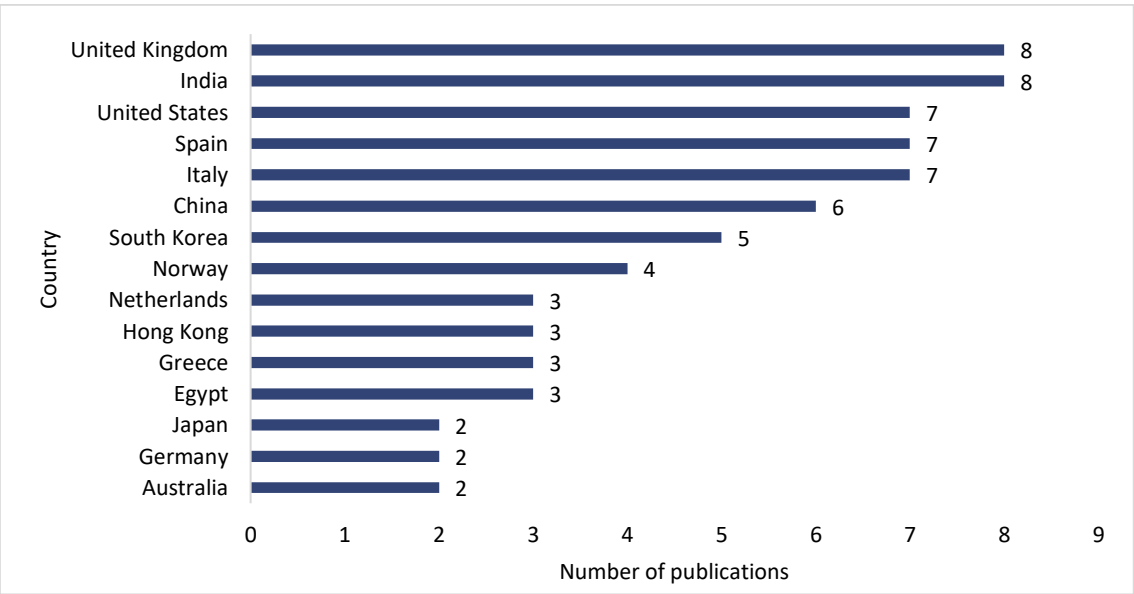
Gerenciamento de Cidades
ISSN eletrônico 2318-8472, volume 09, número 74, 2021

Figure 5 - Publications per country indexed in the Scopus database. Search keywords: "sustainable cit*" and "smart cit*"



Source: Created by the authors, 2021.

Figure 6 - Publications per country indexed in the Scopus database. Search keywords: "sustainable cit*" and "smart cit*" and environment.



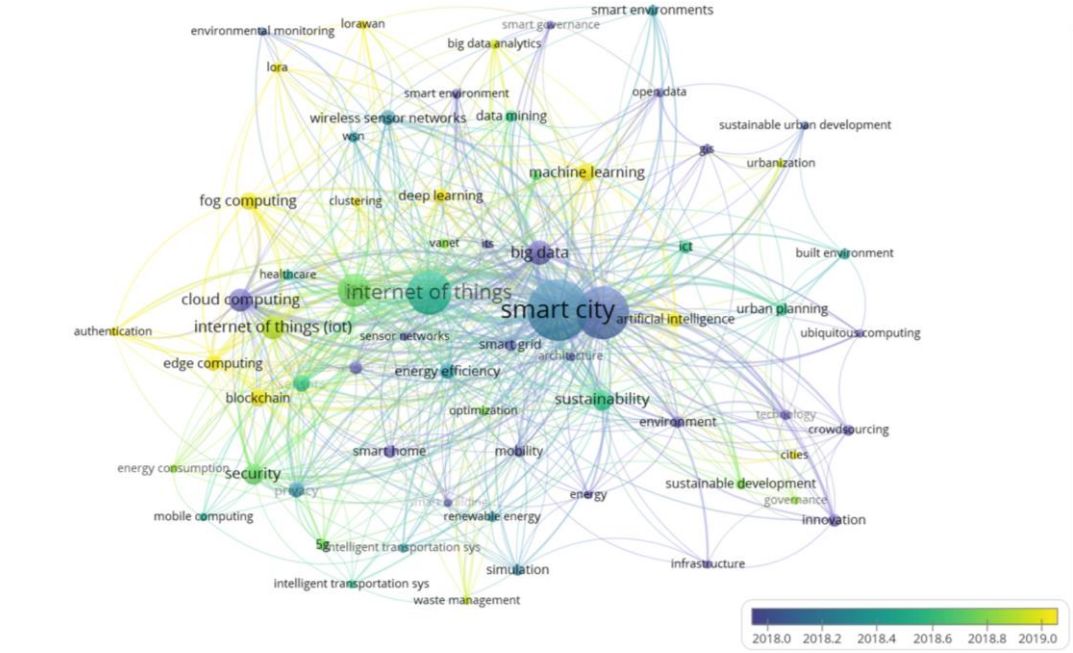
Source: Created by the authors, 2021.

