EVALUATING SUSTAINABLE TERRITORIAL DEVELOPMENT WITH BUILT CAPITAL INDICATORS

AVALIAÇÃO DO DESENVOLVIMENTO SUSTENTÁVEL DO TERRITÓRIO UTILIZANDO INDICADORES DE CAPITAL CONSTRUÍDO

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ABSTRACT

In order to bolster the concept of sustainable territorial development in conjunction with the three capitals — natural, social, and built capital —, a conceptual methodology was elaborated. It utilized the infrastructure systems to group indicator dimensions of built capital, highlighting what actually corresponds to the territorial development reality and not just economic growth. This resulted in the selection of 70 indicators that were tested with data from the Curitiba Metropolitan Region (CMR). Thirty-five indicators were selected from the data available to evaluate the development in 29 municipalities that form the CMR. Finally, the Sustainable Territorial Development Index (INFRASTDI) and Inequality Index (II) were proposed to summarize the information collected.

Keywords: capital theory; urbanization; indicator framework; infrastructure; method; inequality index.

RESUMO

Para reforçar o conceito de desenvolvimento territorial sustentável em conjunto com os três capitais — natural, social e construído —, foi proposta uma metodologia conceitual. Os sistemas de infraestrutura foram empregados para agrupar as dimensões de indicadores do capital construído, destacando o que corresponde à realidade do desenvolvimento territorial e não apenas o crescimento econômico. Isso resultou na seleção de 70 indicadores que foram testados com dados da Região Metropolitana de Curitiba (RMC). Um total de 35 indicadores foi selecionado com base nos dados disponíveis para avaliar o desenvolvimento em 29 municípios que formam a RMC. Por fim, o Índice de Desenvolvimento Territorial Sustentável (INFRASTDI) e o Índice de Desigualdade (II) foram propostos para sintetizar as informações coletadas.

Palavras-chave: teoria dos capitais; urbanização; modelos de indicadores; infraestrutura; método; índice de desigualdade.

INTRODUCTION

Since the publication of the Brundtland Report in 1987, the theme of sustainable development has been the subject of innumerous debates motivated by the necessity to seek new productive and technological processes that can, at a minimum, combine the concept of sustainability to that of development. This entails the explicit attempt to draw a new economic paradigm that considers impacts on natural resources and guarantees social justice.

In this report, sustainable development is understood as the management of resources in such a manner as to guarantee the existence of these resources for current and future generations, considering potential gains and losses in different temporal and spatial scales. This recognizes that the concept is not static, but it is a process of change immersed in the complexity of elements that surround the quality of human life.

The discussions about sustainability indicators also emerged from the Brundtland Report and from Agenda 21, elaborated at the United Nations Conference on the Environment in Rio de Janeiro, 1992. Sustainability indicators evolved from "environmental indicators", developed in the 1980s, and "indicators of sustainable dimensions", developed in 1990. Based on Malheiros *et al*. (2012), Cavalcanti *et al*. (2017a, p. 334) defined sustainability indicators "as a way to materialize the concept of sustainability and at the same time integrate its dimensions".

In order to aid the efficacy of public policies, the creation of space-delimited indicators is important, starting with the municipal realities since they are closer to the needs of the population (SCHWARZ, 2010).

However, indicator development has traditionally been focused on environmental, social and economic dimensions, often not considering the systemic nature of development, leaving out an important aspect, viz., infrastructure systems, which are part of the built capital. This gap was confirmed by a literature search conducted on August 03, 2018 through Portal de Periódicos da Capes (http://www-periodicos-capes-gov-br.ez129.periodicos.capes.gov.br/), which congregates 491 databases, including Compendex, PubMed, Scopus, Springer, Web of Science, to name only a few. The search was performed using the terms "Built Cap-

ital" to select articles from peer-reviewed journals, resulting in 1,097 articles. These results were filtered, selecting the descriptor "Infrastructure" (343), publication period 2010/2018 (186), and topics related to "sustainability" and "urbanization", leading to 72 articles. Among these, 30 papers presented a built capital approach from the perspective of urban infrastructure, and only 10 studies considered this perspective for the development of indicator systems.

Built capital, according to Meadows (1998), comprises the physical structures built by men. It is the infrastructure, services, industry, highways, technological and scientific equipment, among others. Thus, the present work focuses on indicators of infrastructure as part of the built capital.

Authors such as Furtado (1974), Polanyi (2012), Sachs (2008), and Max-Neef (1993) consider infrastructure as the fundamental element of built capital and the fundamental dimension of development, as well as natural and social capital. Access to appropriate infrastructure can significantly improve the quality of life in communities and their socioeconomic outcomes, also influencing consumption patterns, and contributing to ecological awareness. This evidences the importance of evaluating sustainable territorial development through built capital indicators (HEGARTY & HOLDSWORTH, 2015; KALTENBORN *et al*., 2017).

The present framework was developed while looking at the Curitiba Metropolitan Region (CMR), seeking to identify sustainable territorial development in metropolitan regions. It is important that public policies aimed at metropolitan regions, and not isolated cities, be based on indicators that reflect both local and regional realities. Thus, the present work contributes to the debate about sustainable development considering both local population aspects and public services policies.

In the following pages, a literature review is presented on sustainable territorial development, considering infrastructure as a representation of built capital, and indicators. After the methods section, the results present the 70 indicators selected for the assessment of sustainable territorial development, as well as the 35 indicators employed to assess the CMR. Combina-

tion of the selected indicators resulted in two indices for the region: one of sustainable infrastructure and another of inequality between the infrastructure of the municipalities that compose the metropolitan region. The latter allows analysis of the sustainable development asymmetry at the regional level.

BACKGROUND

Sustainable territorial development

Chapter 28 of Agenda 21 highlighted that many of the problems it treated have their origins in local activities. The text recognizes that it is local public power that constructs, operates, and maintains economic and social infrastructure that impacts the environment, establishing the local processes and reflecting the execution of regional and national development policies (UNITED NATIONS, 1992).

The importance of local power is increasing with the recognition that in the territory are the critical challenges for human and sustainable development in all its dimensions. Initiatives such as the New Urban Agenda (UNITED NATIONS, 2017) and the Agenda for Sustainable Development 2030 have set the goal of making cities and human settlements inclusive, resilient and sustainable. The movement to seek sustainable actions from the public authorities closest to the population highlighted cities as a central point of sustainable development because it is the location of most activities and people (KLOPP & PETRETTA, 2017).

Taking the local territory as a starting point of development that directly affects the population permits a systematic analysis of sustainable development that is only viable if all the parts that compose the whole are identified and addressed (FÜRST *et al.*, 2013). The maturation of themes connected to the environment views the local economy and its spatial relations in relation to sustainable territorial development (BOSSEL, 1998).

Sustainable territorial development is argued by Dallabrida (2011) as a structural process, which constitutes a territoriality, employed by an organized society, sustained by the potential local natural resources, tangible and intangible, that reorganizes the socioeconomic relations and aims to improve the population's quality of life. It also aims at: a synchronic solidarity with the current generation and a diachronic solidarity with future generations; assured access to basic conditions of universal healthcare and education; and a respect for customs and traditions, as well as the legitimacy of institutions (SACHS, 2006).

According to Champollion (2006), territoriality is an inter and transdisciplinary concept with contribution from several disciplines, such as Geography, Anthropology, and Sociology, involving macro themes such as environmental issues, urban planning, and land use. Territoriality has two origins, legal and ecological, and three dimensions: an existential one (life), a physical one (frame) and an organizational or symbolic one (society). At the same time, it is also a human and social construction in which identity is produced (HOROCHOVSKI *et al.*, 2011; SOUZA *et al.*, 2013).

The idea of sustainable territorial development reinforces the importance given by Agenda 21 to local actions. The objective is to stimulate reflections, discussions, conflict resolution, stakeholder integration, and synergy with sustainable development (BAYULKEN & HUISINGH, 2015).

In the urban reality of large cities, it is important to note that the territory is not only in the city, as indicated by Local Agenda 21, but includes all of the cities in the surrounding region. Given the inert interdependence among the spaces arising from human activities (SILVA & FORTUNATO, 2007), the surrounding municipalities cannot be ignored.

Public policy management, during sustainable territorial development processes, should be more effective at improving the quality of goods and services offered to local populations. The implementation of these policies is, nevertheless, difficult and complex, facing uncertainties, diverging interests, different levels of government, and other restrictions. For more assertive decision-making, it is important to have management tools, such as indicators, that can recognize the complexity and structurally organize it (SCHWARZ, 2010; SANTANA *et al.*, 2011).

