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Review Article

Multi actor multi criteria analysis (MAMCA) as a tool to build indicators and localize sustainable development goal 11 in Brazilian municipalities

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Ana C.L. Almeida [*]

School of Environment and Science, Griffith University, 170 Kessels Road, Nathan, Brisbane, Queensland, 4111, Australia

A B S T R A C T

The Sustainable Development Goals (SDGs) were adopted in 2015 to be a guideline to promote sustainable development through partnerships. Goal 11 was designed to improve the quality of life in cities however, confronted local governments with new challenges to delivery services and increase citizen participation. In this study, a conceptual framework was developed, and distinct indicators were analyzed to facilitate the implementation of SDG 11 in Brazilian municipalities. Two case studies were deployed based on the Multi-Actor Multi-Criteria Analysis (MAMCA) to guarantee stakeholder participation during the whole process. The results brought to light important challenges to urbanization at local levels. Also, the results suggest shifts in the ongoing model to evaluate the implementation of SDG 11 in Brazil. Governance, transparency and social participation were identified as critical issues to be addressed. Moreover, it will be necessary to adjust existing indicators and organize a consistent and frequent method to evaluate progress towards achieving SDG 11 targets at local levels. Integration of plans and policies related to climate change and disaster risk reduction represents another challenge to be faced by local governments. Finally, MAMCA can be a helpful tool to support local decision-makers to implement SDG 11 based on a multi-stakeholder view.

1. Introduction

Localising is the process of considering the subnational context in the achievement of Agenda 2030 and comprises two main processes: planning and implementing the SDGs, and monitoring SDG progress (United Nations Development Programme, UN-Habitat, & Global Taskforce of Local and Regional Governments, 2016). From the 17 Sustainable Development Goals (SDGs), Goal 11, "Make cities and human settlements inclusive, safe, resilient and sustainable" is considered as a lynchpin for local governments (United Nations Development Programme et al., 2016). Goal 11 targets relevant urban issues, such as housing, transportation, water, and air quality, development planning and integration between national and regional plans, and international agreements. The United Nations (UN) adopted a global indicator framework comprising 232 indicators to support SDG's achievement (United Nations General Assembly, 2017). Those indicators should be aligned to current local or regional indicators to facilitate the analysis of progress of SDGs (United Nations, 2015).

Indeed, sustainable city indicators are useful tools for monitoring, for evaluating progress of sustainability in the cities, and for fostering active

social participation (Hiremath et al., 2013; Pupphachai and Zuidema, 2017; Shen et al., 2011; Tran, 2016). However, there are many challenges in selecting an appropriate indicator framework for measuring progress towards sustainable development, especially at local levels (Yang et al., 2017).

Many scholars have developed indicator tools and indexes from the perspectives of economics, society, and the environment to assess sustainability in the cities (Alkhalidi et al., 2018; Braulio-Gonzalo et al., 2015; Costa et al., 2007; European Commission DG Environment, 2018; Florissi, 2009; Hiremath et al., 2013; Munier, 2011; Pupphachai and Zuidema, 2017; Shen et al., 2011; Xiang, 2017). Also, international organisations such as World Bank, European Commission, Organisation for Economic Co-operation and Development (OECD), and UN-Habitat are working on indicators to assess urban development sustainability. The advantages and disadvantages of 28 toolkits were determined when assessing sustainable cities (Science for Environment Policy, 2018). Among the limits of assessment, the definition of a set of indicators covering the totality of the urban picture to assess sustainable development (Gómez-Álvarez et al., 2018) and the lack of comparison between the distinct systems of indicators (Keirstead, 2007; Yang et al., 2017)

* Corresponding author.
E-mail address: ana.almeida@griffithuni.edu.au.

seem to be the most challenging limitations. Regarding the SDGs, the lack of well-designed conceptual frameworks for selecting indicators can result in ambiguous and confusing assessments (Hák et al., 2016).

In this research, national and local indicators were analysed to facilitate the implementation of SDG 11 in Brazilian municipalities, based on the Multi-Actor Multi-Criteria Analysis (MAMCA). MAMCA was adopted to provide a broader stakeholder approach in the selection of indicators. Multi-Criteria Analysis (MCA) has been used as a decision analysis technique for several decades and as well as with methodologies for thousands of applications (Greco et al., 2016). MAMCA is a type of multi criteria analysis (MCA) technique that has gained much popularity over the past decades (Kourtit et al., 2014) and has been used to enhance policy analysis by explicitly considering the opinions of various stakeholders (Kourtit et al., 2014; Macharis et al., 2009; Stathopoulos et al., 2012; Sun et al., 2015). The methodology differs from the classical approach of MCA because it allows the introduction of stakeholders at a very early stage of methodology (Bergqvist et al., 2015), takes into consideration all stakeholders' opinions and priorities, and facilitates the identification of key indicators and their linkages (De Brucker, Macharis and Verbeke, 2013).

In Brazil, perhaps, one of the main factors that will be an essential part of localising SDG 11 is developing guidance for municipalities implementing the targets and mapping out their capacity to deliver sustainability (Almeida et al., 2018). Regarding indicators, the Brazilian Institute of Geography and Statistics (IBGE) is developing a set of indicators to monitor the SDGs, taking into consideration the official list of indicators adopted by the United Nations (Instituto Brasileiro de Geografia e Estatistica, 2018). However, this initiative is focused on the national level rather than local level.

The present research was carried out in Brazil to support the municipal government in the implementation of SDG 11. The first part of this research aims to analyse existing sustainable urban indicators and their contribution to the achievement of SDG 11 at local levels, regarding a more comprehensive and holistic view of urban sustainability. The second part focuses on multi-stakeholder analysis with the aim of integrating distinct stakeholder visions into the selection of indicators. The results reflect relevant urban issues and offer a set of key indicators that can contribute to the performance evaluation of Brazilian municipalities in terms of SDG 11 achievement.

