08, 09, 10 e 11 de novembro de 2022
ISSN 2177-3866

TRENDS IN RESEARCH: FUNDING GREEN AND SMART CITIES

STEPHANE LOUISE BOCA SANTA
UNIVERSIDADE DO SUL DE SANTA CATARINA (UNISUL)

THIAGO COELHO SOARES
UNIVERSIDADE DO SUL DE SANTA CATARINA (UNISUL)

CARLOS ROGERIO MONTENEGRO DE LIMA
AGÊNCIA DE FOMENTO DO ESTADO DE SANTA CATARINA - BADESC

JOSÉ BALTAZAR SALGUEIRINHO OSÓRIO DE ANDRADE GUERRA
UNIVERSIDADE DO SUL DE SANTA CATARINA (UNISUL)

Agradecimento à orgão de fomento:
This article was conducted by the Centre for Sustainable Development (Greens), from the University of Southern Santa Catarina (Unisul), in the context of the projects BRIDGE - Building Resilience in a Dynamic Global Economy: Complexity across scales in the Brazilian Food-Water-Energy Nexus and Technological Empowerment for family-farming agriculture in Santa Catarina: BRIDGE-TESC; FAPESC, CAPES, CNPq, Instituto Ânima, Research Councils United Kingdom (RCUK) and Global Challenges Research Fund (GCRF).

TRENDS IN RESEARCH: FUNDING GREEN AND SMART CITIES

1. INTRODUCTION

Cities generate around 70% of global greenhouse gas emissions (Giles-Corti, Lowe & Arundel, 2020). They are getting bigger and faster and for the first time in history, more than half of the world's population lives in them (Bibri, 2021). To minimize these impacts, sustainable cities have become a new option with the proposal of models aimed at redesigning and restructuring urban places to make life in cities more sustainable (Boca Santa et al., 2020). This has allowed cities to function in ways that reduce energy consumption, reduce material use, mitigate pollution, improve social equity, improve human well-being, minimize waste, and improve quality of life (Bibri, 2021).

To implement innovations in the processes of restructuring cities, one of the barriers faced is financial, as there is a lack of capacity for public investment and, also, unavailability of private funding. Therefore, funding smart solutions requires an innovative approach to funding, budgets, sources of capital and business models (Blanck & Ribeiro, 2021).

Traditional city funding is related to city infrastructure, with renewable projects, where the intended money is expected to come from cash flow, funding banks or companies. But the funding of sustainable and smart cities has a technology perspective, where many of them are still in development, such as internet of things, cloud technology, green technology, among others. These technologies are not always financed by banks and therefore need innovative funding methods (Kavta & Yadav, 2016).

In this context, it is important to understand how the themes related to the funding of cities (where the money comes from) relate to the other themes that involve sustainable and smart cities (characteristics / indicators / sub-indicators). Thus, this article aims to understand the connections between studies on the topic "funding sustainable and smart cities", through an analysis of publications in international journals. For this, the bibliometric method was used considering articles published in the Web of Science database from 1997 to 2020.

The main authors, concepts and theories were analysed in the context of the 565 articles found on the topic, using the analysis of citations, co-citations, and matching, multidimensional scaling, and exploratory factor analysis. Thus, due to the scope of the present study, through a broad bibliographic survey and of the most influential authors, it will seek to explore and synthesize knowledge on the topic of funding sustainable cities. This article is structured in six parts. In addition to the introduction, the second part contains a review of the literature based on primary studies of the combination of the theme of funding sustainable cities. In the third, the method used is discussed, including data collection, sample selection and analysis procedures. In the fourth, the results of the research are found through techniques of co-citation analysis, bibliographic pairing, co-citation map, and exploratory factor analysis. In the fifth part, a discussion is carried out that includes the analysis of the factors found in the previous step. And in the last part, the final considerations are presented with the contribution and limitations of this study, as well as possible paths for future research.

2. LITERATURE REVIEW

2.1 Sustainable and Smart Cities

The urbanization process of modern cities is challenging, as economic activities generate jobs, however, they also degrade the environment, as they generate waste and pollutants (Yi, 2020). Still, natural resources are relevant for the development of society, but have been exploited in a predatory way (Jing & Wang, 2020). Problems in cities are increasingly worrying, and the need for urban sustainability is discussed. Sustainability is a process that aims to make choices using common sense, intuition, and ethics to consider the consequences of these choices in the long term (El Ghorab & Shalaby, 2016). According to de Lima (2021), sustainable development encompasses three dimensions – economic, social, and environmental – and according to Yi (2020), these dimensions must be considered when managing cities. These dimensions are considered subsystems for Jing and Wang (2020), where according to the authors, these subsystems have a complex relationship, but which supports all human activities in terms of resource flow, information flow and capital flow.

The city plays a central role in achieving sustainable development. (Diamantini & Zanon, 2000), even during and after the Covid-19 pandemic period (Boca Santa et al 2021). In addition to being the place where a large part of the population lives, it is where there is more consumption of resources and production of waste. However, urban conditions are different depending on the city. Both the quality of life and the damage to the environment depend on a variety of factors, such as economic, environmental, cultural. Municipal managers need to deal with these local conditions, attitudes, and traditions (Diamantini & Zanon, 2000).

The contemporary city model has been an important factor for the propagation of more sustainable, equitable, liveable, and efficient cities. The wide diffusion of sustainable development in the early 1990s served as a stimulus for growing academic contributions in this area. With population growth, sustainable cities will still face new challenges, such as improving the quality of life, creating low-cost environments, maintaining economic growth, and constantly adapting to new concepts that emerge. (Bibri, 2021).

Economic, technological, and sustainable development depends on investment. There is economic development when there are roads, railways, ports, electrical networks, and fiber optics developing the industry. Investment in infrastructure provides physical capital, but there is also a need for investments in human capital, such as education and health. (Sachs, 2017).

With technological advances, the globalization process, and the need to think about the environment, the management of cities has become complex (Rotmans, Asselt & Vellinga, 2000). Still, cities are relevant consumers and distributors of goods and services, thus, the management of cities focused on sustainability is a significant component for sustainable development (Bao & Toivonen, 2014). The sustainability theory of the 1990s advocated the triple bottom line (economic, social, environmental). This definition of sustainability applied to city management gave rise to several concepts, such as sustainable city, sustainable urbanism, among others. The concept of green cities is more recent and encompasses the efforts and research carried out by a city to make the city more sustainable and liveable. The concept of sustainable city encompasses the triple bottom line, but also other issues such as health, transport, and education, however, environmental issues prevail (Brilhante & Klass, 2018).

The concept of sustainable city focuses on technical results aimed at urban efficiency, with the main objective of implementing sustainable policies that reduce negative impacts and contribute to the regeneration of the environment. However, defining sustainable cities is not easy, as cities are different, with different characteristics and needs, whether in terms of climate, history, geography, wealth, culture, among other characteristics. These peculiarities make it difficult to define a single approach to urban sustainability (Macke et al., 2019).

Sustainable cities are increasingly embracing the technologies that smart cities have to offer, such as new apps to monitor, measure and improve sustainability performance. These cities are being called smart sustainable cities (Bibri, 2021). A city can be considered a smart city when it performs well in at least six indicators, namely: smart economy; smart mobility; smart environment; smart people; intelligent life; and smart governance (Lazaroiu & Roscia, 2012). Sustainability indicators are not just traditional performance metrics, they are also important to support city development (Mazon et al., 2019).