2.3 Keywords analysis

The following are the keyword networks obtained in each of the three searches by year of publication. The minimum occurrence of keywords - respectively, 10, 3 and 1 - was adjusted to optimize the visualization in each network. In Figure 7, one can observe the word cloud obtained by the searches performed with the first sentence, and except for "Waste

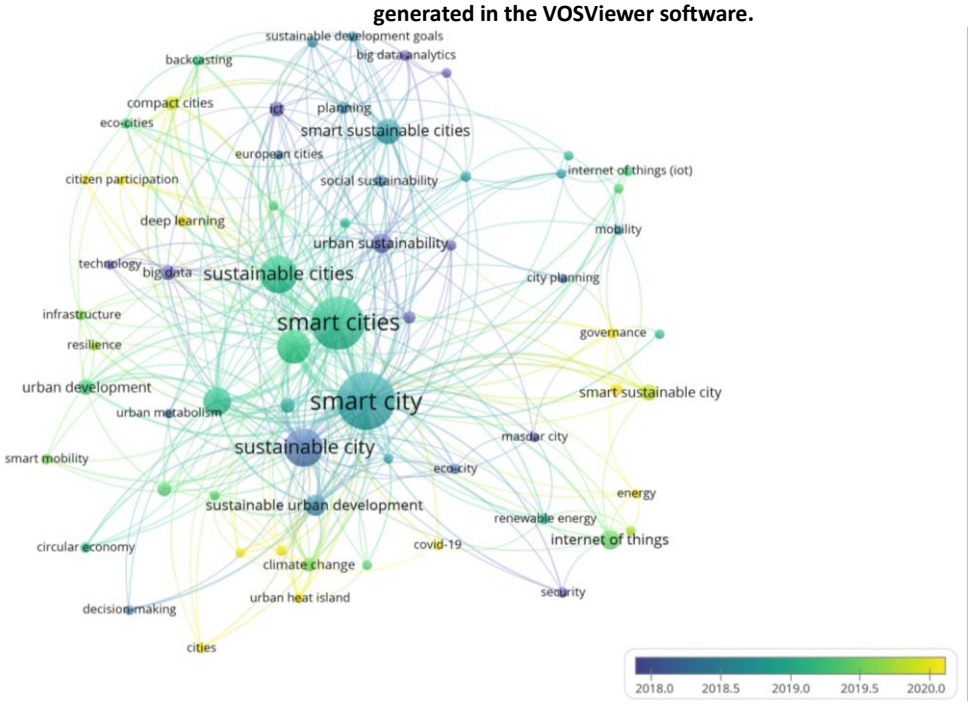
management", all other more recent keywords have a closer connection with a virtual environment than with the environment. This reality changes in Figure 8, where we see a higher incidence of keywords with a stronger connection to environmental, social, economic and political issues.

Figure 7 - Visualization of the keyword network. Search keywords: "smart city" or "smart cities" and environment, image generated in the VOSViewer software.



Source: Created by the authors, 2021.

Figure 8 - Visualization of the keyword network. Search keywords: "sustainable cit*" and "smart cit*", image generated in the VOSViewer software.



Source: Created by the authors, 2021.

