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Smart mobility and sustainability: a bibliometric analysis

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ABSTRACT

At the end of the 1980s, sustainability became a focus of attention worldwide. More recently, with the consolidation of researches and implementations of smart cities, characteristics that permeate this concept were also studied in greater depth, in terms of smart mobility and smart environment. This study seeks to make a bibliometric analysis on smart mobility and sustainability. The results found show that the researches in this area are recent, with less than a decade of publication, in which Europe concentrates the largest percentage of participation in number of publications and citations, and the main subject addressed in the most cited works is the questioning of the connection between smart cities, smart mobility and sustainability. The map of keywords presents research gaps, which represent opportunities of scientific contribution for future studies.

KEYWORDS: Bibliometrics. Smart Cities. Smart Environment. Smart Mobility. Sustainability.

1. INTRODUCTION

Making existing cities more ecological is an urgent priority in the global push for sustainability. However, changing urban development from its current unsustainable trends and patterns is a challenging process (KENWORTHY, 2006). The need to promote an ecologically balanced, socially just and economically viable environment is essential to the quality of life of the present and future generations (BRASIL, 1988), and currently this inevitability is inseparable from information and communication technologies (ICTs) and the internet of things (IoT), both essential to the so-called smart cities.

The concept and development strategy of smart cities is understood as a model in which there is a high investment in ICTs and IoT, as well as in human and social capital, in order to promote universal quality of life and sustainability, *i.e*., the smart city is multidimensional and the sustainability of its initiatives is an intrinsic condition (ALBINO *et al*., 2015). With the consolidation of smart city research, several related topics have also been researched. Giffinger *et al*. (2007) mention six characteristics of a smart city: 1) Smart economy or the level of competitiveness; 2) Smart people, the social and human capital; 3) Smart governance, with emphasis on the participation of society; 4) Smart mobility, in general the use of ICT's and IoT in urban transportation; 5) Smart environment, the management and use of natural resources; and 6) Smart living, *i.e.*, quality of life. Studying how these characteristics relate to each other allows one to visualize trends and opportunities for scientific contribution in the area.

According to Bibri and Krogstie (2017), there is no definitive concept of sustainability, but the global spread of the concept occurred in the late 1980s. Sustainability is a paradigm of social thought that is advocated to guide and shape the development of society in its prominent spheres, including science and innovation, technology, economics, urban planning, policy, and institutionalization. Also, in general terms, sustainability is a state in which society does not harm natural and social systems.

Mobility is an important factor in the context of sustainable development because of the pressure it exerts on the environment and its economic and social impacts. For Kenworthy (2006), one of the ten critical points for a sustainable city is to favor active travel modes and public transportation systems, minimizing the use of cars and motorcycles. However, just like the concept of sustainability, the concept of smart mobility is vague, ambiguous or even absent in the literature. Often, sustainable is used as a synonym for smart, however, despite the fact

that the definition of sustainability is part of the definition of smartness, it is not enough to encompass the totality of what can be understood as smart. Briefly, it can be said that smart mobility is that which: i) uses technology to generate and share data, information, and knowledge for better decision making; ii) uses technology to improve vehicles, infrastructure, and the services; and iii) provides improvements for transportation system operators, users, and investors (LYONS, 2018; NOY; GIVONI, 2018).

Lyons (2018) states that urban mobility should contribute to sustainability and that the relationship between sustainable and smart is evolving. It is perceived, therefore, that the themes are interdependent, and just as Ferreira *et al*. (2017) analyzed smart cities from the characteristics of governance and governability, it is necessary to analyze the academic productions and identify the existing gaps between the aspects of a smart city. Presented below are the objectives of this study, the methodology used, the results observed, and the conclusions drawn from the results analysis.

2. OBJECTIVES

This study aims to identify gaps and possibilities for research on the topics of smart mobility and sustainability through a bibliometric analysis.

3. METHODOLOGY

The methodology of this work is composed of two stages: i) bibliographic data collection; and ii) bibliometric analysis of the results.

3.1 Bibliographic data collection

The first step comprised a search in the Scopus database, which is multidisciplinary and indexes journals of great relevance. The terms searched were "smart mobility" and "sustainability", with restriction to publications in English. The search was performed on April 28, 2021, as follows:

TITLE-ABS-KEY ("smart mobility" AND "sustainability") AND (LIMIT-TO (LANGUAGE, "English"))

The results were collected in spreadsheet format to be analyzed with bibliometric software. The data collected includes date of publication, country of origin, keywords, among others.