The concept of smart city emerged related to the technological context, aiming at social benefits. But today, the connection of this concept with environmental issues is also observed. Therefore, the smart city concept and the sustainable city concept are in the process of being integrated (Vukovic, Rzhavtsev & Shmyrev, 2019), where together they form a new concept and incorporate related terms. Due to environmental challenges and population expansion in cities, it is not enough that city management is focused only on the characteristics of a smart city, but also that it is a sustainable city (Anand, Rufuss, Rajkumar & Suganthi, 2017).

Smart cities include wireless connectivity, smart homes, smart urban management, smart transport, smart public services, social management, smart health, smart tourism, green city initiatives, smart infrastructure, smart governance, smart economy, smart policies, smart agriculture, smart education, smart environment, smart industry, smart energy, smart feedback, and other smart functions (Ullah et al., 2021). An addendum regarding smart technologies is that it is not enough that they are efficient and bring benefits to the environment. For there to be adherence to smart technologies, there is also a need for them to bring economic benefits. Otherwise, the technologies may not be relevant to all stakeholders at the same level and may still not meet expectations. In other words, it is necessary to balance the social, economic, and environmental dimensions, avoiding conflict of interests (Macke et al., 2019).

There are two main approaches to smart cities, they are: (1) technology-oriented approach (infrastructure, platforms, systems, architectures, models, applications); and (2) people-oriented approach (citizens, knowledge, stakeholders, services, and data). However, recently, sustainability has also become one of the goals of smart cities (Bibri, 2021). Therefore, a sustainable smart city is one that uses information and communication technologies to improve the quality of life of its citizens, as well as the efficiency of urban operations and services, in addition to the competitiveness of services, however, also prioritizing the concepts of sustainability (Ullah et al., 2021).

2.2 Funding Smart and Sustainable Cities

Building smart and sustainable cities is one of the goals of municipal governments around the world, aiming to mitigate the effects of climate, population increase and depredation of nature on the planet. However, funding the transition to smart and sustainable cities is a challenge. Thus, some cities have been experimenting with innovative financial mechanisms. In terms of funding for energy efficiency, some move faster than their national governments, however, overall, the financial competence for cities to transition is inadequate (Bai et al., 2020).

There are many obstacles that block the shift to smarter and more sustainable cities, such as political disagreement, lack of funding and institutional weakness. Operationally speaking, some of the obstacles are disputed information, rising costs, fraud and inadequate oversight. Therefore, intelligent institutions, by focusing on efficiency, must promote sustainable growth with quality, restricting their extraction modes. Therefore, there is a need for guidance on resilience, creativity, and willingness to collaborate, seeking not to reinforce structural inequalities (Huston, Rahimzad & Parsa, 2015).

Making a city smart and sustainable requires funding. Funding programs are important to revitalize the city and provide better living conditions for the population, so these programs are considered socio-political measures. Thus, funding programs for urban planning projects should also be seen as long-term investments (Zabel & Kwon, 2021).

Public funding can serve as a financial lever for cities' transition to sustainability, and thus encourage private sector investment. Furthermore, the public sector can subsidize new technologies that aim to promote climate action, since subsidized resources are not aimed at a financial return on the amount invested, which reduces the difficulties of acceptance and implementation of actions by stakeholders, reducing the initial cost. for the adopters. Therefore, subsidies and concessions are widely used (Bai et al., 2020).

Most nature-based solutions tend to rely only on public funding, however, the requirements to achieve public funding can hamper projects to some extent. Strong business models are less reliant on public funding, can quickly generate revenue and self-finance their operations (Kampelmann, 2021). In this context, there is the concept of green finance, which is funding that aims to provide environmental benefits. Green finance includes green financial bonds, carbon market tools, green banks, new financial instruments, new policies, green central bank, fiscal policy, green community funds, among others (Khan et al., 2021).

There are several effects of adopting green finance. Green finance is a support for green innovation organizations, as it helps in the purchase of green equipment, in the introduction of new environmentally efficient technologies, among other actions. Furthermore, green finance can help stakeholders fund research and development on environmental issues, thus reducing the risk related to green policies, which may have higher costs than traditional practices. Green funding includes renewable energy and efficiency, but also extends to biodiversity protection, recycling, pollution control and environmental protection (Khan et al., 2021).

The funding of smart and sustainable cities can be through direct investment (the capital received comes directly from the owner of the capital), or through indirect investment (the process of receiving funding has an intermediary that finances a given initiative, but the capital comes from other stakeholders). A challenge for governments is to select the best funding option for each initiative (Blanck & Ribeiro, 2021).

One source of funding is to capture the rise in land values when there are improvements nearby, such as transportation, construction, or street beautification. The mechanism can be direct or indirect. The direct mechanism works through rental fees or infrastructure connection fees. The indirect mechanism works through taxes. In this funding modality, you must designate the project benefits and value capture rate and then assign the collection rights to the project proponent, usually a special purpose company (Huston, Rahimzad & Parsa, 2015).

Various methods have emerged to finance sustainability projects, such as green banks, green bonds, and village funds (microfinance program). Green banks have some advantages: they offer better credit conditions; aggregation of small projects; market expansion; and creating innovative financial products. Green bonds can provide affordable long-term capital to refinance projects, however, a high rate of return guarantee is required to mitigate risks. (Yoshino, Taghizadeh-Hesary & Nakahigashi, 2019). Another funding option is incubation mechanisms, aimed at creating value for startup entrepreneurs, promoting research and development via university-company collaboration. (Blanck & Ribeiro, 2021; Perdoná & Soares, 2021).

Crowdfunding is also carried out successfully, but although discussed in the mainstream media, it lacks academic analysis (Toxopeus & Polzin, 2021). Crowdfunding allows an idea to be shared with others over a fixed period, usually a few weeks, attracting interested parties to the proposed idea. (Motylska-Kuzma, 2018).

3 METHODOLOGICAL PROCEDURES

The present study will make use of bibliometric research, as it has the potential to introduce a systematic, transparent, and reproducible review process based on statistical measurement of science, scientists, or scientific activity. In addition to defining the overall productivity in each area, bibliometric research can also be used to assess the productivity of individual researchers, journals, countries, or any other type of data of interest to scholars.

As for data collection, these were collected in the Web of Science Core Collection of the Web of Science, as it is one of the most widely used in applied social sciences. In addition, this database has search tools that facilitate bibliometric research. The Web of Science was used for data collection due to its wide coverage of scientific publications and citations in the context of the social sciences.

As for the search strategies, these involved the following keywords and Boolean operators: *(funding OR funding) AND ("green*" OR "smart*") AND ("cit*" OR "urban")*. The use of an asterisk at the end of the keyword captured all possible variations of these words in the titles, abstracts, and keywords ("topic" option) of the selected articles, which totalled 1,189 articles. Subsequently, the selection took place manually to ensure that all articles were related to the topic, by reading the titles and abstracts, which resulted in 565 articles, until November 2020, eliminating articles not related to the topic. These validated articles used 26,160 references, and for the purpose of this article, the most cited references in the sample will be analysed.

