Revista Nacional de
Gerenciamento de Cidades
ISSN eletrônico 2318-8472, volume 10, número 76, 2022

Urban sustainability in Brazil and its applications: a systematic review

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Revista Nacional de
Gerenciamento de Cidades
ISSN eletrônico 2318-8472, volume 10, número 76, 2022

ABSTRACT

The depletion of natural resources has stimulated debates on urban sustainability. Thus, this paper aims to analyze articles on urban sustainability in Brazilian territory, as well as its instruments and indicators. To achieve the proposed aim, this work uses the systematic review method. The studies on urbanization arise as legitimators of a process of modernity and industrialization. Thus, the theme “urban sustainability” gained notoriety when it was introduced in the 17 Sustainable Development Goals. Many studies analyzed used indicators, with a quantitative and/or qualitative approach, with various applications, among cities, neighborhoods, and even projects. In Brazil, there is a legal framework that favors the development of urban sustainability. However, it is necessary to use adequate methodologies to reduce the subjectivity of sustainability assessment. One of the major difficulties in applying urban sustainability assessment is data availability.

Keywords: Indicators. Urban. Sustainable development.

INTRODUCTION

Natural resource depletion and climate change have stimulated debates on sustainability and urbanization, which are advancing on the global agenda (SOTTO et al., 2019; SOUZA & SILVA, 2019). Soon, urbanization has become one of the most important issues that define the human relationship with the ecosystem (VERMA; RAGHUBANSHI, 2018). Understanding this process is necessary to solve its problems and, consequently, enable directions for the promotion of a space that brings together adequate living conditions (MARTINS; RODRIGUES, 2021).

Urbanization is commonly regarded as one of the most important social processes, a fact that generates a huge environmental impact at local, regional, and global levels (HIREMATH et al., 2013). People continue to move to cities in search of a better life and economic opportunities, and it is necessary to promote sustainable urbanization, essential in meeting global sustainability goals.

For cities to achieve urban sustainability, they must ensure access to safe, adequate, and affordable housing; guarantee basic services for all, among other achievements, such as the proportion of the population that has adequate access to public transport; access to safe, inclusive, accessible and green public spaces; significantly reducing the number of deaths and the number of people affected by disasters and consequently reducing economic losses; and supporting positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning (ODSBRASIL, 2021).

Thus, it is essential the collaboration of the federative entities (Union, States, Federal District, and Municipalities) in effective, transparent, and participatory urban planning, aligned with international agreements and converging with public policies adopted nationally, thus fostering human development and sustainable development. In the document "Transforming Our World: The 2030 Agenda for Sustainable Development", the theme "urban sustainability" gained notoriety when it was introduced in the 17 Sustainable Development Goals - SDGs (AGENDA 2030, 2021).

However, there is a general lack of knowledge about the contextual understanding of the concept of urban sustainability. Based on this context, this research has as problem-issues how studies in Brazil have been conducted, and whether it is possible to define, measure, and monitor urban sustainability. So, the main objective is to analyze articles on urban

sustainability in Brazil, as well as its instruments and indicators, to verify what these studies have in common, allowing a more complete analysis.

THEORICAL REFERENCE

LEGAL CONTRIBUTION OF SUSTAINABILITY IN BRAZIL

The Federal Constitution of 1988 preserves, in Article 225, the right of all to an ecologically balanced environment (including the urban environment), an asset for common use by the people, and it is the duty of the government and the community to defend and preserve it for present and future generations. It is noteworthy that the Federal Constitution expresses the need for a balance between “economic growth”, “environmental preservation”, and “social equity” (BRASIL, 1988). Therefore, development can only be sustainable when the three aspects are effectively respected (THOMÉ, 2020). Thus, it can be inferred that if any of these elements is absent, it is not sustainable development, i.e., one cannot ensure a sustainable urban environment and consequently sustainable cities and communities.

The "Agenda 21", a document approved at the United Nations Conference on Environment and Development, in 1992, in Rio de Janeiro, established guidelines for changing the global development pattern for the 21st century. According to Bezerra and Fernandes (2000, p. 12),

> the theoretical framework used considers two key notions for the Sustainable Cities theme: that of expanded sustainability, which works on the synergy between the environmental, social, and economic dimensions of development, and the notion of progressive sustainability, which works on sustainability as a pragmatic process of sustainable development.