3.2 Bibliometric analysis

Bibliometrics makes it possible to observe the state-of-the-art of the research topic and of a given field of science by analyzing the scientific production indexed in a data repository. Through bibliometric analysis, it is possible to identify production trends, the impact of scientific production, historical evolution, authors, institutions and relevant journals in a given area. It is

also possible to glimpse opportunities for scientific contribution in the research area (SOARES *et al*., 2016; FERREIRA *et al*., 2017).

The results obtained in the data collection were imported into the VOSViewer software, responsible for building and visualizing bibliometric networks. The historical evolution of publications, the countries that publish the most in this area, types of publication indexed in the database, the most cited papers and, finally, a thematic map with keywords used by the authors were created for analysis of the main connections of research themes in this area.

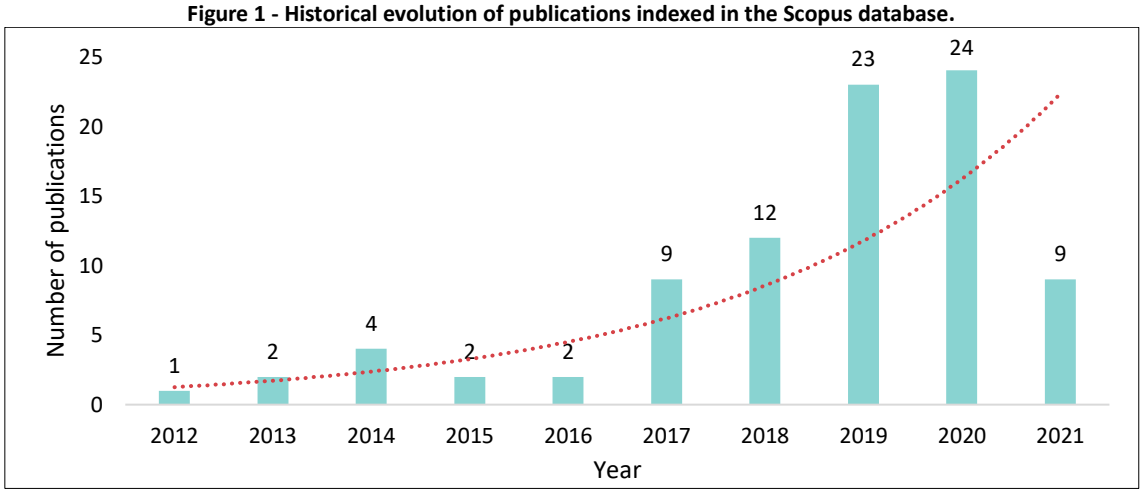
4. RESULTS

The search with the terms "smart mobility" and "sustainability", limited to publications in English, obtained 88 results, with 286 authors and a set of 318 related keywords. These results are detailed in the following subsections.

4.1 Historical Evolution

The rising of research in this area is recent, with less than a decade of development, as can be seen in Figure 1. Even though it is a recent subject, with few publications since 2012, one can see a trend of increasing publications. The peak until now was in the year 2020, with 24 publications, thus demonstrating a profile of exponential growth.

Figure 1 - Historical evolution of publications indexed in the Scopus database.



Source: Created by the authors, 2021.

4.2 Geographical division of the publications

An important aspect to be analyzed is where in the world publications on the theme of smart mobility and sustainability are being produced. To this end, country related data was aggregated and the number of publications and corresponding citations were counted. In this analysis, 8 publications that had no country information were excluded. Figure 2 compiles the data by continent. Europe concentrates the majority of publications (70%) and citations (58.8%), followed by Asia with 12.5% of publications and 11.7% of citations. In South America, all