In this research, four main types of analysis were performed: citations, co-citations, bibliographic pairing, and analysis of the most frequently researched contents (factor analysis). Citation analysis is used to recognize the influence of studies and their authors on the researched content. This analysis is based on counting the number of times a primary study is cited by other researchers, thus expressing relevance to their own research (Lima, et al, 2020; da Silva, et al, 2022; de Souza, Proença & Soares, 2022). All references from the 565 articles were involved in the citation analysis, and articles that were cited 6 or more times, according to Lotka's Law, were analysed, totalling 39 articles.

The co-citation analysis is based on examining how often a given pair of primary studies is cited by other works, seeking to show their interrelationships, allowing the identification of a community of authors based on their positions in the researched field. Pairing analysis is based on the frequency with which two articles in the sample share at least one common reference (Vogel & Güttel, 2013).

To verify the theoretical relationships between the 565 studies, a co-citation matrix was created, using the Bibexcel software, which allows the generation of data files that can be imported into Excel. The co-citation matrix was converted into a Pearson correlation matrix, using SPSS software, to support Exploratory Factor Analysis (EFA). To extract the factors from the primary studies (articles), the principal components method was also used, with Varimax rotation and Kaiser normalization (Vils et al., 2019).

In bibliometric research, a factor is a subfield of study, based on the analysis of authors who have high loads on that factor. Authors with factor loadings greater than 0.5 were included in a factor, as recommended by Hair, Black, Babin, & Anderson (2019). The recognition and naming of each factor are made from the reading and identification of the theoretical line common to the works that belong to a certain group.

The pairing network was created with the help of the Ucinet 6 software. The function of the pairing network is to present the main links between the authors, showing a connection about the line of research worked by them, following the same base of references and studies. Thus, using the Web of Science database and using the four main analyses mentioned at the beginning of this section, it was possible to trace the theoretical structure of the theme "funding sustainable and smart cities".

4 RESULTS

4.1 Analysis of co-citations

The co-citation analysis is based on examining how often a given pair of primary studies is cited by other works, seeking to show their interrelationships, allowing the identification of a community of authors based on their positions in the researched field. Based on the results obtained with the co-citations, studies with a factor loading greater than or equal to 0.50 were retained. Vogel & Güttel (2013) point out that when grouping primary studies to factors, only those with main loadings are considered, while those studies with crossed loadings, which mean interrelationships between different research streams, are not considered. For the exploratory factor analysis of co-citation, adjustments to the values of Commonalities>0.5, KMO>0.5, Bartlett $p<0.05$, Explained Variance>60% were observed (Hair et al., 2019). Thus, the selected sample of 39 references was reduced to 21 due to adjustments during the factor analysis procedure using these adjustments. To define the titles of the factors, the readings of the primary studies (articles) were made, observing the similarities between them.

Table 1 presents the results of the factorial analysis of co-citation, with the four most important factors, the titles assigned to each of them and the articles that comprise them. Each set of articles composes a factor, where the articles have a similarity relationship, and each article belongs to a certain factor with a factor loading (Nerur, Rasheed & Platts, 2008).

Tabela 1. Factor analysis of co-citation

Factor 1- making sense of smart cities		Factor 2 - performance in smart cities		Factor 3 - Ecosystem services in urban areas		Factor 4 - green space and infrastructure	
Authors	**Factor Load**	**Authors**	**Factor Load**	**Authors**	**Factor Load**	**Authors**	**Factor Load**
Kitchin R (2015)	0.833	Hollands Robert G (2008)	0.791	Haase D (2014)	0.882	Fletcher T (2015)	0.856
Lee J (2014)	0.818	Ahvenniemi H (2017)	0.731	Bolund P (1999)	0.864	Wolch J (2014)	0.835
Kitchin R (2014)	0.792	Bakici T (2013)	0.729	Costanza (1997)	0.658	Lovell S (2013)	0.805
Hollands R (2015)	0.753	Chourabi H (2012)	0.726	Gomez-Baggethun(2013)	0.573		
Vanolo A (2014)	0.744	Giffinger R (2007)	0.700				
Angelidou M (2015)	0.718	Soderstrom O (2014)	0.671				
Caragliu A (2011)	0.676	Albino V (2015)	0.670				

Source: Prepared by the authors

Factor 1 is related to the concept of smart cities. The concept of Smart Cities is not yet consolidated, as different authors propose different concepts and perspectives for this theory. The concept of smart cities started in the 1980s with the discussions that took place about easy-to-manage cities. These cities would then be focused on the speed and flexibility of adapting to global markets, which would make them efficient and competitive (Sokolov, et al, 2019).

Subsequently, this concept was used again in the late 1990s by the Intelligent Growth movement, thus promoting a new urban growth policy. In the 2000s, this term began to be used by high-tech companies to describe complex information systems for the integration of municipal infrastructure. Since then, the term smart city has been used for technological innovations related to urban planning, development, and operations (Sokolov, et al, 2019).

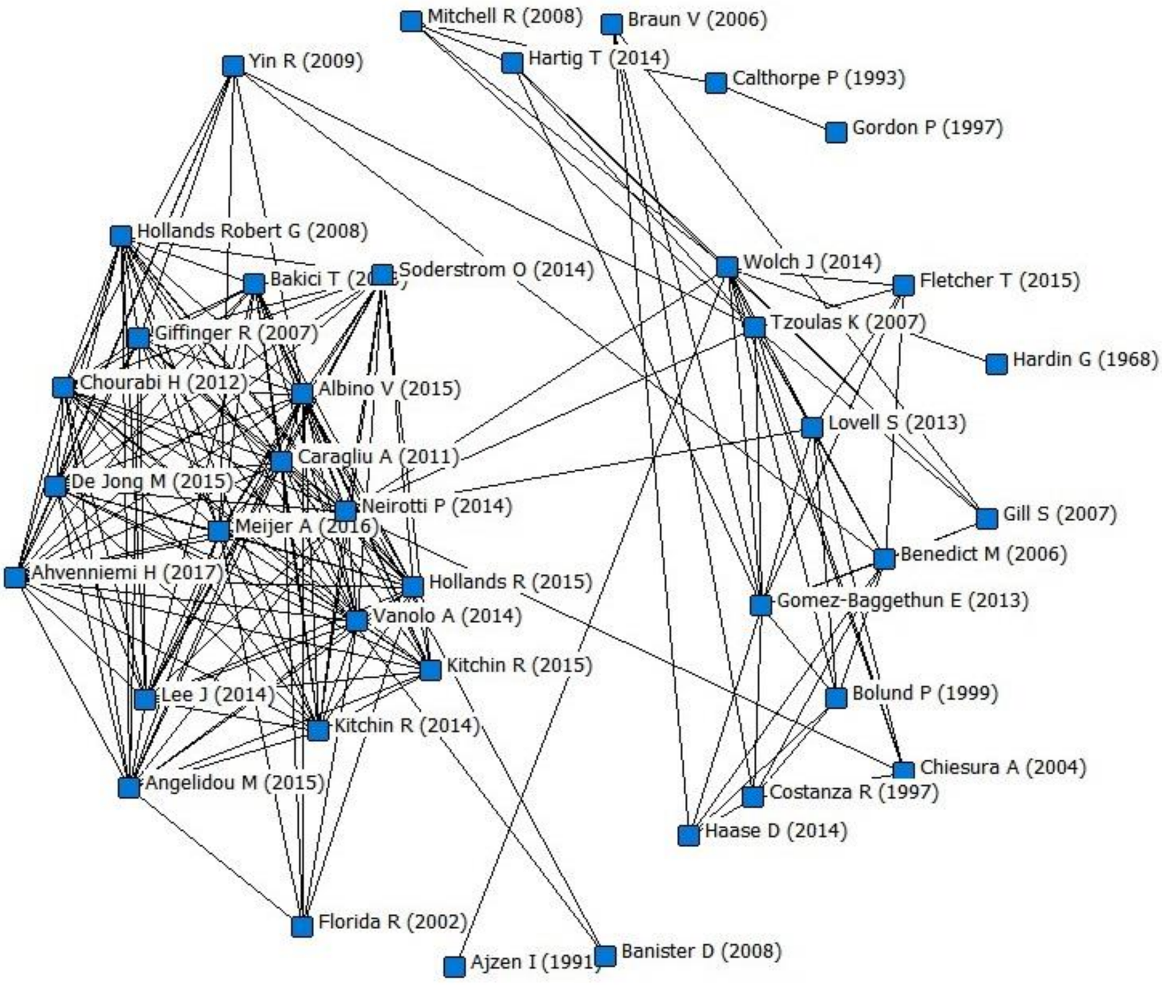
Factor 2 refers to performance in smart cities. City-focused systems approaches date back to the 1960s (Rotmans, Asselt & Vellinga, 2000). With the implementation of Agenda 21, the use of more comprehensive indicators has been promoted. Thus, the number of indicators has grown, to the point of covering almost all aspects of a city (Rosales, 2011). The management and performance models of actions aimed at the sustainability of cities can become appropriate strategies for planners and policymakers who aim at the transition of cities, aiming at sustainability. Because they can provide qualitative and quantitative information to follow the evolution, identify problems and prepare strategies (Dong et al., 2016).