In 2015, in the document “Transforming Our World: The 2030 Agenda for Sustainable Development” the topic “urban sustainability” was included in one of the seventeen Sustainable Development Goals (SDGs) - Goal 11: Sustainable Cities and Communities, to make cities and human settlements inclusive, safe, resilient, and sustainable (AGENDA 2030, 2021).

Thus, for the SDGs to become effective, instruments that help regional governments in incorporating the 2030 Agenda are needed (SOTTO et al., 2019). Brazil holds a set of laws, such as Law No. 6,938/1981, Law No. 10,257/2001, and Law No. 12,608. Law No. 6,938/1981, disposes of the National Environmental Policy (PNMA), its purposes and formulation, and application mechanisms, and makes other provisions (BRASIL, 1981). The PNMA (1981) defined basic concepts such as environment, degradation, and pollution, and determined objectives, guidelines, and instruments. These instruments are mechanisms used by the Public Administration to achieve the PNMA’s objectives. One instrument instituted by PNMA is Environmental Licensing, which aims to promote a balance between environmental preservation and socio-economic growth.

Law 9,433, “establishes the National Policy of Hydric Resources (PNRH), creates the National System of Hydric Resources Management, regulates item XIX of Article 21 of the Federal Constitution, and amends Article 1 of Law No. 8,001, of March 13, 1990, which modified Law No. 7,990, of December 28, 1989” (BRASIL, 1997, p. 1). The PNRH structured the

integrated, decentralized, interdisciplinary, and participatory management of water resources, considering their multiple uses and taking the watershed as the territorial unit for planning (SOTTO et al., 2019). In addition, it brought the management instruments of the PNRH, such as master plans of hydrographic basins, and the granting and charging for the use of water resources.

Law No. 10,257/2001, better known as the City Statute, "came to regulate Articles 182 and 183 of the Federal Constitution, establish general guidelines for urban policy and make other provisions" (BRASIL, 2001). The City Statute aims to protect the environment in a balanced and sustainable way by providing general guidelines, such as guaranteeing the right to sustainable cities, democratic management through popular participation and cooperation among governments, the private sector, and other sectors of society during the urbanization process, always serving the social interest (BRASIL, 2001).

As for the general instruments, the municipalities promote urban planning through Master Plans, Zoning Laws, Land Division Laws, Land Use and Occupation Laws, and Building and Construction Codes.

Finally, Law No. 12,608, establishes the National Policy for Protection and Civil Defense - PNPDEC, which has as its guidelines prevention, mitigation, preparedness, response, and recovery actions aimed at civil protection and defense, adopting the watersheds as the unit of analysis of the actions (BRASIL, 2012).

URBAN SUSTAINABILITY INDICATORS

In the view of Martins and Cândido (2015, p. 138), “to build sustainability systems that support urban public policies, one must start from the understanding of the investigated urban space, adopting a comprehensive theoretical conception to urban problems [...]”. However, to be sustainable, urban areas must maintain an internal balance, that is, for sustainable urban development it is necessary to achieve a balance between the development of urban areas and protecting the environment aiming at income equality, employment, housing, basic services, social infrastructure, and transportation in urban areas (HIREMATH et al., 2013, MICHALINA et al. 2021).

In this sense, a set of urban sustainability indicators are under constant development to understand the state of urban areas for the promotion of changes towards their sustainability (SHEN et al., 2011). According to the European Commission (2018), urban sustainability indicators are tools to assess the socio-economic and environmental impact of urban projects, allowing the diagnosis of problems and pressures, and monitoring the success and impact of sustainability interventions.

The urban sustainability indicators must be meaningful, based on each reality (BUTTON, 2002), and easy to understand for the stakeholders (SAYER et al. 2007). An appropriate selection of these indicators is necessary, and their elaboration must be based on the needs where they will be applied. It is also essential to the involvement of different sectors in the definition of objectives and strategies because it represents an important step in obtaining recognition and support when adding efforts to achieve them (SHEN et al., 2011). Therefore, it is necessary to use methodologies that can “reduce the subjectivity of sustainability and the fragility of some indicators, regarding the availability, quality, and

updating of data, providing them with the capacity of information provider" (MARTINS; CÂNDIDO, 2015, p. 138).

METHODOLOGY

To achieve the proposed aim, this work uses the systematic review method. For Page et al. (2021, p. 3), "a review that uses explicit and systematic methods to compare and synthesize the results of studies that address a planned question".

For this research, the Web of Science, Scopus, Scielo, and Google Academic databases were used, not establishing a time cut, and evaluating all articles found. As the article seeks to analyze urban sustainability in Brazil, the geographic cut-off was established as studies that evaluated the theme in Brazilian cities.