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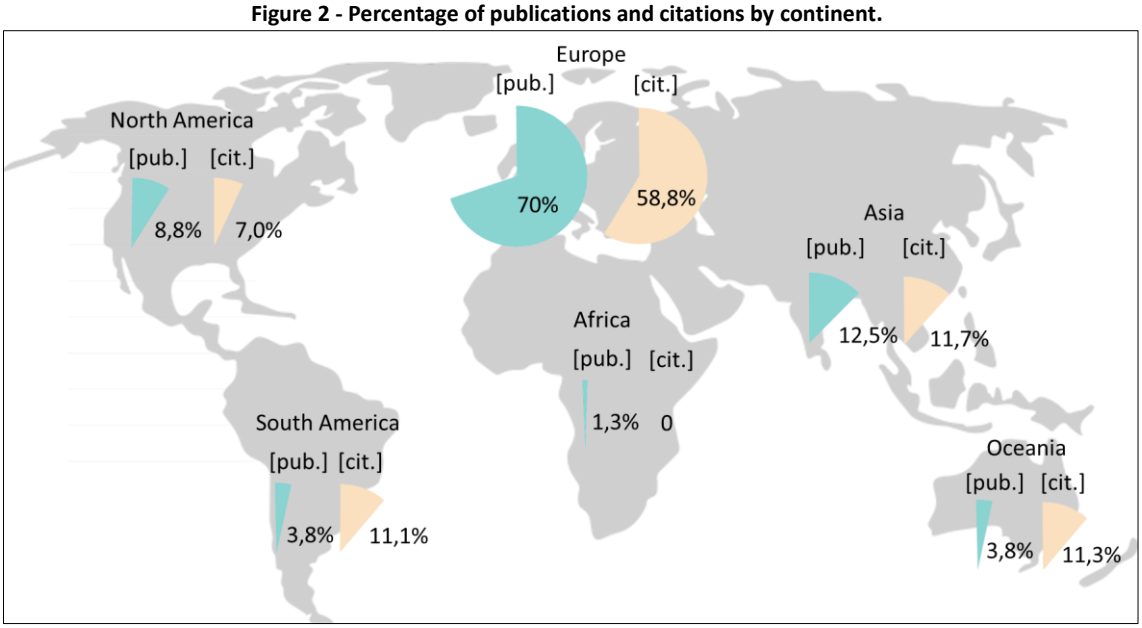
publications are from Brazil and, despite the small percentage participation in the total of publications (3.8%), have 11.1% of citations.

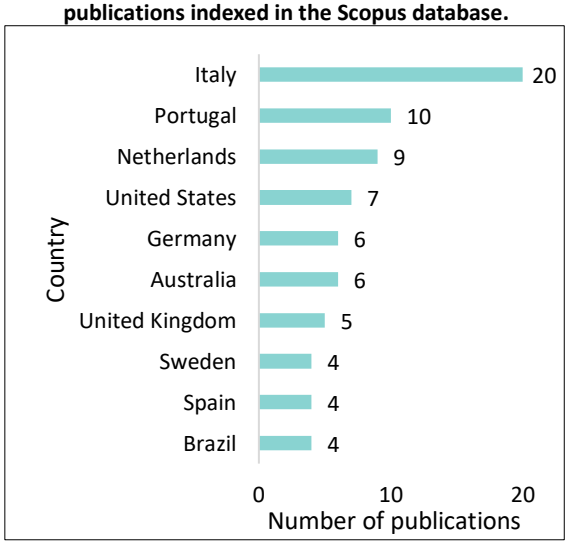
Figure 2 - Percentage of publications and citations by continent.



Source: Created by the authors, 2021.

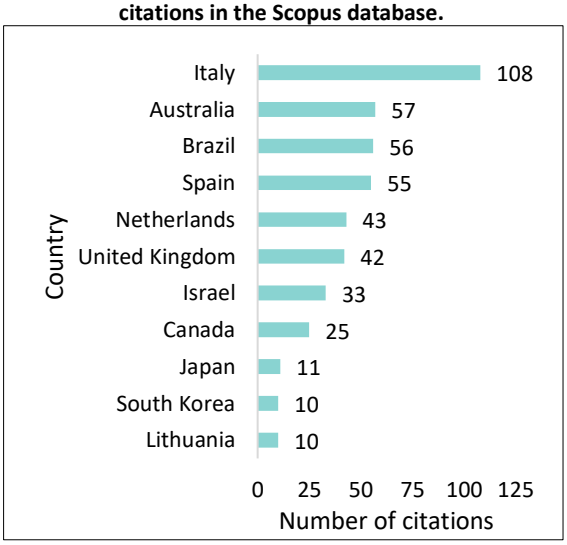
Figure 3 shows the number of publications from the ten countries with the most publications. Italy is the country with the largest number of publications, having twice as many publications as Portugal, which is the second country on the list. Brazil appears in tenth place, with four publications. When analyzing the number of citations per country (Figure 4), Italy remains in first place and well ahead of the other countries, followed by Australia, Brazil and Spain, these with similar number of citations. Portugal, despite being one of the largest scientific producers, is not among the countries with the highest number of citations.