2. Main text

2.1. Methodology

2.1.1. Study areas

This research comprises two distinct geographic areas: Niteroi city, state of Rio de Janeiro, and the Inter-Municipal Consortium of the Paranapanema Valley (CIVAP) that is a cooperation arrangement between 27 municipalities located in Sao Paulo state (Fig. 1).

The choice of those localities was purposeful. Niteroi is a big city that has faced many urban issues due to rapid urbanization and local government has already developed participatory planning processes as a tool to improve sustainability in the city notably, the strategic plan Niteroi que Queremos 2033 (Prefeitura de Niterói, 2017). In contrast, CIVAP is a cooperation arrangement between 26 small municipalities and one big city and none of the municipalities have experience in strategic planning with social participation. Niteroi city is in the metropolitan area of Rio de Janeiro State, has an estimated population of 511,786 inhabitants and
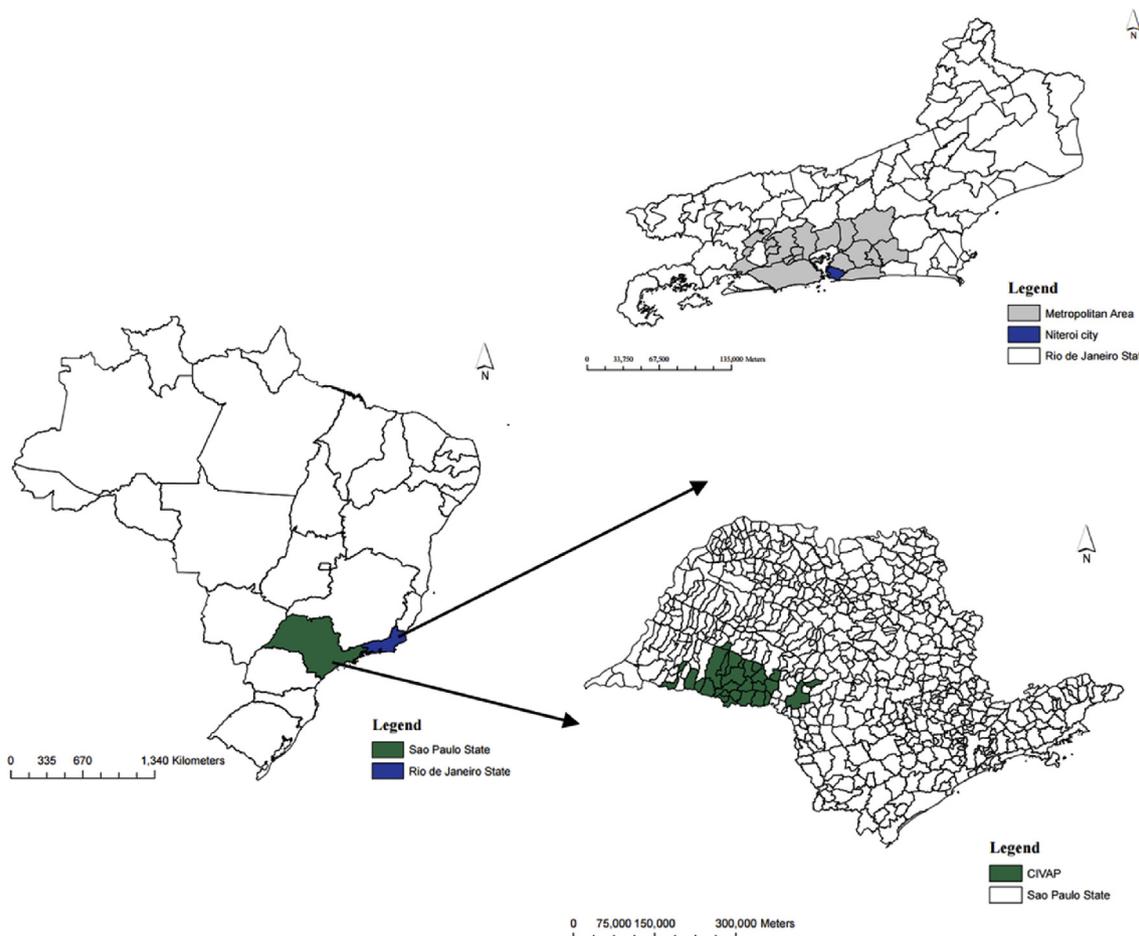

Fig. 1. Location of Niteroi city and Inter-Municipal Consortium of the Paranapanema Valley (CIVAP).

covers an area of 134,074 km[2] (Instituto Brasileiro de Geografia e Estatistica, 2015). The total population lives in the urban area, which represents a challenge for promoting local sustainable development. In CIVAP area most municipalities are small, and the region has an estimated population of 1.207,105 inhabitants, covering an area of 9.101, 718 km[2] (Instituto Brasileiro de Geografia e Estatistica, 2017). Table 1 shows differences and similarities between the municipalities evaluated in this research, according to available social and economic development indicators.

2.1.2. Research method

Qualitative research was designed to support the municipal government in implementing SDG 11, combined with a bottom-up approach to developing indicators. A conceptual framework composed of two stages was devised and is summarized in Fig. 2. First, a review of existing national and local indicators in the field of sustainable urbanization was conducted. At the local level, four major systems were selected: (1) the set of indicators adopted by the strategic plan Niteroi que Queremos 2033 (Gomes and Reys, 2015), (2) the set of indicators adopted by the Municipal Management's Effectivity Index (Tribunal de Contas do Estado de Sao Paulo, 2014), (3) SDG Mandala (Confederação Nacional de Municípios, 2017), and (4) the Sustainable Cities Program Indicators (Programa Cidades Sustentaveis, 2017).