The use of indicators, composite indices and ranking has been used to inform city policy (Laslett & Urmee, 2020). The indicators are divided into economic, social, and environmental, each with a series of sub-indicators (Rotmans, Asselt & Vellinga, 2000). A model tested in Mexico presents indicators for water, energy, and materials, aiming to quantify urban sustainability (Rosales, 2011). Bao and Toivonen (2014) proposed dimensions of the eco-city concept, with the following indicators: Urban expansion; Local self-sufficiency; rebuilding biodiversity; Renewable energy; Better water supply; Treatment of sewage and garbage; Sustainable food production; Green buildings; Public transportation; and social harmony.

According to Pereira Ribeiro, et al. (2021) the water, energy and food nexus are crucial for the future of cities. Factor 3 refers to ecosystem services in urban areas, where, according to Haase (2014), urban landscape is the built environment. The city environment involves several sectors in the city. Themes related to this factor are energy efficient technologies, clean transport, air pollution (including noise) (Anand, et al, 2017), afforestation area, wastewater capacity, use of solid waste (Jing & Wang, 2020), green spaces (Rotmans, Asselt & Vellinga, 2000; Sokolov, et al, 2019; Meerow, 2020; Jing & Wang, 2020; Lowe et al., 2020). In short, the entire ecosystem of urban areas. Factor 4 refers to green spaces and infrastructure. A sustainable city must invest in green spaces (Kourtit, Nijkamp & Soushi Suzuki, 2020; Jing & Wang, 2020), because they contribute in several aspects related to the city, such as economic growth (attractiveness of foreign capital) (Su et al., 2019) and reduction of greenhouse gases (Subadyo, Tutuko & Jato, 2019). Furthermore, the green spaces are home to different species of animals that live in the city (Meerow, 2020). This theme has also been related to the mental health of the city's inhabitants (Meerow, 2020).

The pairing network presented was elaborated with the aid of the Ucinet 6 software. In the drawings of the pairing networks, it is possible to perceive the existence of some lines with different contours. In this case, this means that the greater the thickness of this contour, the greater the relationship between the researchers, and the smaller the thickness, the smaller this relationship. The nodes demonstrate the authors, and it is through them that the relationships happen, as shown in Figure 1.

Figure 1. Pairing network



Source: Prepared by the authors

Factor 1 was named “making sense of smart cities”. Together, these articles seek to present a framework for building smart cities (Kitchin, 2015, Lee et al., 2014, Angelidou, 2015, Vanolo, 2014, Soderstrom, 2014), examples of smart cities (Lee et al., 2014, Caragliu et al., 2011), critical interventions in smart cities (Hollands, 2015, Kitchin, 2014). Also, factor 2 was named “performance in smart cities”. This set of articles presents a basis for discussing the characteristics and evolution of smart cities (Hollands, 2008, Bakici et al., 2013, Chourabi et al., 2012, Soderstrom et al., 2014) highlighting the differences between smart and sustainable cities (Ahvenniemi et al., 2017), smart cities ranking (Giffinger, 2007) and performance indicators for smart cities (Albino et al., 2015).

When analysing the articles in factor 3, the factor was named “ecosystem services in urban areas”. The articles that make up this factor discuss practical applications (Bolund & Hunhammar, 1999, Haase et al., 2014) and implications for governance (Haase et al., 2014), the relationship between ecosystem services and natural capital (Constanza et al., 2014). al., 1997) and classifying and evaluating ecosystem services (Gomez-Baggethun & Barton, 2013). Factor 4, when analyzing the articles, named the factor as “green space and infrastructure”. The articles discuss the application and evolution of green spaces (Fletcher et al., 2014), how green spaces, public health and environmental justice make cities fairer (Wolch et al., 2014) and the discussion of infrastructure green in the United States (Lovell & Taylor, 2013).

4.2 Bibliographic pairing

Pairing analysis is based on the frequency with which two articles in the sample share at least one common reference. The greater the number of shared references, the greater the similarity between them.

Table 2. Factorial analysis of bibliographic pairing

Factor 1- SC: past, present, and future		**Factor 2 - Smart growth**		**Factor 3- Park access**		**Factor 4 - SC initiatives**		**Factor 5 - Urban forests**		**Factor 6 - Evaluation of green spaces**	
Authors	**Factor Load**	**Authors**	**Factor Load**	**Authors**	**Factor Load**	**Authors**	**Factor Load**	**Authors**	**Factor Load**	**Authors**	**Factor Load**
O'Dwyer, E (2019)	0.912	Hamin, EM (2006)	0.862	Tu, XY (2018)	0.947	Wathne, MW (2020)	0.623	van der Jagt, APN (2019)	0.905	Xiao, Y (2016)	0.868
Viktoria, J (2019)	0.912	Howland, M (2007)	0.862	Oliphant, EL (2019)	0.947	Hu, Q (2020)	0.565	Raum, S (2019)	0.839	Li, F (2005)	0.861
van Winden, W (2017)	0.912	Carruthers, JI (2008)	0.808	Rigolon, A (2019)	0.947	Moradi, S (2020)	0.565	Davies, HJ (2018)	0.839	Baycan-Levent, T (2009)	0.861
Pevcin, P (2019)	0.850	Danielsen, KA (1999)	0.731								
Araral, E (2020)	0.557										

Source: Prepared by the authors

Factor 1 refers to several articles that aim to survey the evolution of the history of sustainable and smart cities, from their first definitions to current studies. Still, there are materials referring to how sustainable and smart cities are and how they will be in the future, aiming that they usually follow technological development.

Factor 2 refers to smart growth, as a sustainable and smart city aims for smart growth, promoting the development of cities and countries efficiently. Smart growth includes population density and growth indicators and appropriate public policies.