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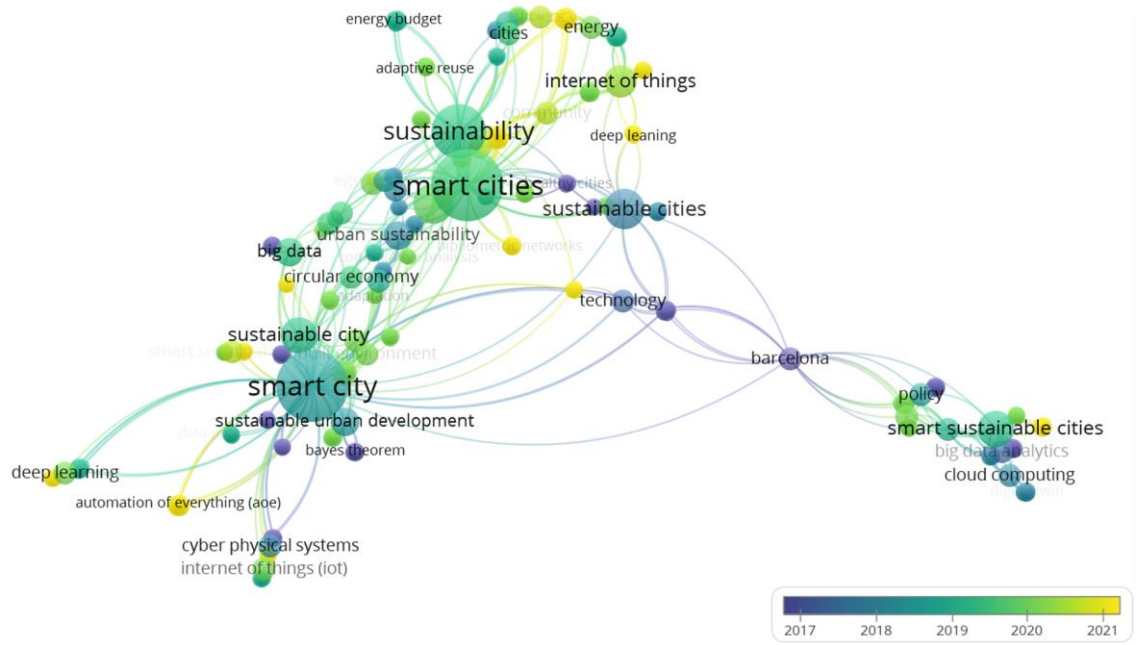
Gerenciamento de Cidades
ISSN eletrônico 2318-8472, volume 09, número 74, 2021

As for Figure 9, some considerations can be made along the lines of what Bibri and Krogstie (2017a, 2017b) and Lyons (2016) point out: (i) connections are still few, opening up research possibilities; (ii) the bulk of recent research orbits around smart cities and sustainability; (iii) there is a separate cluster, whose connecting point is the city of Barcelona, this cluster has "Smart sustainable cities" as its central keyword; (iv) the keywords of the most recent research, referring to the years 2019 and 2020, show a growing attempt to bring together typical smart city technologies with issues related to the environment and sustainability; and (v) even if there is a trend of incorporating the term "sustainable" by "smart", this movement still needs to be realized in research.

Figure 9 - Visualization of the keyword network. Search keywords: "sustainable cit*" and "smart cit*" and environment, image generated in the VOSViewer software.



Source: Created by the authors, 2021.

5. CONCLUSION

This study sought to present potential connections and research opportunities, as well as trends and main references on the intersection of the themes of smart and sustainable cities. In this sense, through the visualization of bibliometric data, it was possible to demonstrate the still incipient character of research that adheres to the necessary approximation between the themes, although there are already theoretical advances. Only in 2019 does research seeking to bridge this gap begin to gain traction.

Among the results found, the countries that stand out the most in number of publications are China, the United States, South Korea, and the United Kingdom, the latter being most prominent in the intersection between sustainability and smartness, as are Italy, Spain, the Netherlands, and Norway. Brazil, however, despite being present in two of the three lists with the fifteen countries that publish the most, does not have a prominent position. Regarding the

keywords, an important point is that the term environment can mean, in the literature, both a virtual environment and the environment, this can be observed by the keyword clouds and by the literature.

The connection of sustainable cities research with smart cities research is indispensable, as this intersection represents a critical point in the discussion regarding the planning, deployment, use, and management of smart city technologies. Studies in sustainability should serve not only as a complement, but as a guide to those in smartness, just as they cannot disregard the possibilities, challenges, and new political and technological paradigms generated by smart urban environments. An effort is needed from researchers from both fields to better face the challenges posed by urban environments, and to develop strategies, systems and structures of resistance to a predatory logic of material and virtual production of the city.

Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) – Finance Code 001.

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