The strategic plan comprises a total of 57 strategies and 29 timely data indicators for monitoring the performance of local priorities in Niteroi city. The Municipal Management's Effectivity Index was launched in 2015 and comprises a total of 152 indicators. These indicators are classified into seven dimensions: education, health, planning, fiscal management, environment, protection of the cities, and information technology governance. The Index aims to promote the effectiveness of municipal management with transparency and accountability. SDG Mandala is a tool comprising 26 indicators and developed to support

local public managers to monitor and evaluate the performance of Brazilian municipalities regarding the achievement of SDGS and Agenda 2030. The indicators are classified into 4 categories of sustainable development: institutional, economic, social, and environmental. The Sustainable Cities Program Indicators aims to improve municipal administration and is composed of 260 indicators categorized by SDG goals. From this total, 29 indicators were developed to assess the implementation of SDG 11 at local levels.

At national level, other two systems were identified: The Sustainable Development Indicators and SDGs Indicator. The Sustainable Development Indicators were developed by IBGE in 2002 for monitoring sustainable development and is composed of 132 indicators, also classified in the 4 categories of sustainable development. The SDGs Indicator is an information system, still under construction, for monitoring the implementation of Agenda 2030 in Brazil and is composed of a total of 244 indicators, 15 of them developed to monitor SDG 11 deployment.

Considering that indicators can be described or measured in different ways, the selection of indicators (first set) was based on six criteria: (1) easy to apply; (2) easy to calculate; (3) relevance to local level; (4) existence of available data; (5) contribution to the achievement of SDG 11 targets; (6) time-bound. The contribution to SDG 11 was the criteria adopted to exclude indicators concerning the strategic plan, SDG mandala, and sustainable development indicators. The other two systems were already organized through SDG 11 targets; thereby, all indicators were analyzed.

In the second stage, two exploratory case studies (Yin, 2003) were designed to contribute to the implementation of SDG 11 in Niteroi city and CIVAP region. The MAMCA consisting of seven key steps was adopted in this research to develop the case studies (Macharis et al., 2004). Steps 1 to 4 were developed during participatory decision-making workshops aimed at discussing the main challenges and opportunities regarding the forthcoming implementation of SDG 11 at local levels.

Table 1

Social and economic characteristics of municipalities evaluated in this research.[a,b]

State**		Municipality	Population (2010)	Population estimate (2018)	GDP per capita* (2010)	GDP per capita* (2016)	HDI (2010)	Income Gini Coefficient (2010)
RJ	1	Niterói	487.562	511.786	23011.46	46202.31	0.837	0.5983
SP	2	Assis	95.144	103.666	14271.72	27921.64	0.805	0.5040
SP	3	Bastos	20.445	20.954	17711.81	39033.19	0.751	0.4175
SP	4	Bora	805	836	40546.42	100029.91	0.746	0.4002
SP	5	Campos Novos Paulista	4.539	4.932	18298.26	28307.64	0.706	0.4379
SP	6	Cândido Mota	29.884	31.212	16692.47	29350.05	0.747	0.4240
SP	7	Cruzalia	2.274	2.100	29208.86	31800.1	0.774	0.4393
SP	8	Echapora	6.318	6.141	14468.87	20518.61	0.745	0.5424
SP	9	Florínia	2.829	2.699	43182.29	43838.84	0.713	0.4944
SP	10	Ibirarema	6.725	7.663	16851.58	47003.22	0.708	0.4352
SP	11	Iepê	7.628	8.124	18280.42	30175.51	0.736	0.4632
SP	12	Joao Ramalho	4.150	4.495	15081.30	35767.38	0.741	0.4235
SP	13	Lutécia	2.714	2.663	18819.34	32273.06	0.720	0.4316
SP	14	Maracaí	13.332	13.967	32163.83	36926.11	0.771	0.4255
SP	15	Nantes	2.707	3.103	34462.89	31673.75	0.714	0.3530
SP	16	Ocaucu	4.163	4.287	14074.49	22459.31	0.717	0.3956
SP	17	Oscar Bressane	2.537	2.602	12419.03	32076.14	0.749	0.4496
SP	18	Palmital	21.186	22.168	22037.14	27670.81	0.746	0.4648
SP	19	Paraguacu Paulista	42.278	45.455	21844.79	26291.19	0.762	0.4641
SP	20	Paulistania	1.779	1.832	16910.60	16802.89	0.718	0.4293
SP	21	Pedrinhas Paulista	2.940	3.085	28143.45	33024.83	0.774	0.5619
SP	22	Pirapozinho	24.694	27.295	15913.46	26952.95	0.776	0.5286
SP	23	Platina	3.192	3.521	19813.06	22182.07	0.719	0.4960
SP	24	Quatá	12.799	14.006	40761.77	32791.62	0.738	0.4175
SP	25	Rancharia	28.804	29.688	29399.97	38668.19	0.751	0.4694
SP	26	Santa Cruz do Rio Pardo	43.921	47.395	22175.53	42021.86	0.762	0.4639
SP	27	Taciba	5.714	6.240	52288.24	21170.25	0.723	0.3861
SP	28	Taruma	12.885	14.812	30087.95	78512.45	0.753	0.5488