Figure 3 - Countries with the largest number of publications indexed in the Scopus database.



Source: Created by the authors, 2021.

Figure 4 - Countries with the highest number of citations in the Scopus database.



Source: Created by the authors, 2021.

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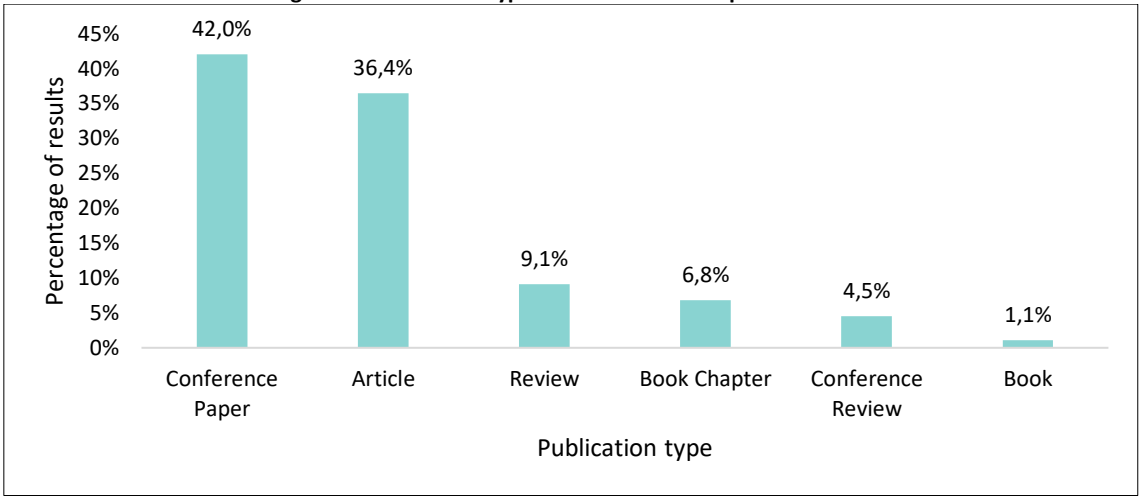
4.3 Type of publications

As presented in subsection 4.1, the historical evolution of publications is quite recent. In a way, this is related to the types of publications returned in the search, since the largest quantity refers to publications at conferences (42%). Articles in journals are the second most frequent type (36.4%). Review articles in journals (9.1%), book chapters (6.8%), reviews published in congresses (4.5%), and books (1.1%) were also returned. The results by type of publication are presented in Figure 5.

Figure 5 - Publication types indexed in the Scopus database.



Source: Created by the authors, 2021.

4.4 Most cited papers

Table 1 shows the ten publications with the highest number of citations. These articles account for 63% of the total citations returned in the search and were published between 2016 and 2019. The primary subject treated in these papers is precisely the questioning of the connection between smart cities, smart mobility and sustainability (PINNA *et al.*, 2017; YIGITCANLAR; KAMRUZZZAMAN, 2019; NOY; GIVONI, 2018; JEEKEL, 2019; ALETÀ *et al*., 2017). Two publications with participation of Brazilian institutions are among the most cited, that of Yigitcanlar *et al*. (2019) and that of Souza *et al*. (2019).

Table 1 – Most cited papers

Authors	Title	Journal / source	Year	Citations
Pinna F.; Masala F.; Garau C.	Urban policies and mobility trends in Italian smart cities	Sustainability (Switzerland) 9(4),494	2017	48
Behrendt F.	Why cycling matters for Smart Cities. Internet of Bicycles for Intelligent Transport	Journal of Transport Geography 56, pp. 157-164	2016	42
Yigitcanlar T.; Kamruzzaman M.	Smart Cities and Mobility: Does the Smartness of Australian Cities Lead to Sustainable Commuting Patterns?	Journal of Urban Technology 26(2), pp. 21-46	2019	36
Yigitcanlar T.; Wilson M.; Kamruzzaman M.	Disruptive impacts of automated driving systems on the built environment and land use: An urban planner's perspective	Journal of Open Innovation: Technology, Market, and Complexity 5(2),24	2019	33
Noy K.; Givoni M.	Is 'smart mobility' sustainable? Examining the views and beliefs of transport's technological entrepreneurs	Sustainability (Switzerland) 10(2),422	2018	33
Lopez-Carreiro I.; Monzon A.	Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology	Sustainable Cities and Society 38, pp. 684-696	2018	30
Qi W.; Shen Z.-J.M.	A Smart-City Scope of Operations Management	Production and Operations Management 28(2), pp. 393-406	2019	25
Jeekel H.	Social Sustainability and Smart Mobility: Exploring the relationship	Transportation Research Procedia 25, pp. 4296-4310	2017	24
de Souza J.T.; de Francisco A.C.; Piekarski C.M.; do Prado G.F.	Data mining and machine learning to promote smart cities: A systematic review from 2000 to 2018	Sustainability (Switzerland) 11(4),1077	2019	23
Aletà N.B.; Alonso C.M.; Ruiz R.M.A.	Smart Mobility and Smart Environment in the Spanish cities	Transportation Research Procedia 24, pp. 163-170	2017	23