Indicators created from local information permit a view of the scenario much closer to reality. This leads to indicators that hold greater relevancy and are more comprehensible of diverse interests, guaranteeing greater representation (COUTINHO, 2006; CENTRULO *et al.*, 2013) alongside the possibility for more effective political action (MARTINET, 2011).

There are many initiatives on sustainable local-level indicators (HENDRICKSON, 2010; COX *et al.*, 2010; MAES *et al.*, 2011; ZHANG *et al.*, 2011; KUSAKABE, 2013; MARTIRE *et al.*, 2015; LUPOLI & MORSE, 2015; CARLSSON *et al.*, 2017; GINÉ-GARRIGA *et al.*, 2016; PATEL *et al.*, 2017; GALLI *et al.*, 2018), but it is observed that few studies effectively address the interaction between local and regional situations, which could be the basis for an analysis of existing inequalities in the region.

To select indicators that are closer to the local reality, Mascarenhas *et al.* (2010) propose a method that allows local sustainability managers to identify local strengths and weaknesses, evaluate ideas and potential actions. More important than assessing the conditions of the municipality is to identify the asymmetries between the neighboring municipalities of the same region with the objective of fomenting new ideas for jointly managing resources shared by all.

Thus, the proposed methodology classifies the indicators based on the natural, social and built capital typology (MEADOWS, 1998), and selects built capital, since infrastructure has great influence on the other two capitals, and it is where a community concentrates its developmental efforts (MEADOWS, 1998; BROCK-LESBY & FISHER, 2003; MULDER *et al.*, 2006; FLORA, 2008). Built capital is fundamental to achieve sustainable development, either through technocentrism that prescribes the responsibility of replacing natural capital with built capital, or the ecocentric vision, in which the built capital complements natural capital over time. Economic theories of sustainable development consider the creation of infrastructure, investment in technology and other manufactured goods essential for the sustainability and well-being of the population. However, because it is often considered an element of economic growth and not part of an integrated development of sustainability, built capital is not adequately explored in the literature (SIRGY, 2011). Natural and social capital indicators are abundant in the literature, but there are few studies that explore built capital, notwithstanding its irrefutable importance for the development and for the assessment of sustainability. Therefore, studies are necessary in this sense, as sought to accomplish here.

This work also proposes a sustainability index and an inequality index to identify differences in infrastructure between metropolitan cities.

Infrastructure systems representative of built capital

The theme of sustainable development involves human, ecological, political, and economic elements that are integrated, which often impedes distinguishing one element from another.

Thus, conceptually separating the elements as a study strategy aims to satisfy the plentitude that the theme demands. The dimensions brought by Sachs (2008) are one strategic approach in this direction. Meadows proposes a systematic structure of the economy, separated into three capitals. Natural, built and social capitals all collaborate for the same sustainable development objective: well-being (MEADOWS, 1998).

The integrated relationship of the capitals is constant, and built capital can increase or decrease the quality of the other capitals (FLORA, 2008). Sustainability on the level of built capital means to invest at least as fast as the capital is depreciated (COMOLLI, 2006). Cross sustainability means maintaining the flux required by built capital within the sustainable returns and capacities of primary resources — natural capital (MEADOWS, 1998).

Here, Meadows' (1988) definition of built capital is adopted. It is an intermediate means that associates man's technology and the created improvements to promote a larger goal, i.e., well-being, without which the development would be disqualified. Built capital, for Meadows (1998), combines the characteristics of being the production capacity of the economy, of growing by investment, and decreasing by depreciation or obsolescence. It is also a transformer of natural capital, thus controlling its use (O'CONNOR, 2000; KARVONEN, 2001; COMOLLI, 2006). Furthermore, built

capital is auto-reproducing (the larger the investment in production, the larger the production and the larger the investment), which the author identifies as a feedback circuit.

In the literature, built capital is defined by its representations. For Flora (2008), it is the infrastructure that supports the community, including the services of telecommunications, industrial parks, water and wastewater treatment systems, highways, and technological and scientific equipment. Often this built capital is the focus of a community's efforts to develop.

Brocklesby and Fisher (2003) include in this category highways, heavy equipment, factories, houses and apartments, in addition to the basic necessities such as food and clothing. They also include items that are not indispensable, but are a part of daily life, such as washing machines, dishwashers, cars, telephones, and computers.

Income and financial flows can be categorized as financial capital (BROCKLESBY & FISHER, 2003; FLORA, 2008), but are considered by Meadows (1998) and Mulder *et al*. (2006) as aspects of built capital.

Built capital is underexplored in the sustainable development studies; the theme is usually related to the natural and social capitals. According to Parkin *et al*. (2003), there are only two true sources of wealth that are the basis of any development process: the Earth (natural capital), and human capacities (human and social capital). Everything else derives from these two primary sources. However, the infrastructure, representative of built capital, is made up of the constructions and public services essential for the quality of human life in their territory, needs to be considered when dealing with sustainable development.

With the aim of improving result measurements, Meadows (1998) subdivided built capital among intertwined categories that remain aligned with the principle of built capital, as well as physical structures built by men. Among these categories is public infrastructure capital exemplified by highways, ports, bridges, and sanitation. The author highlights the public infrastructure category, since it is the base of the economy, which is reflected in all other categories of built capital.

Public infrastructure was then selected to represent built capital, since it is defined as that infrastructure which supports the life of a community (BROCKLESBY & FISHER, 2003; FLORA, 2008), and also highlighted as the principal category of built capital by authors such as Meadows (1998) and Mulder *et al*. (2006).

It was then necessary to select among all infrastructure systems those fundamental to the structure of civil life. These consisted of basic public subsidies for local development, capable of stimulating economic movements, and generating demand for new structures. With the infrastructure systems defined, the corresponding indicators were compiled.

Aiming to develop adequate infrastructure indicators for the current reality of the CMR — similar work was conducted by Cavalcanti *et al*. (2017a; 2017b), focusing on urban mobility projects in Curitiba —, a method was developed to select and analyze indicators that measure sustainable territorial development.

METHOD

The method adopted in this work is similar to that described by Bardin (2007) in his content analysis method, including: pre-analysis, exploration of the material, and treatment of the results.

In the first stage, indicator systems were selected from international organizations — United Nations (UN), World Bank, Organisation for Economic Co-operation and Development (OECD) —, universities and government institutions from countries such as Canada, the Netherlands, the United States, the United Kingdom and the European Union. The indicators that make up each selected system were classified in the categories proposed by Meadows (1998) of natural, social and built capital. For the second stage, only the built capital indicators were used. Based on the theoretical references described, a search was made in the literature of infrastructure systems considered part of the core of public buildings and services relevant to local development.

As a result, the cited systems were compiled as the basis of public infrastructure for economic activation and basic quality of life for the population: transpor-

tation, sanitation, health, education, energy, housing, communication.

Urban infrastructure is part of the concept of sustainable development and directly related to the well-being of the population. Urban policy projects are one of the most challenging problems for public managers, since rapid urbanization has increased the need for better governance of cities (ZHANG & LI, 2018). The limit of the substitution of natural capital by built capital, one of the bases of the theory of weak sustainability, defended by neoclassical economics, is also a question of management of public infrastructure and integrates the perspective of sustainable development (RAMOS & CAEIRO, 2010).

The capital indicators selected in the first stage and also present in the indicator systems selected in the second stage make up the final selection. This resulted in the 70 indicators listed in Tables 1 to 7.

The second phase of the content analysis method of Bardin (2007) deals with the exploration of the material, in which the collected textual material is submitted

to an in-depth study, guided by theoretical references, as happened in the analyses following the selections from the first phase.

The third phase involves the treatment of the results, highlighting information for the elaboration of conclusive interpretations, making a reflexive and critical analysis possible. Corresponding to the last step, the indicators relevant to the CMR were selected.

For this last stage, a survey was carried out in national official databases — Instituto Brasileiro de Geografia e Estatística (IBGE), Instituto Paranaense de Desenvolvimento Econômico e Social (IPARDES), Federação das Indústrias do Estado do Paraná, Government of the State of Paraná, Ministries, Government Agencies, City Halls —, in search of data concerning the 70 indicators. Absence of data or inadequacy of existing official data were criteria for discarding indicators (SICHE *et al*., 2007). Thus, 35 indicators of infrastructure were obtained from the perspective of territorial development for the CMR, aligning the concept of sustainable development with the identity of the territory.