Note. *GDP in Reais (R$). **In urban areas.
[a] National Bureau of Statistics of Brazil. https://cidades.ibge.gov.br/.
[b] Information Technology Department of the Public Health Care System. http://tabnet.datasus.gov.br/cgi/ibge/censo/cnv/ginibr.def.
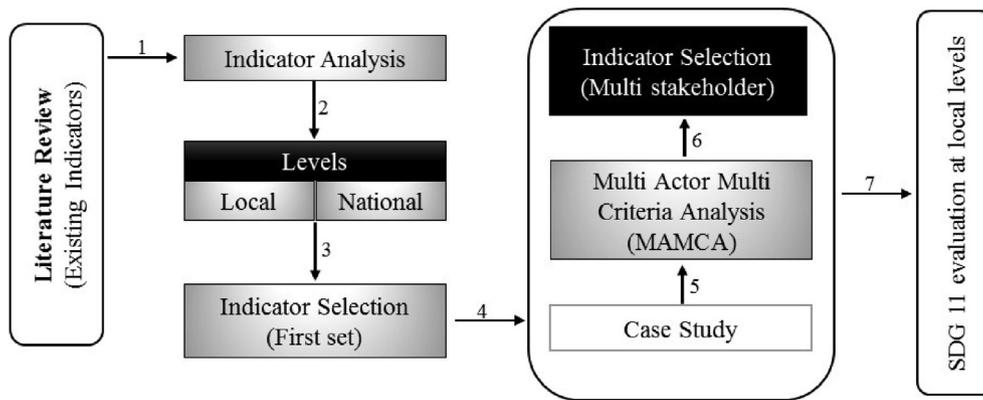
Fig. 2. Conceptual framework for evaluating the implementation of SDG 11 in Niteroi City.

These workshops were carried out in Niteroi city and CIVAP region in June 2017. In Niteroi city the workshop comprised the participation of 16 key stakeholders aggregated into 4 groups: eight from municipal government, three from business sector, two from universities, and three from state audit office. In the CIVAP region, the workshop involved the participation of 15 key stakeholders aggregated into 2 groups: ten from municipal government and five from scientific and technological community. It is important to highlight that two representatives from the business sector participated in the workshop carried out in the CIVAP region. However, they did not want to take part in the evaluation. Informed consent was obtained from all workshop participants. Ethical approval was obtained from the Griffith University Human Research Ethics Committee in accordance with the National Statement on Ethical Conduct in Human Research (GU 2016/748).

As shown in Fig. 3, the first step of MAMCA methodology is to define the problem and alternatives for evaluation. In this research, SDG 11 targets are chosen as preselected alternatives and are submitted for stakeholder evaluation during the workshop. The second step in the MAMCA involves the definition of the range of stakeholders to be consulted. Selecting the range of key stakeholders was an early challenge. Many techniques have been developed to define a representative. The snowball sampling was the method adopted in this research to identify relevant stakeholders (Berg, 2001). This strategy was the best way to locate key stakeholders in different Municipalities. In the step 3, stakeholder groups identify objectives and criteria. The criteria were not tracked by the literature (Turcksin et al., 2011), but identified during the workshops, based on interactive discussions between the stakeholders. Stakeholder groups identified a specific set of criteria and allocated weights to each distinct criterion. The weights are determined by the importance the stakeholders give to each criterion and distinct weighting methods can be adopted as direct weights, direct allocation, and so on (Grafakos et al., 2015). This approach solves the problem related to the (in)dependency of the criteria (Macharis et al., 2009). A weight scale ranging from 1 to 9, with 1 meaning "not so important" and 9 "extremely important", was adopted to help stakeholders to identify their preferences. It is important to note that the same value could be used to distinguish criteria if they had the same importance. Also, considering that a stakeholder group was constituted by distinct members, the geometric mean was calculated (Turcksin et al., 2011). Step 4 consists of constructing indicators to evaluate each individual criterion and defining the measurement method. Steps 1 to 4 are considered mainly analytical and anticipate the overall analysis (Macharis et al., 2012).

For the fifth step, the Analytical Hierarchy Process (AHP) was used to obtain the relative importance of the criteria identified by the four stakeholder groups simultaneously (Saaty, 1980). Within AHP, the different measures or alternatives are compared to support the decision-maker in the final decision. A multi-criteria decision analysis (MCDA) is performed for each stakeholder group. In step 6, criteria are analyzed to provide a multi-stakeholder view on the different alternatives. Step 7 is referred as the implementation phase. This is the final step of MAMCA and compile the points of view of each stakeholder. Based on the information gathered from the previous steps, the local government would decide the alternatives to be implemented (Macharis et al., 2010).

2.2. Results

Existing national and local indicators were evaluated according to six criteria as shown in Tables 1 and 2, respectively. Concerning national
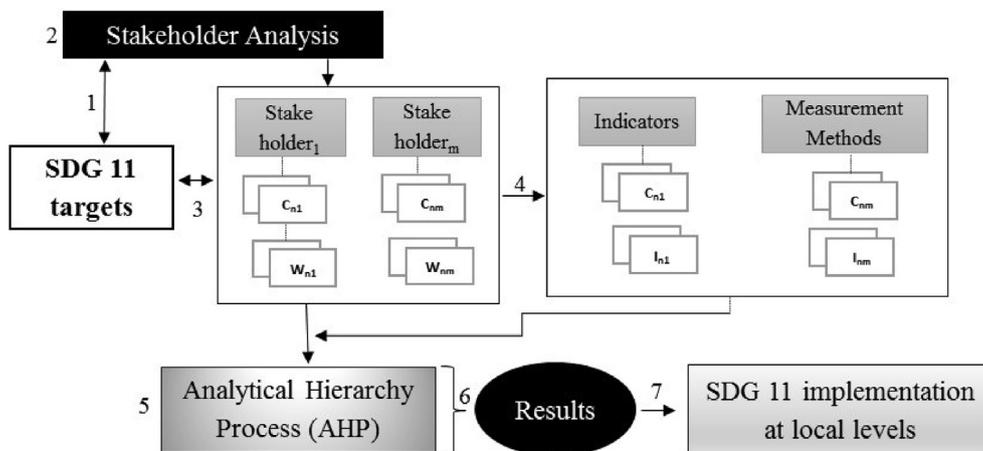

Fig. 3. Schematic diagram of the seven key steps of Multi Actor Multi Criteria Analysis (MAMCA). Source: adapted from Macharis et al. (2004).