As keywords, it was used the string "urban sustainability AND Brazil", both in Portuguese and English. After removing the duplicates, a filter was made by the title and abstract of the articles, and, finally, the complete reading of the texts, excluding the theoretical reviews and those that were not in the study's scope.

Among the exclusion criteria, it is important to highlight that, after reading the abstract, studies that were not developed in Brazil and theoretical review papers were excluded and, studies applied in Brazilian territory were included. After this initial screening, it carried out a full reading of the papers to check whether they developed the urban sustainability dimensions throughout the text. Some texts were excluded because they only mentioned urban sustainability in the keywords and did not apply the dimensions of urban sustainability throughout the text.

Thereafter, the articles were evaluated regarding data collection, whether the indicators used were qualitative or quantitative, and, in the latter case, which scale was used by the studies. This step aimed to facilitate the comparison between the evaluated studies.

Then, the tools used by them were evaluated, addressing the sustainability dimensions used, whether these tools worked with qualitative or quantitative data, and whether they used primary or secondary data.

RESULTS

Studies on cities and urban analysis emerge, to some extent, as legitimators of a process of modernity and industrialization that begins in the nineteenth century and progresses throughout the twentieth century (PRADO, 2015). As a reaction, environmental studies emerge in the second half of the twentieth century.

This complexity that involves cities is supported by the 17 Sustainable Development Goals (SDGs) proposed by the UN 2030 Agenda, which should be translated into "interdisciplinary, interdependent and systemic" public policies (YOUNG, 2018, p. 17). Its implementation represents a challenge and an opportunity for Brazilian cities "to correct historical economic, social and environmental inequities, through incorporating mitigation, adaptation and resilience strategies, to urban planning and management, with popular participation and governance parameters" (SOTTO, et al., 2019, p. 74).

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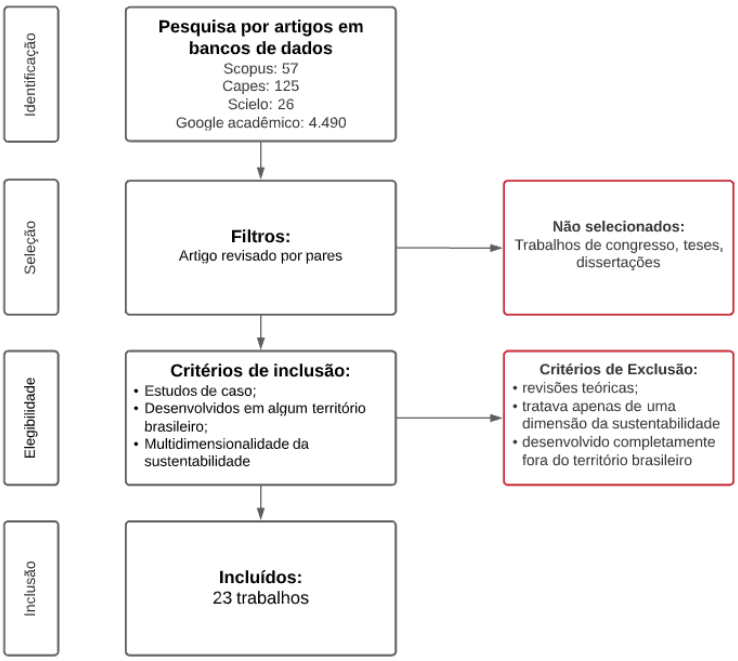
Gerenciamento de Cidades
ISSN eletrônico 2318-8472, volume 10, número 76, 2022

According to Mendonça (2011, p. 117), “it is noted the beginning of the use of the concept of resilience to the analysis of the manifestations of phenomena of extreme character”. The threats to which cities are exposed are environmental, technological, economic, social and, political and, for their confrontation, the different parts or scales of the system must be considered: functional, organizational, physical, particular and their interrelation to achieve a resilient urban system (SOTTO, et al., 2019). To this end, “understanding and promoting urban socio-environmental management has become a pressing challenge in countries like Brazil, in which the density and magnitude of the urban network and cities are marked by problems of all kinds” (MENDONÇA, 2011, p. 114).