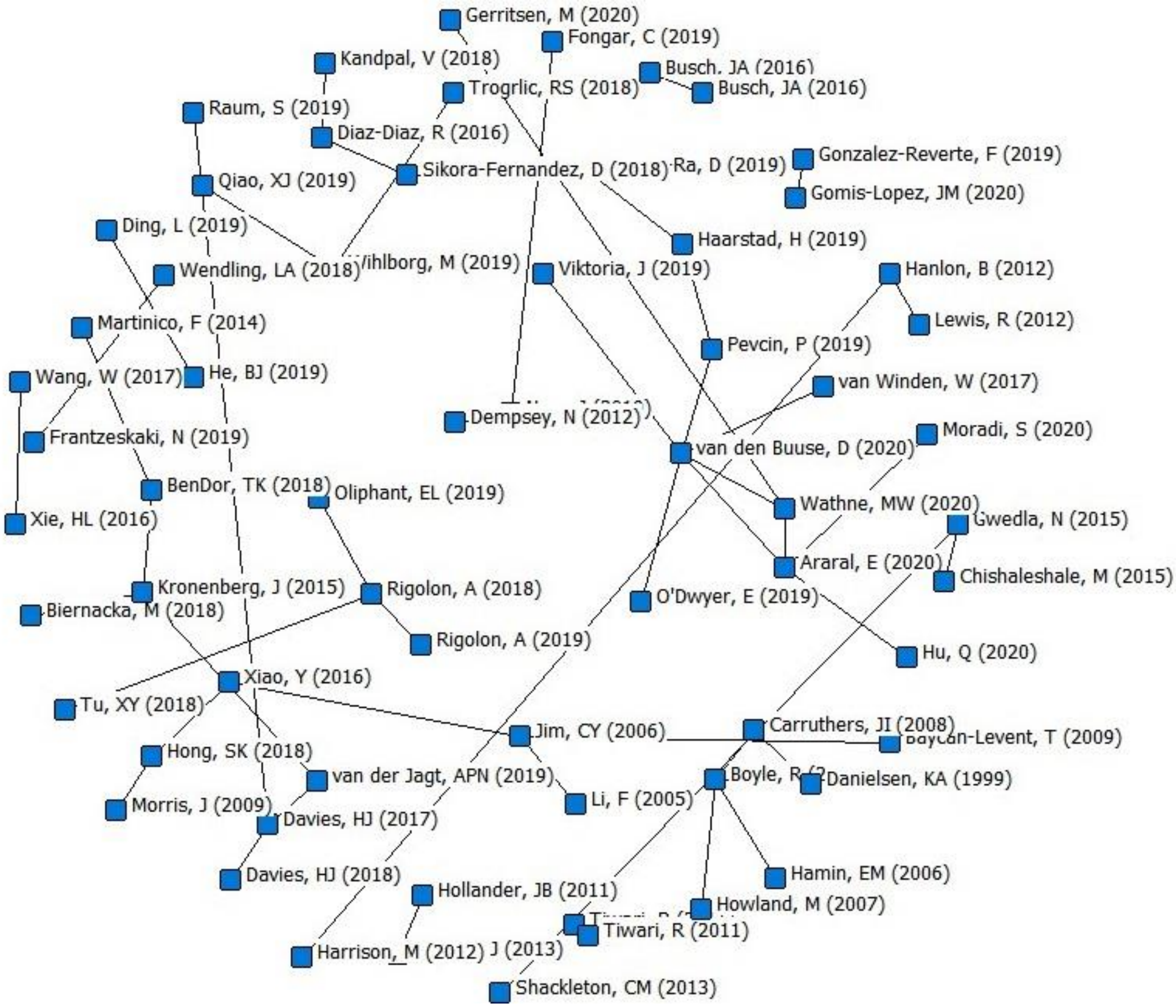
Regarding Factor 3, access to parks is one of the main characteristics of a sustainable and smart city, as it influences indicators aimed at the health of the population. The parks provide space for the practice and promotion of sports, providing the population with benefits related to mental and physical health.

Regarding Factor 4, smart cities have a series of initiatives to promote cities in a sustainable way, aiming at the efficiency of processes with the use of artificial intelligence and other technologies.

In Factor 5, forests that are close to cities are included as urban forests, several cities have environmental reserves within cities. But also, the term can be used to define the afforestation of a city, which can be both on the streets and in green spaces. Community gardens and urban agriculture are also considered.

Regarding Factor 6, the evaluation of green space is carried out with the help of environmental performance assessment systems, where green spaces become an indicator and consists of several sub-indicators. The following sub-indicators can be found in this indicator of green spaces: Access to green spaces, Urban agriculture, Public green area per capita, Fitness Park and Square.

Figura 2. Pairing network



Source: Prepared by the authors

Factor 1 was named "Smart Cities: past, present and future". Articles on this factor discuss current developments (Dwyer et al., 2019; Pevcin, 2019; Viktória & Ildikó, 2019), trends (Dwyer et al., 2019; Pevcin, 2019) and future directions (Dwyer et al., 2019; Pevcin, 2019), technology adoption (Araral, 2020), smart cities pilot projects (Vanwiden & den Buuse, 2017).

Also, factor 2 was named as "Smart growth". Articles on this factor discuss the implementation of growth management (Hamin & Steere, 2006), investment in water and sewage (Howland & Sohn, 2007), public funding for the growth of cities (Carruthers & Ulfarsson, 2008) and the future of housing (Danielsen et al., 1999). Factor 3 was named "Park access". Articles on this factor discuss access to parks and public funding for these spaces (Tu et al., 2018, Oliphant et al., 2019, Rigolon, 2019). And factor 4 was named as "Smart Cities initiatives". The articles on this factor discuss mobile policy (Wathne & Haarstad, 2020), a comparative study between cities (Hu & Zheng, 2020) and scientometrics of literature (Moradi, 2020).

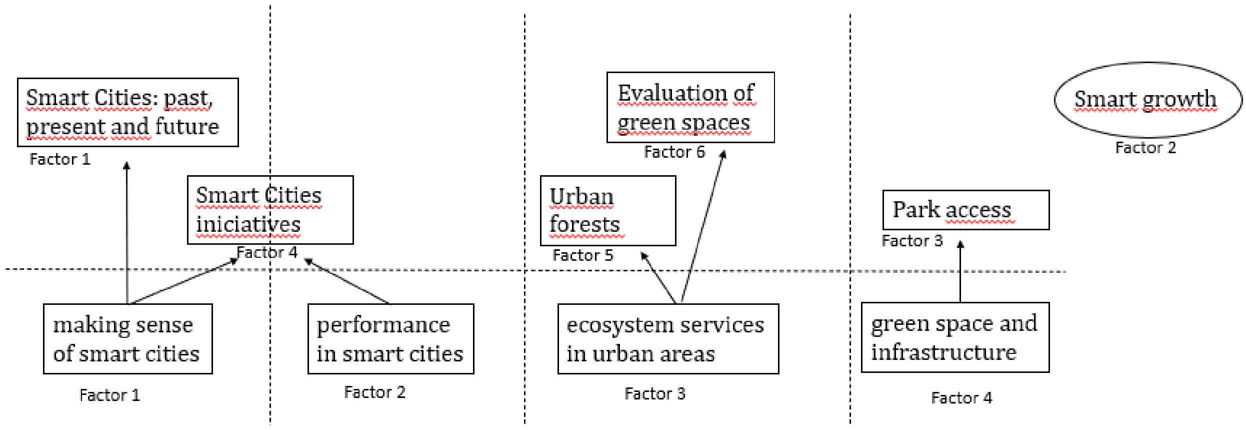
When analysing the articles, factor 5 was named "Urban forests". The articles discuss local government and governance of urban forests (van der Jagt & Lawrence, 2018), ecosystem assessment and urban green space appreciation (Raum et al., 2019) and business attitudes (Davies et al., 2108) . Also, factor 6 was named "Evaluation of green spaces". The articles promoted a multi-criteria evaluation (Baycan-Levent et al., 2009), development patters (Li et al., 2005), influence factors (Li et al., 2005), research prospects and the relationship between urban public green spaces and property value (Xiao et al., 2016).