Table 2
Selection of existing national indicators.

System	Theme	Indicators	Criteria					
			c.1	c.2	c.3	c.4	c.5	c.6
Sustainable Development Indicators	Air quality	Annual mean levels of fine particulate matter (i.e. PM10)	✓	✓	✓	2011	✓	◆
	Housing	Percentage of adequate housing	✓	✓	✓	2015	✓	◆
	Participatory planning and management	Number of civil society organizations per 100,00 inhabitants	✓	✓	✓	2010	**	◆
		Number of municipalities with environmental council	✓	✓	✓	2013	**	◆
		Percentage of public consortium	✓	✓	✓	2015	**	◆
	Safety	Number of deaths per 100,000 inhabitants	✓	✓	✓	2012	✓	◆
	Transportation	Number of deaths due to traffic accidents	✓	✓	✓	2012	**	◆
	Waste management	Percentage of solid waste regularly collected	✓	✓	✓	2015	✓	●●
		Percentage of solid waste with adequate final discharge	✓	✓	✓	2008	✓	◆
		Number of municipalities with adequate waste final discharge	✓	✓	✓	2008	**	◆
SDGs Indicators	Air quality	Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)	✓	✓	✓	○	✓	◆
	Cultural and natural heritage	Total expenditure (public and private) per capita spent on the preservation, protection and conservation of all cultural and natural heritage, by type of heritage (cultural, natural, mixed and World Heritage Centre designation), level of government (national, regional and local/municipal), type of expenditure (operating expenditure/ investment) and type of private funding (donations in kind, private non-profit sector and sponsorship)	✓	✓	✓	○	✓	◆
	Disaster risk reduction	Number of deaths, missing persons and persons affected by disaster per 100,000 people	✓	✓	✓	2015	✓	●●
		Direct disaster economic loss in relation to global GDP, including disaster damage to critical infrastructure and disruption of basic services	✓	✓	✓	○	✓	◆
	Housing	Percentage of urban population living in slums, informal settlements or inadequate housing	✓	✓	✓	2010	✓	●●
	Integrated policies and plans related to climate change and disaster risk reduction	Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030	✓	✓	✓	2013	✓	◆
		Number of countries with national and local disaster risk reduction strategies	✓	✓	✓	○	✓	◆
	Participatory planning and management	Ratio of land consumption rate to population growth rate	✓	✓	✓	○	✓	◆
		Proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically	✓	✓	✓	○	✓	◆
	Integrated planning	Proportion of population living in cities that implement urban and regional development plans integrating population projections and resource needs, by size of city	✓	✓	✓	○	✓	◆
	Sustainable and resilient buildings	Proportion of financial support to the least developed countries that is allocated to the construction and retrofitting of sustainable, resilient and resource-efficient buildings utilizing local materials	✓	✓	✓	○	✓	◆
	Transportation	Percentage of population with adequate access to public transport, by sex, age and persons with disabilities	✓	✓	✓	○	✓	◆
	Waste management	Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities	✓	✓	✓	○	✓	◆

c.1 - Easy to apply; **c.2 -** Easy to calculate; **c.3 -** Relevant to local levels; **c.4 -** Latest available data; **c.5 -** Contributes to SDG 11 target; **c.6 -** Time-bound. [(a)] - Data available only for a few metropolitan regions.

✓ - Indicator fits criteria; ** - Indicator is not explicit in the SDG official list, but contributes to SDG 11 targets; ○ - No data available; ●● - Annual; ◆ - Frequency unknown.

indicators, all data are collected by IBGE, and a total of 24 quantitative indicators were selected (Table 2). All the selected indicators are easy to apply, easy to calculate, relevant to local levels, and contribute to achievement of SDG 11 targets. Nevertheless, data availability and time-bound factors can be constraints to the analysis of progress of SDG 11 implementation. Most of the data required for SDGs indicators is not readily available because the system is under construction. Concerning the sustainable development indicators, the main barrier is that the indicators are not frequently updated in order to facilitate monitoring and evaluation.

Regarding the local systems (Table 3), a total of 53 indicators was selected, both quantitative and qualitative. All the indicators are easy to apply, easy to calculate, and relevant to local levels. The Municipal Management's Effectivity Index is skewed towards preventing disasters and waste management improvements. The system can be applied to all municipalities and should be updated yearly. The SDG Mandala is the system with fewer indicators for evaluating the implementation of SDG 11 and was developed to be updated yearly, which can be a problem because some crucial data for monitoring evolutions are not frequently

collected. Concerning the Sustainable Cities Program, the system covers almost the totality of SDG 11 targets and is skewed towards improving transportation. However, as mentioned, some flaws with the measurements can be noted because some data are not readily available and/or not frequently updated. Also, some indicators have not been previously tested or implemented in any municipality.

Finally, regarding the indicators of the strategic plan, it already included some SDG 11-related indicators. Importantly, although many indicators are based on data not readily available, all required data can be handled by municipalities. No local system includes indicators to evaluate integrated planning strategies to support positive economic, social, and environmental development. The integration of plans and policies related to climate change and disaster risk reduction is also not considered by any system.