RESULTS

The review of the literature identified 23 indicator models that are described in the Appendix, which encompass 7 infrastructure systems and 70 indicators. Most of these indicator models, 20 of 23, were proposed by international organizations involved in the sustainable development debate. The infrastructure systems comprise: transportation, sanitation, health, education, energy, housing, and communication. Tables 1 to 7, each pertaining to one of the infrastructure systems, present the indicators found, which are related to built capital, in descending order of occurrence in the models. These indicators cover broad aspects of infrastructure, and validation in the territory is important to ensure that they adequately represent geographic, social, and cultural realities.

Table 1, showing the transportation system, offers an example of the importance of considering indicators under the perspective of the specific territory: indicators evaluating the existence of ports and maritime transportation services are only relevant to coastal territories. Other indicators, such as train

transportation, the ability to travel by train, high speed trains, and river transportation, also were not utilized for CMR due to the absence of these services in the region, even though they are considered good infrastructure indicators according to the criteria proposed by Meadows (1998), fulfilling the conditions of content, efficiency, and relevancy. Table 2 shows the indicators for the sanitation system, the only type of infrastructure for which all indicators were included in the evaluation of the CMR. Heeding the precepts of Siche *et al*. (2007), they can capture the available information, permitting the analysis of territory scenario and reflect on the combination of public policies in the area of sanitation.

The health and education systems, listed in Tables 3 and 4, respectively, were considered as infrastructure, but could also be classified as social capital (MEADOWS, 1998). Their inclusion seeks to include in the analysis the infrastructure built for the health and education sectors, even if some of the indicators selected provide indirect measurement of the available infrastructure.

Table 1 – Compiled transportation system indicators in descending order of occurrence in the researched indicator models that consider built capital.

Number of occurrences	Indicator acronym	Indicators (framework – Appendix)
6 – Maximum	TRANS 1	Highways (km) **(1,3,10,12,14,18)**
6	TRANS 2	Public transport coverage (km) (**5,6,7,12,14,18**)
6	TRANS 3	Number of automobiles per inhabitant (**5, 6,7,8,14,19**)
4	TRANS 4	Railways (km) **(1,10,12,18)**
3	TRANS 5	Number of airports **(8, 10, 18)**
2	TRANS 6	Bicycle lanes (km) (**5,7**)
2	TRANS 7	Pedestrian walkways **(5,7)**
2	TRANS 8	Number of ports **(10,18)**
1	TRANS 9	Condition of roads and bridges **(7)**
1	TRANS 10	Availability of maritime freight transport **(8)** (yes/no)
1	TRANS 11	Availability of railway freight transport **(8)** (yes/no)
1	TRANS 12	Availability of highway freight transport **(8)** (yes/no)
1	TRANS 13	High speed trains (km) **(8)**
1	TRANS 14	River transportation (yes/no) **(8)**
1	TRANS 15	Number of seats in public transportation **(5)**

Table 2 – Compiled sanitation system indicators in descending order of occurrence in the researched indicator models that consider built capital.

Number of occurrences	Indicator acronym	Indicators – (framework – appendix)
15	SAN 1	Number of residences connected to the drinking water network **(2,4,5,7,8,9,10,12,13,14,15, 16,17,19,22**)
14	SAN 2	Number of residences connected to the wastewater network (**2,4,7,8,9,10,12,13,14,15,16,17,19,22**)
4	SAN 3	Volume of solid wastes collected (m³) **(5,6,7,17)**
4	SAN 4	Adequate destination of collected wastes **(12,15,16,22)**
3	SAN 5	Screening and treatment of urban water (m³) **(8,15,16)**
2	SAN 6	Coverage of the domestic waste collection services (%) **(8,16)**
2	SAN 7	Coverage of the recyclable waste collection services (%) **(5,16)**
1	SAN 8	Number of solid waste landfills **(7)**
1	SAN 9	Volume of wastes deposited in landfills **(7)**
1	SAN 10	Utilized portion of the water abstracted from sources (%) **(8)**
1	SAN 11	Water intensity* (m³/currency unit $) **(6)**
1	SAN 12	Investment in water system update (% GDP) **(17)**

*According to Grimoni *et al*. (2004), water intensity is the total water demand divided by the gross domestic product (GDP).

Table 3 – Compiled healthcare system indicators in descending order of occurrence in the researched indicator models that consider built capital.

Number of occurrences	Indicator acronym	Indicators (framework – appendix)
4	HLTH 1	Inclusion in the healthcare system (% of the population) **(11,12,16,22)**
2	HLTH 2	Public investment in healthcare (% of GDP) **(7, 19)**
2	HLTH 3	Number of health establishments **(8,12)**
2	HLTH 4	Number of hospital beds offered per 1000 inhabitants **(8,22)**
2	HLTH 5	Efficiency: average length of stay **(5,11)**
1	HLTH 6	Infant mortality rate (for every 1,000 live births - UN) **(10)**
1	HLTH 7	Life expectancy **(10)**
1	HLTH 8	Healthcare costs (% of GDP) **(11)**
1	HLTH 9	Number of doctors per inhabitants **(5)**
1	HLTH 10	Number of hospital admissions –patients admitted per day **(5)**
1	HLTH 11	Quality – % of satisfied persons in the public healthcare system **(11)**
1	HLTH 12	Hospital infection***(3)**

UN: United Nations; *according the National Agency of Sanitary Surveillance (ANVISA, 2016), hospital infection is the number of primary bloodstream infections related to the use of a central venous catheter, in patients interned at an ICU of 10 or more beds, per 1,000 interments.

The connection between the health and education sectors and sustainable development, translated as the well-being of the population, is underexplored in the literature. Thus, the present work aims to contribute to the discussion and the evaluation of the health and education sectors as infrastructure systems, representative of built capital.

The indicators for the education system, listed in Table 4, included those used in the school census by the Ministry of Education that reflect the infrastructure conditions of the educational establishments in the municipalities.

The infrastructure conditions of public elementary, secondary and adult schools were analyzed through the indicators recommended by Unesco in the document Monitoring Education Indicators Agenda 2030 (UNESCO, 2015):

- accessible toilets;
- accessibility for people with physical limitations;
- public energy network;
- water system network;
- clean drinking water;
- internet;
- computers available to students;
- computers available for pedagogical support.

The School Census (BRASIL, 2010) reports the percentage of total public elementary, secondary, and adult schools in each municipality that satisfy Unesco indicators. The ideal to be achieved is that all existing educational establishments fulfill the indicated criteria.

An index (INFRACON) was calculated for each level of education, using indicators a-f from the list above, and assigning equal weights to all.

**Table 4 – Compiled education system indicators in descending order of
occurrence in the researched indicator models that consider built capital.**

Number of occurrences	Indicator acronym	Indicator (framework – appendix)
5	EDU 1	Primary education enrollment rate (% - of enrolled per age group) **(4,8,12,17,19)**
4	EDU 2	Secondary education enrollment rate (% - of enrolled per age group) **(4,8,17,19)**
3	EDU 3	Higher education enrollment (% - number of enrolled per age group) **(4,17,19)**
3	EDU 4	Public investment in education (% of GDP) **(8,10,19)**
3	EDU 5	Access and coverage of public education(% population) **(11,12,19)**
2	EDU 6	Adult enrollment rate (% - number of enrolled per age group population) **(7,8)**
1	EDU 7	Number of daycare spots (% - number of spots per age group population) **(7)**
1	EDU 8	Number of preschool spots (% - number of spots per age group population) **(7)**
1	EDU 9	Number of schools in sustainable school programs (% - per number of schools) **(7)**
1	EDU 11	Professional secondary education enrollment (ratio between professional and non-professional secondary education enrollment - %) **(8)**
1	EDU 12	Research investment (% of GDP) **(10)**
1	EDU 13	Teaching quality –Basic Education Development Index (BEDI) based on the National Institute of Studies and Research (Inep) of the Ministry of Education (MEC) combined yield data. **(11)**
Ministry of Education	INFRACON 1	Infrastructure conditions of elementary schools (% schools meet Unesco indicators)
Ministry of Education	INFRACON 2	Infrastructure conditions of secondary schools (% schools meet Unesco indicators)
Ministry of Education	INFRACON 3	Infrastructure conditions of adult schools (% schools meet Unesco indicators)

GDP: gross domestic product; Unesco: United Nations Educational, Scientific and Cultural Organization.