5 DISCUSSION OF THE RESULTS

This research sought to analyse the theme "funding sustainable cities", through a bibliometric study, using citation, co-citation, pairing and factor analysis in 565 primary studies. With the analysis of citations, the evolution of the theme over the years and its importance to society and organizations was verified, from the implementation of strategies, policies, projects, among other initiatives.

The studies of factors generated in co-citations (based on references from 565 primary studies) and pairing (based on 565 primary studies) generated a research framework that shows the evolution of research on funding for healthy and smart cities.

Figure 3 – Funding framework for healthy and smart cities



Source: Prepared by the authors

The results of co-citation and bibliographic coupling need to be reconciled, considering the structural relationships between the two approaches. In this way, it became possible to identify the evolution of research in the area. To investigate the influence of the literature structure on the works in progress, an analysis was carried out between the results of co-citation and pairing. To achieve this objective, a co-occurrence matrix was created for the references that constitute the co-citation factors and for the articles in the pairing analysis. In this matrix, the co-citation references were the lines, and the matching articles were the columns, both grouped in the factors previously obtained. The cross between rows and columns was binarized, and we filled it with "1" if such a reference was used in any of the articles and "0" if not. This matrix made it possible to assess the influences of intellectual roots (co-citation) on current research (pairing).

The articles of co-citation factor 1 were in the references of the articles that make up the pairing factors 1 "smart cities: past, present and future" and 4 "smart cities initiatives". The articles that make up factor 4 also had references to factor 2 of the "performance in smart cities" co-citation. Thus, it is understood that the research of these two initial factors identified in the co-citation migrated to factors 1 and 4 of the pairing, evidencing the evolution of research in the area. The "making sense of smart cities" factor shifted from the discussion of what smart cities were to "smart cities: past, present and future", that is, how cities should be in the future. Another discussion that emerged from the "making sense of smart cities" factor was "smart cities initiatives", that is, what are the initiatives that cities should adopt in their practice so that they can be considered smart cities.

The "performance in smart cities" factor began to discuss, in addition to issues related to the performance of cities, what they need to do to be smart cities. The articles that make up factor 3 "ecosystem services in urban areas" were present in the references of articles from two other matching factors, factor 5 "urban forests" and factor 6 "evaluation of green spaces". The articles that make up factor 4 "green spaces and infrastructure" were present in factor 3 "park access". This demonstrates the evolution of research in these areas of study. Bibliographic matching factor 2 "smart growth" did not have any reference identified in the co-citation factors. Thus, it is understood that this is an emerging theme that arises from new demands from the field of study and not from previous studies like the other 5 factors.

6 CONCLUSIONS

The purpose of this work was to investigate the theoretical approaches that supported the studies on the topic of funding sustainable cities, which shows an evolution in the last three decades, through bibliometric research. The present research proved to be comprehensive and relevant, as an extensive search was carried out in the Web of Science database, in a more recent period, from 1997 to 2020, presenting a more current perspective of the field studied here.

In the present research, it was possible to contextualize the theme of funding sustainable cities, analysing its theoretical foundations. In the citation analysis, it was possible to identify: i) evolution of publications according to the years researched; ii) sorting of works according to the number of citations in the Web of Science; iii) frequency of citations according to citations by other articles in the sample; iv) identification of the frequency of the most used keywords, according to the theme addressed.

For co-citation analysis, the Exploratory Factor Analysis approach was used to identify the factors indicated in the research. 39 works were selected from the initial list of 565 publications, divided into 4 factors: Factor 1- making sense of smart cities; Factor 2 - performance in smart cities; Factor 3 - Ecosystem services in urban areas; Factor 4 - green space and infrastructure.

In the pairing analysis, the Exploratory Factor Analysis approach was used to identify the factors indicated in the research. The articles were grouped into six factors: Factor 1- Smart Cities: past, present, and future; Factor 2 - Smart growth; Factor 3- Park access; Factor 4 – Smart Cities initiatives; Factor 5 - Urban forests; Factor 6 - Evaluation of green spaces. In the pairing network, the relationships between the authors were found, who, in this case, cited one or more references, because the greater the number of cited documents, the greater the bond established between their studies. Also with this analysis, it was possible to identify the research fronts, which allowed us to understand the current discussions on funding cities.

This research has limitations that are typical of bibliometric research. One of them refers to the use of certain keywords to search for articles. Although the choice was made with care, without using categorizations and having used the asterisk (*) at the end of each keyword to capture all possible variations, this is still a limitation. However, choosing a broader combination of keywords reduced this limitation when compared to other literature reviews. Other limitations are related to citation, co-citation, and pairing analyses, since the decision to analyse the most cited studies, even if they are more expressive, excludes other works and ignores what is happening in the entire scientific field linked to the topic. As for co-citation, which shows the similarity between two articles, as they are cited together, the limitation concerns the lack of analysis of how and under what circumstances the articles were cited.

However, these findings may lead to proposals for future research. A possibility for future research would be the use of other content analysis methods to assess how and in what context the citations occurred, enabling a better understanding of the connection between the studies. Another research possibility would be to consider the evolution of studies over time and carry out analyses in separate periods. Finally, the research can also be extended to works that are not among the most cited, enabling an even more comprehensive study of the theoretical field.

REFERENCES

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., & Airaksinen, M. (2017). What are the differences between sustainable and smart cities?. Cities, 60, 234-245.

Albino, V., Berardi, U., & Dangelico, R. (2015). Smart Cities: Definitions, Dimensions, Performance, and Initiatives. Journal Of Urban Technology, 22(1), 3-21

Anand, A., Winfred Rufuss, D., Rajkumar, V., & Suganthi, L. (2017). Evaluation of Sustainability Indicators in Smart Cities for India Using MCDM Approach. Energy Procedia, 141, 211-215.

Angelidou, M. (2015). Smart cities: A conjuncture of four forces. Cities, 47, 95-106.

Araral, E. (2020). Why do cities adopt smart technologies? Contingency theory and evidence from the United States. Cities, 106, 102873.

Bai, C., Dallasega, P., Orzes, G., & Sarkis, J. (2020). Industry 4.0 technologies assessment: A sustainability perspective. International Journal of Production Economics, 107776.

Bao, S., & Toivonen, M. (2014). The specificities and practical applications of Chinese eco-cities. Journal Of Science And Technology Policy Management, 5(2), 162-176.

Baycan-Levent, T., Vreeker, R., & Nijkamp, P. (2009). A Multi-Criteria Evaluation of Green Spaces in European Cities. European Urban And Regional Studies, 16(2), 193-213

Bibri, S. (2021). Data-driven smart sustainable cities of the future: An evidence synthesis approach to a comprehensive state-of-the-art literature review. Sustainable Futures, 3, 100047.