Acselrad (1999, p. 82) criticizes a techno-material view, in which the city must follow an eco-energy rationality model, only focusing on minimizing the consumption of energy and "other material resources, exploiting local flows to the maximum, satisfying the criterion of stock conservation and reducing the volume of waste". Thus, the conceptual dimension adopted in this study starts from the premise of the multidimensionality of urban sustainability, which includes cities that are "socially inclusive, environmentally balanced, economically productive, culturally diverse, and politically participatory" (SOTTO et al., 2019, p. 74), leaving aside this techno-material view.

With this, from the dimensions of sustainability of the urban environment discussed, led to the inclusion and exclusion of some works from this study. Next, in Figure 1, the results got through the search and the number of selected articles is presented.

Figure 1 - Flowchart of the selection of eligible papers for review



Source: Authors

Finally, the selected articles were evaluated and categorized concerning their application and approach. The first analysis was about the use of indicators to assess urban sustainability. Chart 1 summarizes the results found, which shows how the data was collected, the use of indicators, whether this indicator is of a qualitative or quantitative nature, and, in

the latter case, which scale (minimum value and maximum value) was used to measure quantitatively.

Chart 1 – Summary of data studies evaluated

	Authors	Data collection	Indicators	Data type	Scale
1	Altamirano-Avila e Martínez (2021)	Secondary, from databases	Yes	Quantitative	0 to 5
2	Amadeo et al. (2017)	Primary, from interviews	Yes	Quantitative	1 to 5
3	Braga (2006)	Secondary, from databases	Yes	Quantitative	0 to 1
4	Caldatto et al. (2021)	Secondary, from databases	Yes	Qualitative	
5	Ferreira e Vieira (2018)	Secondary, from databases	Yes	Quantitative	0 to 1
6	Gonçalves et al. (2020)	Primary from field visits and secondary from databases	Yes	Quantitative	0 to 1
7	Lopes e Guerra (2020)	Primary, from interviews and secondary, from project data	No		
8	Larbi et al. (2021)	Secondary, from literature review	No		
9	Macêdo e Martins (2015)	Primary, from questionnaire-driven	Yes	Quantitative	0 to 5
10	Marins (2017)	Secondary, from literature review	Yes	Quantitative	0 to 10
11	Martins e Rodrigues (2021)	Primary, from field visits and secondary, from database	Yes	Quantitative	0 to 1
12	Martins et al. (2021)	Primary, from questionnaire-driven	Yes	Quantitative	1 to 5
13	Martins et al. (2017)	Primary, from field visits and secondary, from local government	No		
14	Nascimento et al. (2014)	Secondary, from databases	No		
15	Nunes et al. (2016)	Secondary, from databases	No		
16	Pereira e Vieira (2016)	Secondary, from databases	Yes	Quantitative	0 to 1
17	Pereira et al. (2020)	Secondary, from databases	Yes	Quantitative	0 to 1
18	Raynal et al. (2021)	Secondary, from literature review	Yes	Qualitative	
19	Silva e Padovano (2015)	Secondary, from literature review	No	Qualitative	
20	Silva e Romero (2015)	Secondary, from databases	No	Qualitative	
21	Silva et al. (2020)	Primary, from field visits and high-resolution satellite images	Yes	Quantitative	
22	Trindade et al. (2021)	Secondary, from local government data	Yes	Quantitative	0 to 1
23	Vilela et al. (2019)	Secondary, from literature review	No		

According to the European Commission (2018), indicators are a parameter or a parameter-derived value that points to, provides information about, and/or describes the state of a phenomenon/environment/area, with a significance that extends beyond that directly associated with a parameter value. Perhaps the most useful way to start is to understand the various purposes for which indicators can be used. They can be applied in three ways: as explanatory tools, pilot tools, or performance assessment tools (SHEN et al., 2011).

As explanatory tools, in which indicators apply to assess the current state of the environmental dimension of sustainability in a city or urban area (EUROPEAN COMMISSION, 2018), some studies have used them in this way. Altamirano-Ávila and Martínez (2021), for example, seek to describe the best sustainable practices for some Latin American cities through the structure of a database, composing the Sustainable Development Index for Energy, Water and Environmental Systems (SDEWES), enabling a comparative analysis between them.

Caldatto et al. (2021) built an urban sustainability performance evaluation model for the city of Coronel Vivida, Paraná, involving environmental protection, quality of life, and economic growth. Ferreira and Vieira (2018), meanwhile, evaluated urban sustainability in the metropolitan region of Santarém, Pará, based on the Urban Sustainability Index System (SISU), composed of three indexes, 10 indicators, and 19 variables. Martins and Rodrigues (2021) evaluated the urban sustainability of the city of Lagoa Seca, Paraíba, which includes 7 dimensions: eco-energy rationality, urban metabolism, purity, citizenship, heritage, efficiency, and equity.