Regarding the stakeholders' view on the important urban issues, a total of 14 criteria were identified by the four stakeholder groups in Niteroi City and eight criteria were identified by the two stakeholder groups in CIVAP region. Those criteria were used to build the value tree (Fig. 4). Not surprisingly, the analysis of the value tree reveals that there

Table 3

Analysis of existing local indicators.

System	Theme	Indicators	c.1	c.2	c.3	c.4	c.5	c.6
Municipal Management's Effectivity Index	Disaster risk reduction	Disaster risk Assessment	✓	✓	✓	2016	**	●●
		Integrated Information System for Disaster Management	✓	✓	✓	2016	**	●●
		Municipal coordination of emergency operations	✓	✓	✓	2016	**	●●
		Municipal infrastructure to organize occurrences	✓	✓	✓	2016	**	●●
		Resilient cities	✓	✓	✓	2016	**	●●
		Training and contingency planning	✓	✓	✓	2016	**	●●
	Urban mobility	Urban mobility plan	✓	✓	✓	2016	**	●●
	Waste management	Adequate final discharge of total solid waste generated	✓	✓	✓	2016	✓	●●
		Adequate discharge of civil construction waste	✓	✓	✓	2016	**	●●
		Integrated solid waste management plan in compliance to the National Solid Waste Policy	✓	✓	✓	2016	**	●●
		Quality of landfill management	✓	✓	✓	2016	**	●●
SDG Mandala	Green areas	Number of municipal conservation units	✓	✓	✓	2015	**	◆
	Safety	Number of deaths per 100,000 people	✓	✓	✓	2018	✓	●●
	Waste management	Percentage of the population with adequate waste collection service	✓	✓	✓	2015	✓	◆
Sustainable Cities Program Indicators	Cultural and natural heritage	Local cultural heritage council	✓	✓	✓	2006	**	◆
		Municipal legislation to deal with environmental issues	✓	✓	✓	○	**	◆
		Share of municipal budget with cultural heritage	✓	✓	✓	○	✓	●●
		Actions on the preservation, protection and conservation of all cultural and natural heritage	✓	✓	✓	○	**	◆
	Disaster risk reduction	Percentage of households in risk areas	✓	✓	✓	2010[a]	**	From 2020
		Local actions or risk management instruments	✓	✓	✓	2017	**	◆
		Economic and physical losses due to natural hazard events	✓	✓	✓	2018	✓	●●
		Number of injuries and deaths due to disasters	✓	✓	✓	2018	✓	●●
	Housing	Housing deficit	✓	✓	✓	2018	**	●●
		Percentage of urban population living in inadequate housing	✓	✓	✓	2018	✓	●●
		Percentage of rented households	✓	✓	✓	2018	**	●●
	Participatory planning and management	Municipal public consortium, partnerships, business sector and/or community support	✓	✓	✓	○	**	◆
		Integrated planning between all municipal Secretaries	✓	✓	✓	○	**	◆
	Safe, green and public spaces	Total of green area per inhabitant	✓	✓	✓	2010	✓	◆
		Percentage of inhabitants living within 300 metres of a green public area	✓	✓	✓	○	**	◆
		Development, implementation and/or review of Master Plan	✓	✓	✓	2017	**	◆
	Sustainable and resilient buildings	Percentage of buildings constructed and retrofitted with criteria of sustainability	✓	✓	✓	○	✓	◆
	Urban mobility	Extension of cycle lanes (km)	✓	✓	✓	○	**	◆
		Congestion and delays monitoring system	✓	✓	✓	2016[b]	**	◆
		Percentage of bus lanes that are meant exclusively for buses	✓	✓	✓	○	**	◆
		Economic losses due to traffic accidents	✓	✓	✓	2016	**	◆
		Accessibility for mobility impaired groups	✓	✓	✓	○	✓	◆
		Share of municipal budget with public transportation	✓	✓	✓	○	**	●●
		Percentage of inhabitants living within 300 metres from public transportation	✓	✓	✓	○	✓	◆
		Affordability of public transport	✓	✓	✓	○	**	◆
		Average daily travel time	✓	✓	✓	2010	**	◆
		Percentage of public transport using renewable energy	✓	✓	✓	○	**	◆
		Percentage of accessible sidewalks (Km)	✓	✓	✓	○	**	◆
	Waste management	Integrated solid waste management plan in compliance to the National Solid Waste Policy	✓	✓	✓	2013	**	◆
Strategic Plan	Cultural heritage	Number of licenses to construct and/or restore the city centre	✓	✓	✓	2013	**	2016/2020/ 2033
	Disaster risk reduction	Number of inhabitants living in risk areas	✓	✓	✓	2014	✓	
	Green areas	Restoration of degraded green areas	✓	✓	✓	○	**	
	Housing	Proportion of urban population living in inadequate housing	✓	✓	✓	2010	✓	
		Housing deficit (%)	✓	✓	✓	2010	**	
	Safety	Number of deaths per 100,000 people	✓	✓	✓	2012	✓	
		Number of robberies and larceny victims per 100,000 people	✓	✓	✓	2013	**	
	Sustainable urbanization	Population density at city centre	✓	✓	✓	2010	**	
	Transportation	Average commute time	✓	✓	✓	2010	**	
		Extension of bicycle lanes	✓	✓	✓	○	**	

c.1 - Easy to apply; **c.2** - Easy to calculate; **c.3** - Relevant to local levels; **c.4** - Latest available data; **c.5** - Contributes to SDG 11 target; **c.6** - Time-bound. [a] - Data available only for some municipalities; [b] - Data available for only 15 cities.