Blanck, M., & Ribeiro, J. (2021). Smart cities funding system: An empirical modelling from the European context. Cities, 116, 103268

Boca Santa, S.L., Soares, T. C., Silva, R. S. M., Guerra, J.B.S.O.A. (2020, novembro) modelo de mensuração de cidades saudáveis sustentáveis e seus efeitos nos objetivos de desenvolvimento sustentável. Anais do Encontro Internacional sobre Gestão Empresarial e Meio Ambiente. São Paulo, SP, Brasil, 26.

Boca Santa, S.L., Cremonezi, G.O.G., Soares, T.C., Deggau, A.B. & de Andrade Guerra, J.B.S.O. (2021). Healthy Sustainable Cities and the COVID-19 Pandemic: A Sustainable Development Goals Perspective. In: Muthu, S.S. (eds) COVID-19. Environmental Footprints and Eco-design of Products and Processes. Springer, Singapore.

Bolund, & Hunhammar. (1999). Ecosystem services in urban areas. Ecological Economics.

Brilhante, O., & Klaas, J. (2018). Green City Concept and a Method to Measure Green City Performance over Time Applied to Fifty Cities Globally: Influence of GDP, Population Size and Energy Efficiency. Sustainability, 10(6), 2031.

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart Cities in Europe. Journal Of Urban Technology, 18(2), 65-82.

Carruthers, J., & Úlfarsson, G. (2008). Does `Smart Growth' Matter to Public Finance?. Urban Studies, 45(9), 1791-1823.

Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J., Mellouli, S., & Nahon, K. et al. (2012). Understanding Smart Cities: An Integrative Framework. 2012 45Th Hawaii International Conference On System Sciences.

Costanza et al. (1997). The value of the world's ecosystem services and natural capital. Nature.

da Silva, L. A., Dutra, A. R. A., Soares, T. C., Birch, R., Guerra, J. B. S.. (2022). Trends in research: carbon footprint reduction in universities as a way to achieve a green campus. International Journal of Sustainability in Higher Education, Ahead of Print.

Danielsen, K., Lang, R., & Fulton, W. (1999). Retracting suburbia: Smart growth and the future of housing. Housing Policy Debate, 10(3), 513-540.

Davies, H., Doick, K., Hudson, M., Schaafsma, M., Schreckenberg, K., & Valatin, G. (2018). Business attitudes towards funding ecosystem services provided by urban forests. Ecosystem Services, 32, 159-169.

de Lima, C.R.M., Deggau, A.B., Mazon, G., Soares, T.C., de Andrade Guerra, J.B.S.O. (2021). Sustainable Development: An Analysis Based on Conference Papers. In: Leal Filho, W., Salvia, A.L., Brandli, L., Azeiteiro, U.M., Pretorius, R. (eds) Universities, Sustainability and Society: Supporting the Implementation of the Sustainable Development Goals. World Sustainability Series. Springer, Cham.

de Souza, C., Proença, O. T., Soares, T. C. (2022). Desempenho organizacional e ferramentas de gestão: Uma análise das publicações e agenda de pesquisa. Revista Estudos e Pesquisas em Administração, 6(1), 08-32.

Diamantini, C., & Zanon, B. (2000). Planning the urban sustainable development The case of the plan for the province of Trento, Italy. Environmental Impact Assessment Review, 20(3), 299-310.

Dwyer, E., Pan, I., Acha, S., & Shah, N. (2019). Smart energy systems for sustainable smart cities: Current developments, trends and future directions. Applied Energy, 237, 581-597.

El Ghorab, H. K., & Shalaby, H. A. (2016). Eco and Green cities as new approaches for planning and developing cities in Egypt. Alexandria Engineering Journal, 55(1), 495-503.

Fletcher, T., Shuster, W., Hunt, W., Ashley, R., Butler, D., & Arthur, S. et al. (2014). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. Urban Water Journal, 12(7), 525-542.

Giffinger, R. (2007). Smart cities Ranking of European medium-sized cities. Centre Of Regional Science.

Giles-Corti, B., Lowe, M., & Arundel, J. (2020). Achieving the SDGs: Evaluating indicators to be used to benchmark and monitor progress towards creating healthy and sustainable cities. Health Policy, 124(6), 581-590.

Gomez-Baggethun, E., & Barton, D. (2013). Classifying and valuing ecosystem services for urban planning. Ecological Economics, 86, 235-245.

Haase, D., Frantzeskaki, N., & Elmqvist, T. (2014). Ecosystem Services in Urban Landscapes: Practical Applications and Governance Implications. AMBIO, 43(4), 407-412.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th ed.). Hampshire: Cengage Learning.

Hamin, E., Steere, M., & Sweetser, W. (2006). Implementing Growth Management. Journal Of Planning Education And Research, 26(1), 53-65.
Hollands, R. (2008). Will the real smart city please stand up?. City, 12(3), 303-320.
Hollands, R. (2015). Critical interventions into the corporate smart city. Cambridge Journal Of Regions, Economy And Society, 8(1), 61-77.
Howland, M., & Sohn, J. (2007). Has Maryland's priority funding areas initiative constrained the expansion of water and sewer investments?. Land Use Policy, 24(1), 175-186.
Huston, S., Rahimzad, R., & Parsa, A. (2015). 'Smart' sustainable urban regeneration: Institutions, quality and financial innovation. Cities, 48, 66-75.
Jing, Z., & Wang, J. (2020). Sustainable development evaluation of the society–economy–environment in a resource-based city of China:A complex network approach. Journal of Cleaner Production, 121510.
Kampelmann, S. (2021). Knock on wood: Business models for urban wood could overcome funding and governance challenges faced by nature-based solutions. Urban Forestry & Urban Greening, 62, 127108.
Kavta, K., & Yadav, P. (2016). Indian Smart Cities and Their Funding: A First Look. From Poverty, Inequality To Smart City, 123-141.
Khan, M., Riaz, H., Ahmed, M., & Saeed, A. (2021). Does green finance really deliver what is expected? An empirical perspective. Borsa Istanbul Review.
Kitchin, R. (2015). The real-time city? Big data and smart urbanism. Geojournal, 79(1), 1-14.
Kitchin, R. (2014). Making sense of smart cities: addressing present shortcomings. Cambridge Journal Of Regions, Economy And Society, 8(1), 131-136.
Kourtit, K., Nijkamp, P., & Suzuki, S. (2020). Are global cities sustainability champions? A double delinking analysis of environmental performance of urban agglomerations. Science of the Total Environment, 709, 134963.
Lazaroiu, G., & Roscia, M. (2012). Definition methodology for the smart cities model. Energy, 47(1), 326-332.
Lee, J., Hancock, M., & Hu, M. (2014). Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco. Technological Forecasting And Social Change, 89, 80-99.
Li, F., Wang, R., Liu, X., & Zhang, X. (2005). Urban forest in China: Development patterns, influencing factors and research prospects. International Journal Of Sustainable Development &Amp; World Ecology, 12(2), 197-204.
Li, W., & Yi, P. (2020). Assessment of city sustainability—Coupling coordinated development among economy, society and environment. Journal of Cleaner Production, 256, 120453.
Lima, C. M., Soares, T. C., Lima, M. A., Veras, M., & Guerra, J. B. S. O. A. (2020). Sustainability funding in higher education: a literature-based review. *International Journal of Sustainability in Higher Education*, *21*(3), 441-464.
Lovell, S., & Taylor, J. (2013). Supplying urban ecosystem services through multifunctional green infrastructure in the United States. Landscape Ecology, 28(8), 1447-1463.
Lowe, M., Arundel, J., Hooper, P., Rozek, J., Higgs, C., Roberts, R., & Giles-Corti, B. (2020). Liveability aspirations and realities: Implementation of urban policies designed to create healthy cities in Australia. Social Science & Medicine, 245, 112713.
Macke, J., Rubim Sarate, J., & de Atayde Moschen, S. (2019). Smart sustainable cities evaluation and sense of community. Journal Of Cleaner Production, 239, 118103.
Mazon G., Berchin I.I., Soares T.C., de Andrade Guerra J.B.S.O. (2019) Importance of Sustainability Indicators. In: Leal Filho W. (eds) Encyclopedia of Sustainability in Higher Education. Springer, Cham.
Meerow, S. (2020). The politics of multifunctional green infrastructure planning in New York City. Cities, 100, 102621.