The last category, performance assessment, is the most widespread and is widely considered the most important role for sustainability indicators (EUROPEAN COMMISSION, 2018). This was the case of Amadeo et al. (2017), who proposes an Urban Sustainability Index, applying it to development in Palhoça, Santa Catarina, evaluating infrastructure, mobility, environment, governance, energy, economy, and people, defining performance for it. Gonçalves et al. (2020), for example, evaluated urban sustainability using a multi-method approach, combining the Blue House Seal and Sustainable Building Tool (SBTool), urban certification tools, in a social housing project.

From the analysis of Chart 1 also, some studies use quantitative or qualitative analysis for the studies. The quantitative approach allows easy comparison between phenomena / environments / areas. Pereira et al. (2020), for example, used the Municipal Sustainable Development Index (IDSM), to assess sustainability in the municipality of Parauapebas, Pará. The result found by the authors evidenced that the city has an acceptable level of sustainability (PEREIRA et al., 2020) from a scale, which allows comparability with other cities.

Other studies used a qualitative approach, such as Raynal et al. (2021). The authors used the method called “sustainability and quality of urban form” proposed by Andrade and Lemos (2015), which includes economic, cultural, emotional, environmental, and social sustainability. In the study conducted by Raynal et al. (2021) in two social interest housing condominiums, the authors checked whether the principles cited are met (yes), not met (no) or not applied to the case (N/A), providing a qualitative sign.

Some evaluated works did not use indicators to assess urban sustainability. This was the case with Larbi et al. (2021). The authors compared two cities, Freiburg, and Curitiba, through a method called Multilevel Perspective, which uses a systematic approach to examine the processes and dynamics of socio-technical transitions, with a clear distinction between the internal and external factors that influence these processes, exploring strengths and identifying limitations (LARBI et al., 2021).

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ISSN eletrônico 2318-8472, volume 10, número 76, 2022

Still on the qualitative approach, Silva and Padovano (2015) evaluated the city of Cuiabá, the capital of the State of Mato Grosso. The authors applied an investigative method, going through research produced between 2011 and 2014, which resulted in urban mapping and analysis. Silva and Romero (2015) also evaluated the city of Cuiabá, from a qualitative and quantitative analysis between 2000 and 2010, with secondary data made available by public agencies.

Lopes and Guerra (2020), applied questionnaires based on the Municipal Housing Plan of the city of São Paulo, aiming to support the work of the architect responsible for the project Bairro Granja Marileusa, in the city of Uberlândia-MG, and also made field visits. Nascimento et al. (2014) used secondary data and qualitative analysis to infer the need for improvements in urban infrastructure in the city of Juazeiro do Norte, Ceará. Nunes et al. (2016) used thematic maps of land use, building height, availability of public transportation, topography, and the locations of parks and squares and discussed the urban sustainability of two neighborhoods in the city of Caxias do Sul, Rio Grande do Sul.

URBAN SUSTAINABILITY INDEXES

A further point was the index chosen to assess urban sustainability. According to the European Commission (2018), an index is a set of aggregated or weighted parameters or indicators. It was possible to identify seven indices: the Municipal Sustainable Development Index (IDSM), the Urban Sustainability Index System (SISU), the Urban Environmental Quality and Sustainability Index (IQASU), the Sustainable Development Index for Energy, Water and Environmental Systems (SDEWES), the Sustainable Building Tool (SBTool), Sustainability and Urban Form Quality (SQFU), and the Neighborhood Sustainability Assessment (NSA). Chart 2 summarizes the comparison between these indicators.

Chart 2 - Comparison between the urban sustainability indexes used in the studies

	IDSM	SISU	IQASU	SDEWES	SBTool Urban	SQFU	NSA
Dimensions							
Social	■	■	■		■	■	■
Demographic	■	■					
Economic	■					■	■
Political-Institutional	■	■		■			■
Environmental	■	■	■	■	■	■	■
Cultural	■					■	
Data type							
Primary	■	■	■	■	■	■	■
Secondary							
Results							
Qualitative						■	
Quantitative	■	■	■	■	■		■

The IDSM, proposed by Martins and Cândido (2012), includes the Social, Demographic, Economic, Political-Institutional, Environmental, and Cultural dimensions. This index evaluates the various dimensions, with a scale of 0 to 1, in which zero is the worst scenario and 1 is the best scenario. This scale enabled the aggregation of these indexes and their aggregation comparability, since the variables that make up the dimensions have

different scales. The index was used by Martins and Rodrigues (2021), Martins et al. (2017), and Pereira et al. (2020), who got results for each dimension and a general index for the cities. This is one of the limitations of this index since it applies only to cities.