**Table 5 – Compiled energy system indicators in descending order of
occurrence in the researched indicator models that consider built capital.**

Number of occurrences	Indicator acronym	Indicators (framework – appendix)
9	ENE 1	Energy consumption (MWh) **(2,4,5,7,8,9,16,19,23)**
2	ENE 2	Energy produced with the use of fossil fuels (% of energy consumed) **(3,23)**
2	ENE 3	Sustainable energy production (% of energy consumed) **(8,20)**
2	ENE 4	Coverage area of the electricity grid (number of households with energy connection) **(12,22)**
2	ENE 5	Efficiency/energetic intensity* (kWh/ currency unit $). **(6,16)**
1	ENE 6	Energy produced using wood as a source (% percent of energy consumed) **(3)**
1	ENE 7	Energy generation (TWh) **(8)**
1	ENE 8	Investment in new energy plants (% of investment in the total sector) **(18)**
1	ENE 9	Investment in research and development (R&D) of energy (% of GDP) **(20)**
1	ENE 10	Fuel Intensity** (L/currency unit $) **(6)**

GDP: gross domestic product; *according to Grimoni *et al*. (2004), efficiency/energetic intensity is the quantity of energy used for economic production divided by the GDP; **according to Grimoni *et al*. (2004), fuel Intensity is the quantity of fuel used for economic production divided by the GDP.

**Table 6 – Compiled housing system indicators in descending order of
occurrence in the researched indicator models that consider built capital.**

Number of occurrences	Indicator acronym	Indicators (framework – appendix)
6	HOME 1	Number of residences in relation to the total population **(3,5,7,8,16,19)**
1	HOME 2	Investment in low-income housing (% of GDP) **(7)**
1	HOME 3	Number of urban settlements **(19)**
1	HOME 4	Investment in low-income lodging (% of GDP) **(19)**
1	HOME 5	Housing coverage (Brazilian Ministry of Cities)

**Table 7 – Compiled communication system indicators in descending order of
occurrence in the researched indicator models that consider built capital.**

Number of occurrences	Indicator acronym	Indicators (framework – appendix)
5	COMM 1	Access to the Internet by number of inhabitants **(2,4,8,16,18)**
3	COMM 2	Access to the telephone network by number of inhabitants. **(4,16,22)**
2	COMM 3	Access to mobile telecommunications by number of inhabitants **(18,22)**
1	COMM 4	Number of inhabitants included in some communication system **(10)**

The number of computers available to students and pedagogical support were not used in the calculation of the index because that information does not depict the situation properly, since ratios of computers to the respective populations would be more adequate to portray infrastructure conditions, and not simply totals.

For the energy system, detailed in Table 5, only two indicators were included (ENE 1 and ENE 4) for the evaluation of CMR, because of the lack of data for the others. The utility company for the state of Paraná, Copel, presents its data for the state as a whole and not by municipality.

Table 6 lists the indicators compiled for the housing infrastructure system. The indicator "number of residences in relation to the total population" (HOME 1) is highlighted because it is the basis for calculating the housing conditions of the population.

There are studies in Brazil that indicate the occurrence of a housing deficit in the country. The main component of the calculation of the housing deficit, in quantitative terms, is based on the subtraction of the total number of families from the total number of households. There will be a housing deficit when the number of families is greater than the number of households (ALVES & CAVENAGHI, 2007).

By this method, there is no housing deficit in the municipalities of the CMR, because the number of households is greater than the number of families, considering the different categories of domicile and the concept of family defined by research institutes IBGE and IPARDES.

Another method, adopted by the federal government through the Ministry of Cities (FURTADO *et al.*, 2013), was developed by the João Pinheiro Foundation and uses qualitative indicators (precarious, rustic or improvised households, families residing in rooms, households whose rental value exceeds 30% of total household income, and three or more people residing in the same room), showing the existence of a housing deficit in Brazil.

The result obtained by the João Pinheiro Foundation's method was adopted as the indicator "housing coverage" (HOME 5).

Among the indicators compiled for housing and communication, listed in Tables 6 and 7, respectively, only one indicator for each system was discarded (HOME 4 and COMM 4) due to imprecise definitions. Indicators must have clear content and no uncertainty in the direction, using units that make sense (BELLEN, 2005; SICHE *et al.*, 2007; PHILIPPI JR. & MALHEIROS, 2012).

Indicator HOME 4 was discarded due to the lack of specific data for the CMR and also due to uncertainty regarding what it exactly attempts to measure (MEADOWS, 1998). Additionally, once the available information was found regarding the expenditures of the municipalities, it was not clear if this responded to the indicator.

COMM 4, which establishes the "number of inhabitants in some communication system", was discarded since it did not stated which indicator system it intended to measure nor how it would be operationalized.

The compiled indicators must be contextualized to the territory being evaluated so that they may effectively measure sustainable territory development.

ANALYSIS AND DISCUSSION

The compiled indicators were tested with data from the CMR in order to verify their capacity of measuring the quality of development for those municipalities integrated in the metropolis. Among the 70 available, 35 indicators were included in this evaluation, which are listed in Table 8.

In order to facilitate interpretation of the results for each infrastructure system, an index (Sustainable Territory Development Index—STDI), defined as the arithmetic mean of the included indicators, was created. The sum of the infrastructure indices divided by the number of systems formed the Sustainable Territorial Development Index (INFRASTDI). In agreement with Mayer (2008), aggregating indicators in an index provides a system overview, and when calculated periodically indicates if this system is becoming more or less sustainable, identifying strengths and weaknesses (CAETANO, 2013). Sustainability indices are specifically developed to aid decision-makers. The INFRASTDI synthesizes the current

Table 8 – The 35 indicators included for evaluation of the Curitiba Metropolitan Region (CMR).

Infrastructure system	Indicator acronym	Indicator
TRANSPORT	TRANS 2	Public transportation coverage (km)
	TRANS 3	Number of automobiles per inhabitant
	TRANS 5	Number of airports
	TRANS 6	Bicycle lanes (km)
SANITATION	SAN 1	Number of residences connected to the drinking water network
	SAN 2	Number of residences connected to the wastewater network
	SAN 3	Volume of solid wastes collected (m³)
	SAN 4	Adequate destination of collected wastes
	SAN 5	Screening and treatment of urban water (m³)
	SAN 6	Coverage of the domestic waste collection services (%)
	SAN 7	Recycled waste collection services coverage (%)
	SAN 8	Number of solid waste landfills
	SAN 9	Volume of wastes deposited in landfills
	SAN 10	Water collection capacity (m³)
	SAN 11	Water intensity
	SAN 12	Investment in water renewal (%GDP)
HEALTH	HLTH 3	Number of health establishments
	HLTH 4	Number of hospital beds offered per 1,000 inhabitants
	HLTH 8	Healthcare costs (% of GDP)
	HLTH 9	Number of doctors per inhabitants
EDUCATION	EDU 4	Public investment in education (% of GDP)
	EDU 5	Access and coverage of public education (% population)
	EDU 11	Professional secondary education enrollment (average with the normal secondary education enrollment rate.
	INFRACON 1	Infrastructure conditions of elementary schools (% schools meet Unesco indicators)
	INFRACON 2	Infrastructure conditions of secondary schools (% schools meet Unesco indicators)
	INFRACON 3	Infrastructure conditions of adult schools (% schools meet Unesco indicators)
ENERGY	ENE 1	Energy consumption (% variation of GDP)
	ENE 4	Electricity grid coverage
HOUSING	HOME 1	Number of residences in relation to total population
	HOME 2	Investment in low-income housing (% of GDP)
	HOME 3	Number of urban settlements
	HOME 5	Housing service
COMMUNICATION	COMM 1	Access to the internet by number of inhabitants
	COMM 2	Access to the telephone network by number of inhabitants.
	COMM 3	Access to mobile telecommunications (number of inhabitants)

GDP: gross domestic product; Unesco: United Nations Educational, Scientific and Cultural Organization.

situation of the system, but it is important to note that indices do not capture all phenomena occurring in a system, such as technology change or the adaptability of social systems (SICHE *et al.*, 2007).

The INFRASTDI does not aggregate the information of all the selected indicators, but only those that could be expressed numerically. Similarly to Zeijl-Rozema and Martens (2010) and Allen *et al.* (2017), relating the numerical indicator to other assessment measures allows for a more meaningful sustainability analysis. Thus, it should be analyzed in conjunction with the additional indicators of a more qualitative nature, such as in the case of the sanitation infrastructure indicator "adequate destination of collected wastes" (SAN 4), because it shows that municipalities can still use dumps as the destination of their wastes.