Source: Created by the authors, 2021.

4.5 Keywords analysis

The search for the terms "smart mobility" and "sustainability" returned 318 keywords from authors, presented as a network in Figure 6. In the network, generated in the VOSviewer software, it is possible to observe the clusters formed by the keywords, differentiated by color, in addition to the links between them and which have greater occurrence - the larger the circle, the greater the number of occurrences of the keyword. One can notice several smaller dots representing research areas in formation, but not yet consolidated. These minor points are mostly linked to broad keywords such as "smart city", "smart cities", as well as the search terms "smart mobility" and "sustainability". This shows that there are research gaps in the area, related to the connection between the clusters presented in Figure 6. As demonstrated by Borchers and Ribeiro (2019) and Pitilin and Da Penha Sanches (2020), in keyword networks generated by older

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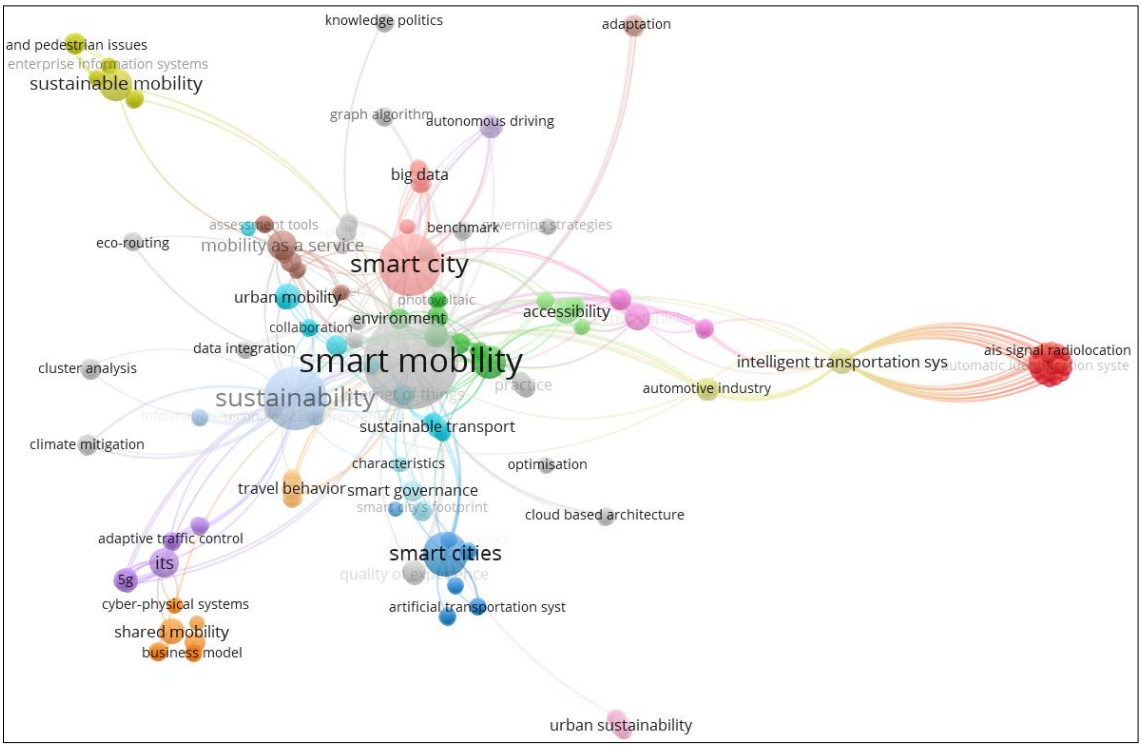
and more consolidated research areas, the clusters have greater interconnection, not being related only to broader keywords.