The SISU according to Braga (2006, p. 51) "is composed of three thematic indexes, environmental index, political-institutional capacity index, and municipal human development index" (IDHM), all with a scale of 0 to 1, facilitating comparison and aggregation and each one relates to a set of objectives related to sustainability. These are composed of a set of indicators, which are composed of a series of variables related to the phenomena studied (BRAGA, 2006).

This method uses mostly databases, such as the Brazilian Institute of Geography and Statistics (IBGE), the Institute for Applied Economic Research (IPEA), and the National Institute for Space Research (INPE), among others. Ferreira and Vieira (2018) and Pereira and Vieira (2016) applied the SISU in two different cities and could verify environmental fragilities in both cases. This index is also limited to application in cities, since it uses the HDHM.

The IQASU has a scoring scale that ranges from 0.0 to 10.0, and its primary aim is to assist in the qualitative and quantitative analysis of the data. This index has as its core the evaluation of open spaces, their vegetation cover of squares, and respective equipment. However, the method is very limited to these factors and leaves out other important dimensions of sustainability, such as economic and demographic aspects. Silva et al. (2020) applied these indexes in some squares in the city of João Pessoa, Paraíba, and noticed deteriorated areas, evidencing that the square does not perform basic social functions.

SBTool Urban presents parameters for urban management and planning, based on the main international assessment methodologies, such as BREEAM and LEED communities for neighborhood development, and adopts quantitative assessment procedures that are flexible and adaptable to the reality of the Brazilian construction market (OLIVEIRA et al., 2020). By adopting the calculation system proposed by SBTool Urban, it is possible to assign a gradation of the sustainability level achieved by civil construction projects, which is a limitation of this index. Gonçalves et al. (2020) applied this index to a social housing project in the city of Araraquara, São Paulo, whose score was 0.32, considered low since the scale ranges from 0 to 1.

The NSA has a conceptual structure that is composed of three levels: the sustainability dimension, which comprises environmental, economic, social, and institutional aspects; twenty categories; and four indicators (MARTINS et al., 2021). This index uses as references tools BREEAM Communities; CASBEE-UD; LEED-ND; Aqua Neighbourhood. Martins et al. (2021) applied questionnaires, with a Likert scale from 1 to 5, to 124 people from 56 different cities and could see a synergy between observed urban problems and positive opinions of respondents, with emphasis on urban infrastructure, social welfare, education, safety, and urban space. The limitation of this method is that it evaluates urban sustainability only from the perspective of the residents, not using other data sources to corroborate the results.

Finally, the SQFU index works on 17 principles, 41 criteria, 92 indicators, and 104 verifiers, in four dimensions: environmental, economic, cultural, and emotional and social (ANDRADE; LEMOS, 2015). Unlike the previous indexes, this one does not have a numerical

scale, giving a qualitative perspective to the analysis. Raynal et al. (2020) applied the method to two social housing condominiums in Salvador, Bahia, and Brasília, Federal District, and could verify that there is a deficiency in infrastructure. A limitation of this index is its application, which is very much linked to civil construction projects.

One of the major difficulties in assessing urban sustainability is the availability of data. Pereira and Vieira (2016) report on the lack of data, which ended up preventing the use of some variables, drawing special attention to the lack of environmental quality data. Braga (2006) highlights the lack of data for most of the municipalities studied for soil quality data. Pereira et al. (2020) stated that the lack of data caused 3 (three) variables to be eliminated from the final calculation.

CONCLUSIONS

The results showed that the dimensions of urban sustainability have broad applicability, which includes cities, neighborhoods, and condominiums. However, the object of analysis and the choice of approach makes all the difference in assessing sustainability.

Sustainability indicators have proven to be important instruments in performance assessment and goal setting, as well as rational and valuable tools to improve the availability of information related to cities and communities with natural boundaries.

It is possible to affirm that the Brazilian legal framework positively influences urban sustainability. Moreover, municipal legislation, such as master plans and mobility plans, among other public policies, can be catalysts for sustainability, when well planned.

For future work, it is suggested to deepen the discussion of the relationship of urban sustainability indicators with the SDGs.

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