For each infrastructure system, a scale classifying the sustainable territorial development of built capital for the municipalities of the CMR was constructed based upon the INFRASTDI results. Following the methodology described by Li and Li (2017), the scale was developed arbitrarily, prioritizing a strong sustainability assessment, considering critical limits for the replacement of natural capital by built capital. The scale considered the level of development high for those municipalities whose score was higher than 80%, medium for scores between 41 and 80%, and low for those with scores below 40%, based on the perception of the authors upon examining the results and considering the apparent/observed levels of development of each municipality. It should also be noted that this subjectivity in the definition of ranges means that these limits should only be applied to the CMR.

The region average indices for each system, as well as the INFRASTDI for the CMR, are shown in Table 9.

The lack of integrated investments in the CMR increases the rising inequality, affecting the development level of cities with better conditions, which have their infrastructure overused and overburdened by the populations of adjacent cities, making the index values, in practice, lower than those calculated.

Figure 1 shows the STD level classification of the CMR cities according to the INFRASTDI values. The scale proposed here considers five levels of development — low, medium low, medium, medium high, and high — to consider the existing amplitude among the cities' levels of development.

No city was classified as having a high level of development. Curitiba had the highest result with 72%. The small differences observed between the development levels of various cities as shown by the INFRASTDI adds to the common criticism of indices, which is that the aggregation of information masks heterogeneous situations through the summation of data (SICHE *et al.*, 2007).

Comparing the average values for the CMR, listed on Table 9, with the data shown on Figure 1 reveals that only Curitiba and São José dos Pinhais have INFRASTDI values above the CMR average. This exposes the mismatch of development in the region that could be of interest to the smaller peripheral cities that compose the region, justifying the need for better infrastructure. Different degrees of sustainability among municipalities in the same metropolitan region were also identified by Carli *et al.* (2018). The discussion stresses the need for effective integrated management of municipal services, infrastructure and communication networks at the metropolitan level, evaluated by a set of indicators consistent with the overall sustainability goal for the metropolis (GIATTI, 2013).

In search of a more precise analysis, the results of the STD classification shown in Figure 1 allow for an inequality analysis and the respective existing levels of integration among the CMR cities, furthering the findings of Queiroz Ribeiro *et al*. (2012). To investigate unequal development among the cities, the Curitiba Metropolitan Region Inequality Index (CMRII) was created. This calculates the percentage deviation between the largest INFRASTDI city, Curitiba (72) and the INFRASTDI value of each city for each infrastructure system (Table 10).

Equations 1 and 2 indicate the manner in which the II was calculated, for each infrastructure system. Equation 1 expresses the calculation of the II for each city, while Equation 2 shows how the region average is calculated, weighted by population.

$$II_{Municipality,\,system} = \frac{(Highest\,STDI\,Value_{system} - STDI_{Municipality,\,system})}{Highest\,STDI\,Value_{system}}.100 \quad (1)$$

In which:

$II_{Municipality,\,system}$ = the Municipal Inequality Index for each specific infrastructure system;

Highest STDI Value $_{system}$ = the largest result obtained for the STDI among the cities for each specific infrastructure system;

STDI$_{Municipality}$ = the STDI value for the city for each specific infrastructure system.

The average Inequality Index for the CMR is defined as the weighted average of the Municipal Inequality Indices, taking population as the weight (Equation 2).

$$(II)_{CMR, system} = \frac{\sum[(II)_{Municipality, system} \cdot \text{Municipal Population}]}{\sum \text{Municipal Population}} \quad (2)$$

The results for the inequality index show the lack of homogeneity in the region's development. The inequality in some systems, such as transport (19.85%) and education (18.48%), is very large when compared to the energy sector (0.13%). Figure 2 shows the inequality index (II) for all cities in the CMR.

Table 9 – Curitiba Metropolitan Region (CMR) averages for each infrastructure system index and for the Sustainable Territorial Development Index (INFRASTDI).

Infrastructure system	Index	CMR value (%)	INFRASTDI CMR (%)
Transportation	IDTSTRANS	75.90	
Sanitation	IDTSSAN	77.86	
Healthcare	IDTSHLTH	67.73	
Education	IDTSEDU	68.78	**67.64**
Energy	IDTSENE	99.87	
Housing	IDTSHOME	91.57	
Communication	IDTSCOMM	58.86	
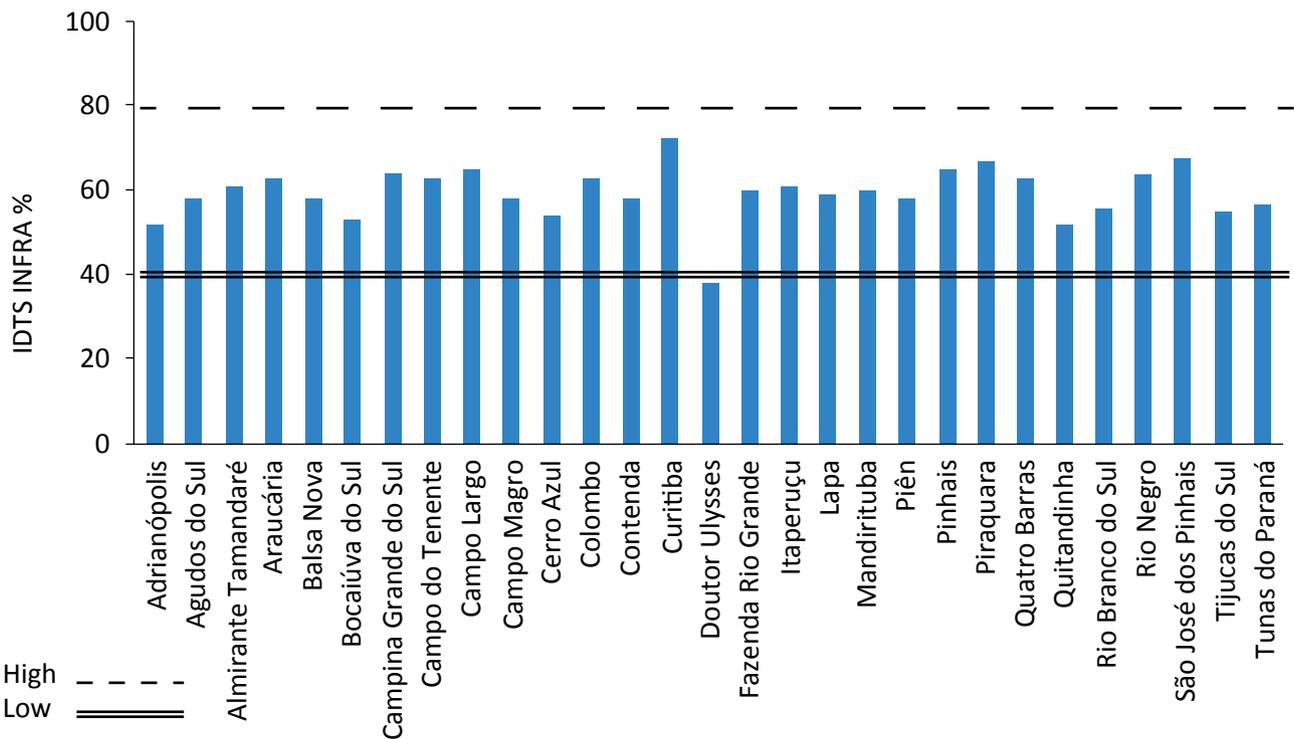
IDTSINFRA: Índice de Desenvolvimento Territorial Sustentável de Infraestrutura.

Figure 1 – Sustainable Territory Development level classification of the Curitiba Metropolitan Region cities conforming to the Sustainable Territorial Development Index values.

The results reinforce the sustainable development classification exhibited in Table 10, the cities with the lowest INFRASTDI values were also those with the highest levels in the II, or, in other words, the lower the inequality in infrastructure conditions in relation to the city, the better the region index.

The historical process of metropolitan planning in Curitiba emphasized issues related to the industrialization process, establishing peripheries in social and economic mismatch in relation to the central municipality (CARMO, 2017), a situation commonly observed in large cities, especially in developing countries.

How can a single municipality be sustainable if the neighboring municipality presents situations of underdevelopment, and which will inevitably impact on the area considered sustainable? Issues such as water

Table 10 – Inequality index for each infrastructure system with a final average for the Curitiba Metropolitan Region (CMR).