Moradi, S. (2020). The scientometrics of literature on smart cities. Library Hi Tech, 38(2), 385-398.
Motylska-Kuzma, A. (2018). Crowdfunding and Sustainable Development. Sustainability, 10(12), 4650.
Nerur, S., Rasheed, A. & Natarajan, V. (2008). The intellectual structure of the strategic management field: an author co-citation analysis. *Strategic Management Journal, 29,* 319-336.
Oliphant, E., Hughey, M., Stowe, E., Kaczynski, A., Schipperijn, J., & Hipp, J. (2019). ParkIndex: Using Key Informant Interviews to Inform the Development of a New Park Access Evaluation Tool. The Journal Of Park And Recreation Administration.
Pevcin (2019). Smart city label: past, present, and future. Zbornik Radova Ekonomskog Fakulteta U Rijeci: Časopis Za Ekonomsku Teoriju I Praksu/Proceedings Of Rijeka Faculty Of Economics: Journal Of Economics And Business, 37(2).
Perdoná, G & Soares, T.C. (2021) O papel da educação no desenvolvimento regional: uma revisão sistemática de literatura. *Brazilian Journal of Development,* 7(11), 109077-109094.
Pereira Ribeiro, J.M., da Silva, S.A., da Silva Neiva, S. et al. (2021) A proposal of a balanced scorecard to the water, energy and food nexus approach: Brazilian food policies in the context of sustainable development goals. Stoch. Environ Res Risk Assess 35, 129–146.
Raum, S., Hand, K., Hall, C., Edwards, D., O'Brien, L., & Doick, K. (2019). Achieving impact from ecosystem assessment and valuation of urban greenspace: The case of i-Tree Eco in Great Britain. Landscape And Urban Planning, 190, 103590.
Rigolon, A. (2018). Nonprofits and park equity in Los Angeles: a promising way forward for environmental justice. Urban Geography, 40(7), 984-1009.
Rosales, N. (2011). Towards the Modeling of Sustainability into Urban Planning: Using Indicators to Build Sustainable Cities. Procedia Engineering, 21, 641-647.
Rotmans, J., Asselt, M. V., & Vellinga, P. (2000). An integrated planning tool for sustainable cities. Environmental Impact Assessment Review, 20, 265–276.
Sachs, J. (2017). A era do desenvolvimento sustentável (1 ed.). Lisboa: Actual.
Schilling, J., & Logan, J. (2008). Greening the Rust Belt: A Green Infrastructure Model for Right Sizing America's Shrinking Cities. Journal Of The American Planning Association, 74(4), 451-466.
Söderström, O., Paasche, T., & Klauser, F. (2014). Smart cities as corporate storytelling. City, 18(3), 307-320.
Sokolov, A., Veselitskaya, N., Carabias, V., & Yildirim, O. (2019). Scenario-based identification of key factors for smart cities development policies. Technological Forecasting and Social Change, 148, 119729.
Su, M., Xie, H., Yue, W., Zhang, L., Yang, Z., & Chen, S. (2019). Urban ecosystem health evaluation for typical Chinese cities along the Belt and Road. Ecological Indicators, 101, 572-582.
Subadyo, A., Tutuko, P., & Bimatyugra Jati, R. (2019). Implementation Analysis of Green City Concept in Malang - Indonesia. International Review For Spatial Planning And Sustainable Development, 7(2), 36-52.
Toxopeus, H., & Polzin, F. (2021). Reviewing funding barriers and strategies for urban nature-based solutions. Journal Of Environmental Management, 289, 112371.
Tu, X., Huang, G., & Wu, J. (2018). Contrary to Common Observations in the West, Urban Park Access Is Only Weakly Related to Neighborhood Socioeconomic Conditions in Beijing, China. Sustainability, 10(4), 1115.

Ullah, F., Qayyum, S., Thaheem, M., Al-Turjman, F., & Sepasgozar, S. (2021). Risk management in sustainable smart cities governance: A TOE framework. Technological Forecasting And Social Change, 167, 120743.

van der Jagt, A., & Lawrence, A. (2018). Local government and urban forest governance: insights from Scotland. Scandinavian Journal of Forest Research, 34(1), 53-66.

Van Winden, W., & Van den Buuse, D. (2017). Smart City Pilot Projects: Exploring the Dimensions and Conditions of Scaling Up. Journal Of Urban Technology, 24(4), 51-72.

Vanolo, A. (2014). Smartmentality: The Smart City as Disciplinary Strategy. Urban Studies, 51(5), 883-898.

Viktória, & Ildikó. (2019). Okos valóság Magyarországon? Okos programok megvalósításának esélyei Miskolcon és a magyar–szlovák határ menti térségben. Tér És Társadalom, 33(1), 66-82.

Vils, L., Freire, O., Mazieri, M., & Rodrigues, G. (2019). Construções mentais e distanciamento psicológico: um estudo bibliométrico. *Revista Gestão & Tecnologia*, *19*(1), 140-158.

Vogel, R. & Güttel, W. (2013).The Dynamic Capability View in Strategic Management: A Bibliometric Review. *International Journal of Management Reviews, 15*, 426–446.

Vukovic, N., Rzhavtsev, A., & Shmyrev, V. (2019). Smart city: The case study of Saint-Peterburg 2019. International Review, (1-2), 15-20.

Wathne, M., & Haarstad, H. (2020). The smart city as mobile policy: Insights on contemporary urbanism. Geoforum, 108, 130-138.

Wolch, J., Byrne, J., & Newell, J. (2014). Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. Landscape And Urban Planning, 125, 234-244.

Xiao, Y., Li, Z., & Webster, C. (2016). Estimating the mediating effect of privately-supplied green space on the relationship between urban public green space and property value: Evidence from Shanghai, China. Land Use Policy, 54, 439-447.

Yang, J., Yu, Q., & Gong, P. (2008). Quantifying air pollution removal by green roofs in Chicago. Atmospheric Environment, 42(31), 7266-7273.

Yoshino, N., Taghizadeh–Hesary, F., & Nakahigashi, M. (2019). Modelling the social funding and spill-over tax for addressing the green energy funding gap. Economic Modelling, 77, 34-41.

Zabel, R., & Kwon, Y. (2021). Evolution of urban development and regeneration funding programs in German cities. Cities, 111, 103008.