Such statements are corroborated by Figure 7, where the keyword network is presented according to the year of publication. The least connected points are the most recent and represent existing gaps that present themselves as opportunities for innovative contributions in the area.

Figure 6 - Visualization of the keyword network for the search "smart mobility" and "sustainability", generated in the VOSViewer software.



Source: Created by the authors, 2021.

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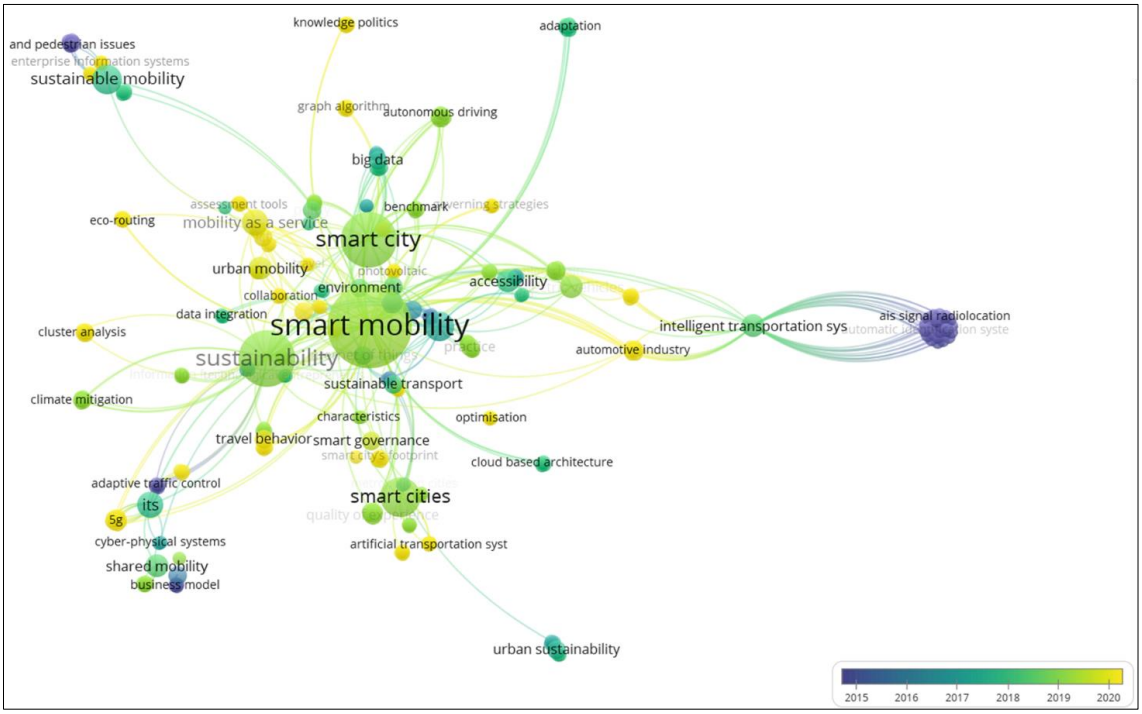
Figure 7 - Visualization of the keyword network for the search "smart mobility" and "sustainability" by year of publication, generated in the VOSViewer software.



Source: Created by the authors, 2021.

5. CONCLUSION

The present work contributes to the identification of the relationship between smart mobility and sustainability through a bibliometric analysis. For this, the articles referring to the theme indexed in the SCOPUS database were analyzed. The search was carried out on April 28, 2021 and resulted in 88 publications in English language, besides 286 authors and 318 related keywords.

The results presented show that the connection between smart mobility research and sustainability is recent and the research dates back to 2012. Italy stands out as the country with the highest number of publications and citations, and in terms of continent, Europe concentrates about 70% of publications and 58.8% of citations. Brazil is the only country in South America with indexed publications and although it accounts for only 3.8% of publications, it represents 11.1% of citations. Possibly, due to the recent nature of the research, most of the publications (42%) are from conferences, followed by journals with 36.4%. The ten most cited articles, including two related to Brazilian institutions, represent 63% of the citations in the area. The main theme addressed by these articles is precisely the questioning of the link between smart cities, smart mobility and sustainability.

The keyword analysis shows a network with connected points mainly with broad terms such as "smart city", "smart cities", besides the search terms "smart mobility" and "sustainability" themselves. Connections between clusters independent of the broader terms

are scarce and represent research gaps, which can represent opportunities for innovative contributions in the area.

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