Infrastructure system	Inequality index CMR (%)	CMRII (%)
Transportation	II-T 19.85	
Sanitation	II-S 14.81	
Healthcare	II-He 15.53	
Education	II-Ed 18.48	II-I
Energy	II-En 0.13	5.44
Housing	II-Ho 4.69	
Communication	II-C 13.22	

CMRII: Curitiba Metropolitan Region Inequality Index.
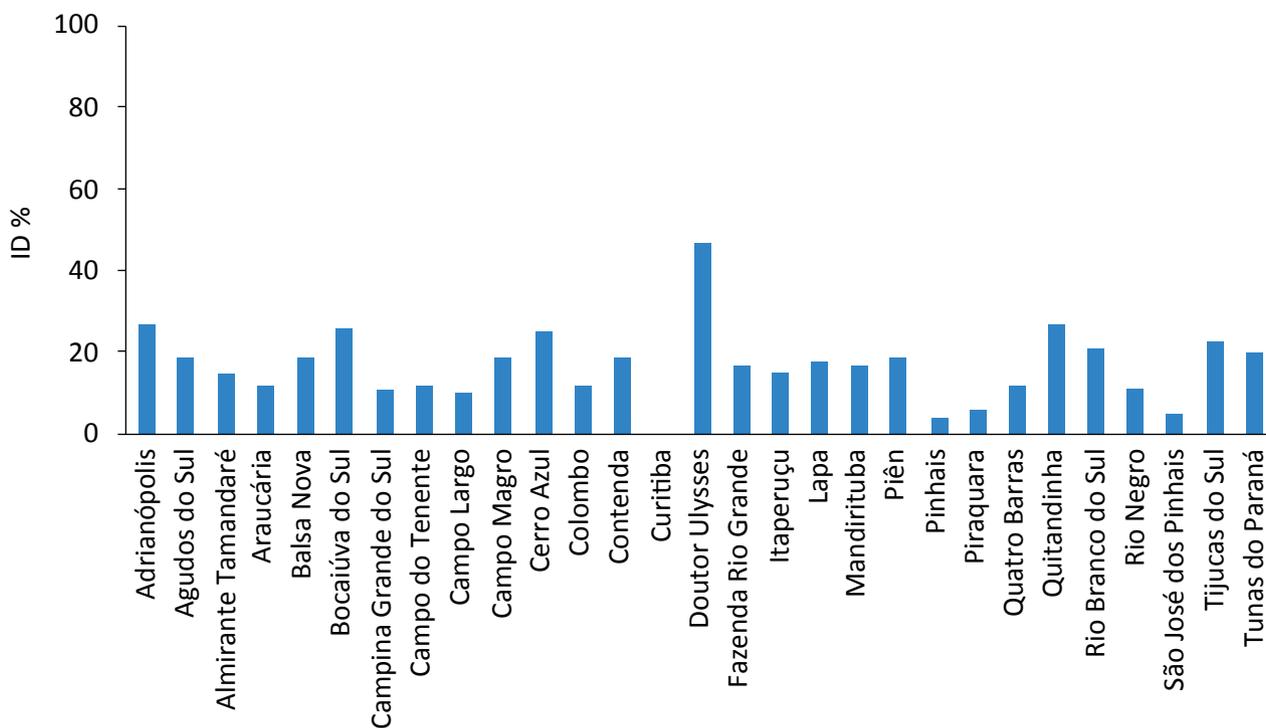
ID: índice de desigualdade.

Figure 2– Infrastructure Inequality Index (II) with respect to the capital city.

supply, sanitation, waste disposal, social and ecological vulnerability do not obey geopolitical boundaries, and generate impacts throughout the region. As observed by Lu *et al*. (2017), local indicators for sustainability assessment need to consider the reality of the next higher scale in which the assessed territory is inserted, under penalty of inefficiency of this indicator.

The inequality shown by index (II) between peripheral municipalities and the central municipality presents a great challenge to an integrated management of metropolitan public policies, which inspires research to develop systems based on regional sustainability indicators, and not only on a single municipality.

CONCLUSION

Infrastructure indicators for sustainable territorial development were proposed, creating a method that allows the selection of indicators considering the specificities of the territory.

The evaluation of the CMR contributes to the sustainable development measure from the built capital perspective, considering the relations among natural, social, and built capital for questions of sustainability and economic growth from a territory point of view.

The indicator framework proposed herein allows the assessment of sustainable development in a territory, despite focusing on a specific aspect, i.e., urban infrastructure. For an infrastructure system to be sustainable, it must be fully employed, allocated efficiently, and progressively cut back on the use of natural resources. Good infrastructure contributes to the reduction of pollution and degradation of natural capital, increasing social well-being.

To contribute to the reflection about infrastructure on the part of public managers, an index was proposed to evaluate the level of sustainable territorial development in the cities of the CMR, the INFRASTDI, from selected and tested indicators using data collected from the region. Seven infrastructure system indices composed the INFRASTDI, which led to the conclusion that there is inequality in the level of development among the CMR cities. From this conclusion, the Inequality Index (II) for the CMR was calculated.

The result of the II confirmed a higher level of inequality between cities that had lower scores on the INFRASTDI in relation to the central municipality. This agreed with the findings of Queiroz Ribeiro *et al*. (2012), that pointed to low levels of integration among the peripheral cities and the central part of the region, which could be accounted for the composition of municipalities in the CMR, as many have unique characteristics and population demands. This

strengthens the relevance of indicators focused on the sustainable development of the territory, with an emphasis on the local necessities and realities, considering the concentrated inequalities found in the CMR cities.

It is important to highlight that the results obtained by the INFRASTDI in the CMR are only as relevant as the developed methodology for the overall formation of sustainable territorial development indicators. The utilization of selected indicators, such as the INFRASTDI, in public management as instruments for evaluating infrastructure systems strengthens the objective of sustainable development in public policy decision-making, which would represent a large improvement in the quality of life in urban centers.

The method adopted for the INFRASTDI can be applied to other metropolitan regions, and, with the selection of new indicators that address other perspectives about infrastructure systems, it is possible to evaluate other types of infrastructure.

Future work could focus on including "parks and recreation" as part of the assessed infrastructure, since they play an important role for the well-being of the population. Another topic to be considered is the improvement of data gathering, something that depends on the collaboration of the region under assessment.

It is recognized, however, that policies, legal, and institutional questions permeate the public administration with major influences in the decision management, configuring themselves as obstacles to the implementation of sustainable public policies.

Nevertheless, the concept of sustainable development is not static, it is a path to be traveled and perhaps not reached in its fullness, but inevitable to maintain the planet. It is necessary to raise awareness and enrich the debate.

REFERENCES

ALLEN, C.; NEJDAWI, R.; EL-BABA, J.; HAMATI, K.; METTERNICHT, G.; WIEDMANN, T. Indicator-based assessments of progress towards the sustainable development goals (SDGs): a case study from the Arab region. *Sustainability Science*, v. 12, n. 6, p. 975-989, 2017. http://dx.doi.org/10.1007/s11625-017-0437-1

ALVES, J. E. D.; CAVENAGHI, S. Família e domicílio no cálculo do déficit habitacional no Brasil. *In*: ENCONTROS NACIONAIS DA ANPUR, 11., 2007. *Anais*... 2007.

AGÊNCIA NACIONAL DE VIGILÂNCIA SANITÁRIA (ANVISA). *Boletim de Segurança do Paciente e Qualidade em Serviços de Saúde nº 14*. Avaliação dos indicadores nacionais das Infecções Relacionadas à Assistência à Saúde (IRAS) e Resistência microbiana. Brasil: Anvisa, 2016. Available at: <http://portal.anvisa.gov.br/documents/33852/3074203/Boletim+de+Seguran%C3%A7a+do+Paciente+e+Qualidade+em+Servi%C3%A7os+de+Sa%C3%BAde+n%C2%BA+14+Avalia%C3%A7%C3%A3o+dos+indicadores+nacionais+das+Infec%C3%A7%C3%B5es+Relacionadas+%C3%A0+Assist%C3%AAncia+%C3%A0+Sa%C3%BAde+%28IRAS%29+e+Resist%C3%AAncia+microbiana/dbd57c96-937f-45d3-93fd-e76684b7f35c>. Acessed on: Dec. 13, 2017.

BARDIN, L. *L'analyse de contenu*. France: Quadrige Manuels, 2007.

BAYULKEN, B.; HUISINGH, D. Are lessons from eco-towns helping planners make more effective progress in transforming cities into sustainable urban systems: a literature review (part 2 of 2). *Journal of Cleaner Production*, v. 109, p. 152-165, 2015. http://dx.doi.org/10.1016/j.jclepro.2014.12.099

BELLEN, H. M. V. *Indicadores de sustentabilidade:* uma análise comparativa. São Paulo: Editora FGV, 2005.

BOSSEL, H. *Earth at a crossroads*. Paths to a sustainable future. U.K.: Cambridge University Press, 1998.