✓ – Indicator fits criteria; ** - Indicator is not explicit in the SDG official list but contributes to SDG 11 targets; ○ - No data available; ●● - Annual; ◆ - Frequency unknown.
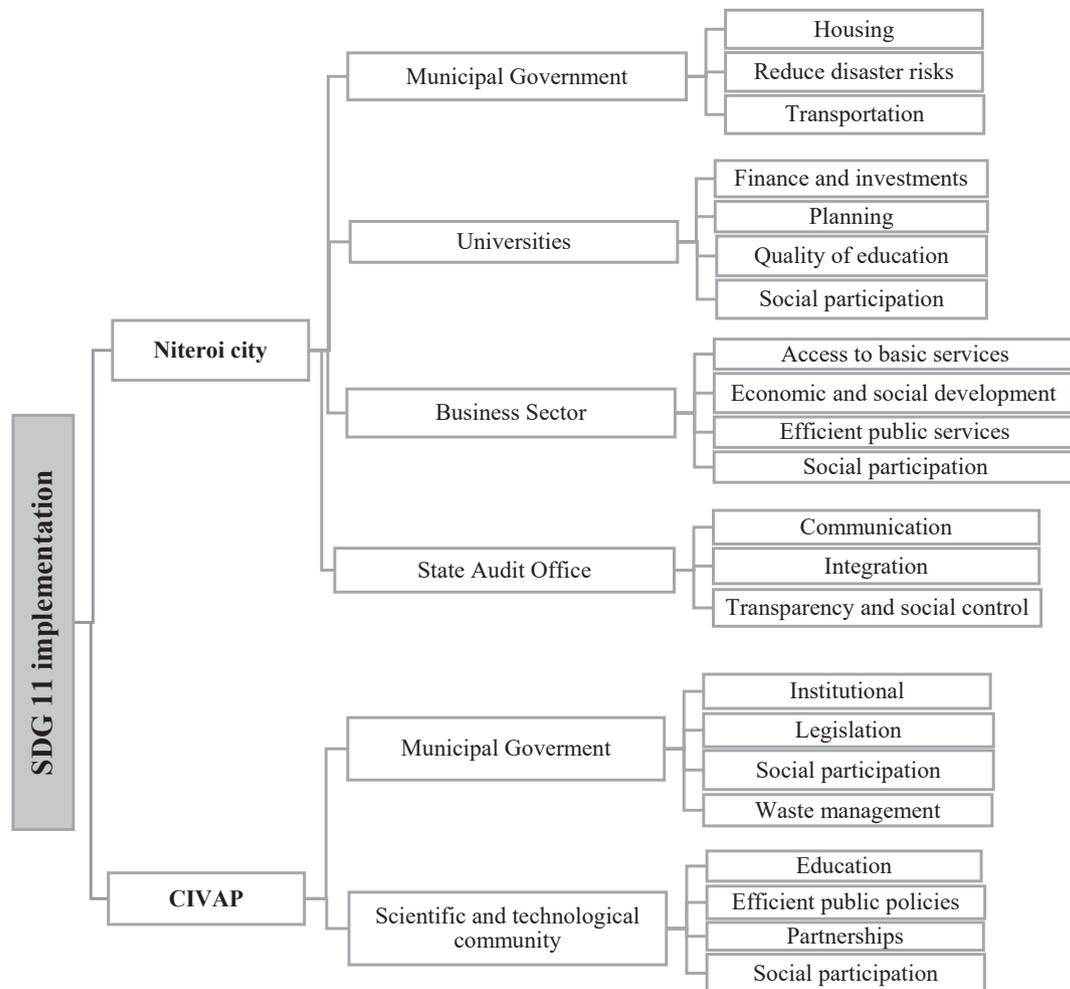
Fig. 4. Value tree for each stakeholder category regarding the implementation of SDG 11 in Niteroi City and CIVAP region.

are important issues regarding the implementation of SDG 11. Some of those issues are directly related to priority areas identified in the the strategic plan Niteroi que Queremos 2033. However, except for the need to increase social participation and to delivery efficient public policies, the results show that each stakeholder group has a distinct opinion about the most important issues. The lack of convergence between the key stakeholders also makes it difficult to align priorities with ongoing efforts promoted by the municipal government.

Concerning the indicators, a total of 31 indicators was identified by key stakeholders and are outlined in Table 4. Those indicators are comprehensive and incorporate a multi-stakeholder view about the main challenges to implementing SDG 11. It is also important to note that, although it was not the intention of this research to analyze trade-offs or interlinkages between SDGs, seven indicators identified by stakeholders are related to other goals, mainly Goal 17 (Partnerships and means of implementation) and Goal 16 (Peace, justice, and strong institutions). Furthermore, the results indicate that some qualitative indicators should be added for more accurate evaluation of SDG 11.

Thereby, it can be said that while municipal government is focused on delivery services in three critical areas, the general population is more interested in monitoring the quality of services, transparency and social participation.

Based on the AHP results, Fig. 5 shows the preference of local stakeholder groups. In Niteroi city, reducing disaster risks and improving transportation were the most preferred criterion by municipal government representatives. Moreover, local public authorities also expressed concern about promoting effective social participation.

University experts consider that guaranteed financial resources and increasing the investments in education are the most important criteria for promoting sustainable cities. Improving the quality of education, planning, and stimulating social control were also identified as priorities among the universities. The business sector showed strong preference for increasing social participation, especially throughout dialogue with stakeholders. Promoting alternatives to integrated economic and social development, especially in poor communities, and increasing efficiency of public services were also ranked as important criteria by the business sector. The access to basic services was identified as a criterion but was given less importance. State audit office representatives gave the highest importance to integration between systems for control purposes, but also, enhancing transparency and strengthen social control, as well as increasing mechanisms for communication with citizens.

Regarding the CIVAP region, Fig. 6 shows the preference of municipal government and scientific and technological community representatives. For the municipal government representatives, compliance with the law is the most important criteria for promoting sustainability in the region. The quality of waste management was also identified as an important criteria as well as social participation and institutional aspects related to local public service.