BRASIL. Ministério da Educação. Censo Escolar. Brasília: Ministério da Educação, 2010. Available at: <www.inep.gov.br>. Accessed on: Sept. 3, 2015.

BROCKLESBY, M. A.; FISHER, E. Community development in sustainable livelihoods approaches–an introduction. *Community Development Journal*, v. 38, n. 3, p. 185-198, 2003. http://dx.doi.org/10.1093/cdj/38.3.185

CAETANO, P. M. D. Em busca do Graal do indicador ambiental sintético único: Contribuições da Termodinâmica e da Teoria da Informação. *Revista Brasileira de Ciências Ambientais*, n. 30, p. 11-20, 2013.

CARLI, R.; DOTOLI, M.; PELLEGRINO, R. Multi-criteria decision-making for sustainable metropolitan cities assessment. *Journal of Environmental Management*, v. 226, p. 46-61, 2018. https://doi.org/10.1016/j.jenvman.2018.07.075

CARLSSON, L.; CALLAGHAN, E.; MORLEY, A.; BROMAN, G. Food System Sustainability across Scales: A Proposed Local-To-Global Approach to Community Planning and Assessment. *Sustainability*, v. 9, n. 6, p. 1061, 2017. https://doi.org/10.3390/su9061061

CARMO, J. C. B. Curitiba Metropolitan Region planning as a study object: analysis of literature production from 1974 to 2006. *Revista Brasileira de Gestão Urbana*, v. 9, n. 1, p. 7-18, 2017. http://dx.doi.org/10.1590/2175-3369.009.001.ao01

CAVALCANTI, C. O.; LIMONT, M.; DZIEDZIC, M.; FERNANDES, V. Sustainability assessment methodology of urban mobility projects. *Land Use Policy*, v. 60, p. 334-342, 2017a. http://dx.doi.org/10.1016/j.landusepol.2016.11.005

CAVALCANTI, C. O.; LIMONT, M.; DZIEDZIC, M.; FERNANDES, V. Sustainability of urban mobility projects in the Curitiba metropolitan region. *Land Use Policy*, v. 60, p. 395-402, 2017b. http://dx.doi.org/10.1016/j.landusepol.2016.11.015

CENTRULO, T.; MOLINA, N.; MALHEIROS, T. Indicadores de sustentabilidade: proposta de um barômetro de sustentabilidade estadual. *Revista Brasileira de Ciências Ambientais*, v. 30, p. 33-45, 2013.

CHAMPOLLION, P. Territory and territorialization: present state of the caenti thought. *In*: INTERNATIONAL CONFERENCE OF TERRITORIAL INTELLIGENCE, 2006. *Anais…* Alba Iulia, 2006.

COMOLLI, P. Sustainability and growth when manufactured capital and natural capital are not substitutable. *Ecological Economics*, v. 60, n. 1, p. 157-167, 2006. http://doi.org/10.1016/j.ecolecon.2005.11.018

COUTINHO, S. M. V. *Análise de um processo de criação de indicadores de desenvolvimento sustentável no município de Ribeirão Pires SP*. Tese (Doutorado) – Departamento de Saúde Ambiental, Faculdade de Saúde Pública, Universidade de São Paulo, São Paulo, 2006.

COX, D.; FRERE, M.; WEST, S.; WISEMAN, J. Developing and using local community wellbeing indicators: learning from an experience of Community Indicators Victoria. *Australian Journal of Social Issues*, v. 45, n. 1, p. 71-88, 2010. https://doi.org/10.1002/j.1839-4655.2010.tb00164.x

DALLABRIDA, V. R. *Governança territorial e desenvolvimento:* uma introdução ao tema. Governança Territorial e Desenvolvimento: descentralização político-administrativa, estruturas subnacionais de gestão do desenvolvimento e capacidades estatais. Rio de Janeiro: Garamond, 2011.

FLORA, C. B. Social capital and community problem solving: combining local and scientific knowledge to fight invasive species. *In*: FALK, I.; SURRATA, K.; SUWONDO, K. (orgs.). *Community Management of Biosecurity*, Special Copublication. Indonesia: Journal of Interdisciplinary Development Studies; Australia: Learning Communities International Journal of Learning in Social Contexts, 2008. p. 30-39.

FÜRST, C.; HELMING, K.; LORZ, C.; MÜLLER, F.; VERBURG, P. H. Integrated land use and regional resource management–A cross-disciplinary dialogue on future perspectives for a sustainable development of regional resources. *Journal of Environmental Management*, v. 127, suppl., p. S1-S5, 2013. https://doi.org/10.1016/j.jenvman.2012.12.015

FURTADO, B. A.; LIMA NETO, V. C.; KRAUSE, C. *Estimativas do déficit habitacional brasileiro (2007-2011) por municípios (2010)*. Brasília: IPEA, 2013.

FURTADO, C. *O Mito do Desenvolvimento Econômico*. Rio de Janeiro: Paz e Terra, 1974.

GALLI, A.; ĐUROVIĆ, G.; HANSCOM, L.; KNEŽEVIĆ, J. Think globally, act locally: Implementing the sustainable development goals in Montenegro. *Environmental Science & Policy*, v. 84, p. 159-169, 2018. https://doi.org/10.1016/j.envsci.2018.03.012

GIATTI, L. L.; FREITAS, C. M. D.; NASCIMENTO, P. R.; LANDIN, R.; GAVIOLLI, J.; CUTOLO, S. A.; MARIA, N. C.; CARBONE, A. S.; TOLEDO, R. F. Estudo de distintos níveis holárquicos para uma região metropolitana por meio da aplicação de Indicadores de sustentabilidade ambiental e de saúde. *Revista Brasileira de Ciências Ambientais*, v. 30, p. 79-88, 2013.

GINÉ-GARRIGA, R.; FLORES-BAQUERO, Ó.; DE PALENCIA, A. J. F.; PÉREZ-FOGUET, A. Monitoring sanitation and hygiene in the 2030 Agenda for Sustainable Development: a review through the lens of human rights. *Science of the Total Environment*, v. 580, p. 1108-1119, 2016. https://doi.org/10.1016/j.scitotenv.2016.12.066

GRIMONI, J.; GALVAO, L. C.; UDAETA, M. *Iniciação a Conceitos de Sistemas Energéticos para o Desenvolvimento Limpo*. São Paulo: EdUSP, 2004. v. 58.

HEGARTY, K.; HOLDSWORTH, S. Weaving complexity and accountability: approaches to higher education learning design (HELD) in the built environment. *Environment, Development and Sustainability*, v. 17, n. 2, p. 239-258, 2015. https://doi.org/10.1007/s10668-015-9626-1

HENDRICKSON, D. J. Community indicators and sustainable consumption: a blended approach toward implementation. *Canadian Journal of Urban Research*, v. 19, n. 1, p. 111-133, 2010.

HOROCHOVSKI, R. R.; JUNCKES, I. J.; MURARO, C. J. L. Participação e planejamento em um programa de desenvolvimento regional sustentável. *Revista Brasileira de Ciências Ambientais*, v. 20, p. 49-65, 2011.

KALTENBORN, B. P.; LINNELL, J. D.; BAGGETHUN, E. G.; LINDHJEM, H.; THOMASSEN, J.; CHAN, K. M. Ecosystem Services and Cultural Values as Building Blocks for 'The Good life'. A Case Study in the Community of Røst, Lofoten Islands, Norway. *Ecological Economics*, v. 140, p. 166-176, 2017. https://doi.org/10.1016/j.ecolecon.2017.05.003

KARVONEN, M. M. Natural versus manufactured capital: win–lose or win–win? A case study of the Finnish pulp and paper industry. *Ecological Economics*, v. 37, n. 1, p. 71-85, 2001. http://dx.doi.org/10.1016/S0921-8009(00)00265-2

KLOPP, J. M.; PETRETTA, D. L. The urban sustainable development goal: Indicators, complexity and the politics of measuring cities. *Cities*, v. 63, p. 92-97, 2017. https://doi.org/10.1016/j.cities.2016.12.019

KUSAKABE, E. Advancing sustainable development at the local level: The case of machizukuri in Japanese cities. *Progress in Planning*, v. 80, p. 1-65, 2013. https://doi.org/10.1016/j.progress.2012.06.001

LI, C.; LI, J. Assessing Urban Sustainability Using a Multi-Scale, Theme-Based Indicator Framework: A Case Study of the Yangtze River Delta Region, China. *Sustainability*, v. 9, n. 11, p. 2072, 2017. https://doi.org/10.3390/su9112072

LU, Y.; GENG, Y.; LIU, Z.; COTE, R.; YU, X. Measuring sustainability at the community level: An overview of China's indicator system on National Demonstration Sustainable Communities. *Journal of Cleaner Production*, v. 143, p. 326-335, 2017. https://doi.org/10.1016/j.jclepro.2016.12.105

LUPOLI, C. A.; MORSE, W. C. Assessing the local impacts of volunteer tourism: Comparing two unique approaches to indicator development. *Social Indicators Research*, v. 120, n. 2, p. 577-600, 2015.

MAES, W. H.; FONTAINE, M.; RONGÉ, K.; HERMY, M.; MUYS, B. A quantitative indicator framework for stand level evaluation and monitoring of environmentally sustainable forest management. *Ecological Indicators*, v. 11, n. 2, p. 468-479, 2011. http://dx.doi.org/10.1016/j.ecolind.2010.07.001

MALHEIROS, T. F.; COUTINHO, S. M. V.; PHILIPPI JR., A. Indicadores de Sustentabilidade: uma abordagem conceitual. *In*: PHILIPPI JR., A.; MALHEIROS, T. F. (Orgs.). *Indicadores de sustentabilidade e gestão ambiental*. Barueri: Manole, 2012. p. 31-76.

MARTINET, V. A characterization of sustainabilitywithindicators. *Journal of Environmental Economics and Management*, v. 61, n. 2, p. 183-197, 2011. http://dx.doi.org/10.1016/j.jeem.2010.10.002

MARTIRE, S.; TUOMASJUKKA, D.; LINDNER, M.; FITZGERALD, J.; CASTELLANI, V. Sustainability impact assessment for local energy supplies' development–The case of the alpine area of Lake Como, Italy. *Biomass and Bioenergy*, v. 83, p. 60-76, 2015. http://dx.doi.org/10.1016/j.biombioe.2015.08.020

MASCARENHAS, A.; COELHO, P.; SUBTIL, E.; RAMOS, T. B. The role of common local indicators in regional sustainability assessment. *Ecological Indicators*, v. 10, n. 3, p. 646-656, 2010. http://dx.doi.org/10.1016/j.ecolind.2009.11.003

MAYER, A. L. Strengths and weaknesses of common sustainability indices for multidimensional systems. *Environment International*, v. 34, n. 2, p. 277-291, 2008. https://doi.org/10.1016/j.envint.2007.09.004

MAX-NEEF, M. *Desarollo a escala humana:* conceptos, aplicaciones y reflexiones. Montevideo: Nordan Comunidad, REDES, 1993.

MEADOWS, D. H. *Indicators and information systems for sustainable development*. Hartland, 1998.

MULDER, K.; COSTANZA, R.; ERICKSON, J. The contribution of built, human, social and natural capital to quality of life in intentional and unintentional communities. *Ecological Economics*, v. 59, p. 13-23, 2006. http://dx.doi.org/10.1016/j.ecolecon.2005.09.021

O'CONNOR, M. *Natural capital*. Environmental valuation in Europe. Policy Research Brief Number 3. Cambridge: Cambridge Research for the Environment, 2000.

PARKIN, S.; SOMMER, F.; UREN, S. Sustainable development: understanding the concept and practical challenge. Proceedings of the Institution of Civil Engineers. *Engineering Sustainability*, v. 156, n. 1, p. 19-26, 2003. https://doi.org/10.1680/ensu.2003.156.1.19

PATEL, Z.; GREYLING, S.; SIMON, D.; ARFVIDSSON, H.; MOODLEY, N.; PRIMO, N.; WRIGHT, C. Local responses to global sustainability agendas: learning from experimenting with the urban sustainable development goal in Cape Town. *Sustainability Science*, v. 12, n. 5, p. 785-797, 2017. https://doi.org/10.1007/s11625-017-0500-y

PHILIPPI JR., A.; MALHEIROS, T. F. *Indicadores de sustentabilidade e gestão ambiental*. Barueri: Manole, 2012.

POLANYI, K. *A Subsistência do Homem:* ensaios e correlatos. Rio de Janeiro: Contra Ponto, 2012.

QUEIROZ RIBEIRO, L. C.; MOURA, R.; DELGADO, P.; DA SILVA, É. T.; RODRIGUES, J. M.; RIBEIRO, M. G.; ZANINELLI, L. *Níveis de integração dos municípios brasileiros em RMs, RIDEs e AUs à dinâmica da metropolização*. Relatório de pesquisa. Rio de Janeiro: Observatório das Metrópoles, 2012.

RAMOS, T. B.; CAEIRO, S. Meta-performance evaluation of sustainability indicators. *Ecological Indicators*, v. 10, n. 2, p. 157-166, 2010. https://doi.org/10.1016/j.ecolind.2009.04.008

SACHS, I. *Caminhos para o desenvolvimento sustentável*. Rio de Janeiro: Garamond, 2006.

_____. *Desenvolvimento:* includente, sustentável, sustentado. Rio de Janeiro: Garamond, 2008. 151 p.

SANTANA, J. S.; GUEDES, C. A. M.; VILLELA, L. E. Desenvolvimento territorial sustentável e desafios postos por megaempreendimentos: o caso do município de Itaguaí-RJ. *Cadernos EBAPE.BR*, v. 9, n. 3, p. 846-867, 2011. http://dx.doi.org/10.1590/S1679-39512011000300009

SCHWARZ, N. Urban form revisited—Selecting indicators for characterising European cities. *Landscape and Urban Planning*, v. 96, n. 1, p. 29-47, 2010. https://doi.org/10.1016/j.landurbplan.2010.01.007

SICHE, R.; AGOSTINHO, F.; ORTEGA, E.; ROMEIRO, A. Índices versus indicadores: precisões conceituais na discussão da sustentabilidade de países. *Ambiente & Sociedade*, v. 10, n. 2, p. 137-148, 2007. http://dx.doi.org/10.1590/S1414-753X2007000200009

SILVA, G. J. C. da; FORTUNATO, W. L. L. Infraestrutura e Crescimento: Uma Avaliação do Caso Brasileiro no Período 1985-1998. *In*: ENCONTRO REGIONAL DE ECONOMIA, 12., 2007. *Fórum BNB de Desenvolvimento*. 2007.

SIRGY, M. J. Theoretical perspectives guiding QOL indicator projects. *Social Indicators Research*, v. 103, n. 1, p. 1-22, 2011. http://dx.doi.org/10.1007/s11205-010-9692-6

SOUZA, C. M. M.; SAMPAIO, C. A. C.; ZUNIGA, C. H.; PASCO, A. D.; AUMOND, J. J. Diagnóstico e construção de indicadores socioambientais participativos: experiências de um Programa de Extensão. *Revista Brasileira de Ciências Ambientais*, n. 30, 2013.

UNITED NATIONS. Agenda 21. *In*: CONFERÊNCIA DAS NAÇÕES UNIDAS SOBRE MEIO AMBIENTE E DESENVOLVIMENTO, 1992, Rio de Janeiro. Rio de Janeiro: United Nations, 1992. Available at: <http://www.un.org/geninfo/bp/enviro.html>. Accessed on: Nov. 22, 2014.

_____. *Habitat III* – United Nations Conference on Housing and Sustainable Urban Development. Quito, Ecuador: United Nations, 2017. Available at: <http://habitat3.org/wp-content/uploads/Habitat-III-the-conference.pdf>. Accessed on: Sept. 15, 2017.

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION (UNESCO). *Thematic Indicators to Monitor the Education 2030 Agenda*. Unesco, 2015. Available at: <http://www.uis.unesco.org/Education/Documents/43-indicators-to-monitor-education2030.pdf>. Accessed on: Jan. 19, 2016.

ZEIJL-ROZEMA, A. V.; MARTENS, P. An adaptive indicator framework for monitoring regional sustainable development: a case study of the INSURE project in Limburg, The Netherlands. *Sustainability: Science, Practice and Policy*, v. 6, n. 1, p. 6-17, 2010. https://doi.org/10.1080/15487733.2010.11908038

ZHANG, X.; LI, H. Urban resilience and urban sustainability: What we know and what do not know? *Cities*, v. 72, part A, p. 141-148, 2018. https://doi.org/10.1016/j.cities.2017.08.009

ZHANG, X.; WU, Y.; SHEN, L. An evaluation framework for the sustainability of urban land use: A study of capital cities and municipalities in China. *Habitat International*, v. 35, n. 1, p. 141-149, 2011. https://doi.org/10.1016/j.habitatint.2010.06.006