Scientific and technological community representatives consider that efficient public policies and educational campaigns are the most important criteria to SDG 11 implementation in the region. Also, enhancing social participation and establish partnerships were identified as important criteria.

Table 4

Set of indicators proposed by key stakeholders regarding the implementation of SDG 11 in Niteroi City and CIVAP region.

Stakeholder Group	Criteria	Indicators	SDG Target
Municipal Government	1. Disaster risk reduction	1.1 Adequate methodology to improve infrastructure in slums	11.1
		1.2 Map risks to slums upgrading	11.5
		1.3 Slums upgrading based on participatory and integrated approach	11.3
		1.4 Proportion of financial support allocated to upgrade slums	11.1
	2. Housing	2.1 Planned settlements	11.1
		2.2 Citizen participation and social control	11.3
		2.3 Housing finance	11.1
	3. Institutional	3.1 Efficient public services	SDG 16
	4. Legislation	4.1 Effective application of the law and regulations	SDG 16
	5. Social participation	5.1 Enhance community participation	SDG 17
	6. Transportation	3.1 Citizens' satisfaction with public transport	11.2
		3.2 Modal Split	11.2
		3.3 Review of bus concession contracts	11.2
		3.4 Proportion of population with convenient access to public transport*	11.2
	7. Waste management	4.1 Efficient waste management services	11.6
		4.2 Regional public landfills	11.6
Universities/ Scientific and technological community	1. Efficiency of public policies	1.1 Citizens' satisfaction with public services	SDG 17
	2. Finance and investments	2.1 Share of municipal budget with education, research, and development	SDG 17
	3. Partnerships	3.1 Establish partnerships with development agencies	SDG 17
		3.2 Establish partnerships with business sector	SDG 17
	4. Planning	4.1 Citizens' satisfaction with opportunities to participate in local planning and decision-making process	11.3
	5. Quality of Education	5.1 Improve the quality of public schools	SDG 4
	6. Social participation	6.1 Projects to enhance social participation	SDG 17
		6.2 Promote community engagement	SDG 17
Business Sector	1. Access to basic services	1.1. Access to improved water	11.1
	2. Economic and social development	2.1. Promote new alternatives to integrate economic and social development	SDG 8
	3. Efficiency of public services	3.1 Citizens' satisfaction with public services	SDG 17
	4. Social Participation	4.1 Dialogue between stakeholders	11.3
State Audit Office	1. Communication	1.1 Mobilize civil society to communicate and raise awareness about SDGs goals	SDG 16
	2. Integration	2.1 Integration of systems to enhance social control	SDG 16

Table 4 (*continued*)

Stakeholder Group	Criteria	Indicators	SDG Target
	3. Transparency and social control	3.1 Existing mechanisms and processes which ensure openness and accountability	SDG 16

* Indicator should be disaggregated by gender, age, and persons with disabilities.

2.3. Discussion

Overall, the results provided in this research reflected the major urban issues in Niteroi city and CIVAP region. The results also brought to light important findings regarding key stakeholder's opinions on SDG 11 achievement. The results show that no local system developed to evaluate sustainable cities in Brazil is totally adequate, suggesting shifts in the ongoing model. Perhaps, municipal government should better integrate planning tools and SDG 11 indicators. Also, the disclosure of municipal data was an issue in this research. Aspects related to governance and social participation need to be taken into consideration; as well, qualitative indicators should be added to the systems of evaluation. Adding some qualitative indicators could provide valuable information to assessments based only on quantitative indicators (Keirstead, 2007). In practical terms, some adjustment of existing indicators will be necessary - mainly disaggregation through gender, age, and persons with disabilities, and integration between plans and policies to gain better information and decision-making. In this sense, special attention should be given to the lack of integration between climate change and disaster risk reduction.

Regarding the process of selecting indicators, although many existing approaches have been developed, creating indicators is still a challenging task (Lützkendorf and Balouktsi, 2017) and can fail to attain the desired performance if an inadequate process is adopted (Organisation for Economic Co-operation and Development, 2003; Pupphachai and Zuidema, 2017). Also, the selection of indicators cannot be based only on gathering information but also on facilitating the analysis of progress of critical issues (Shen et al., 2011). The methodology adopted in this research can be helpful for facilitating stakeholder participation at local levels, including a comprehensive evaluation of stakeholders' concerns, and facilitating consensus-building (Macharis et al., 2009; Macharis et al., 2012). The methodology allows a better understanding about distinct stakeholders' expectations because it includes all points of view and several criteria in the analysis, avoiding the situation where the results are the least of the outcomes (Innes, 2004). The adoption of a localized approach to select indicators can give a more accurate picture about urban dynamics (Gómez-Álvarez et al., 2018) and identify key issues that demand transformations in Niteroi city and CIVAP region. Importantly, the methodology can be used by all municipalities and also other governmental levels since it is not exclusively applied.

Hence, MAMCA results can be seen from four perspectives: municipal government, universities/scientific and technological community, business sector, and audit state office. In Niteroi city, the municipal government representatives considered that the indicators are helpful for improving public services and reducing some important urban vulnerabilities. For the universities, the indicators can be used as tools for better public management and for enhancing social participation. For the business sector, the indicators are useful for improving services for the public and improving social participation. The audit state office considers that indicators can help to enhance local governance, mainly matters of transparency and social control. In CIVAP region the indicators chosen by the municipal government can help to improve social participation but mainly institutional aspects. For the scientific and technological community, the indicators should be using to enhance efficiency of public policies and quality of education. Indeed, evaluations involving different geographical levels can lead to distinct perspectives and different
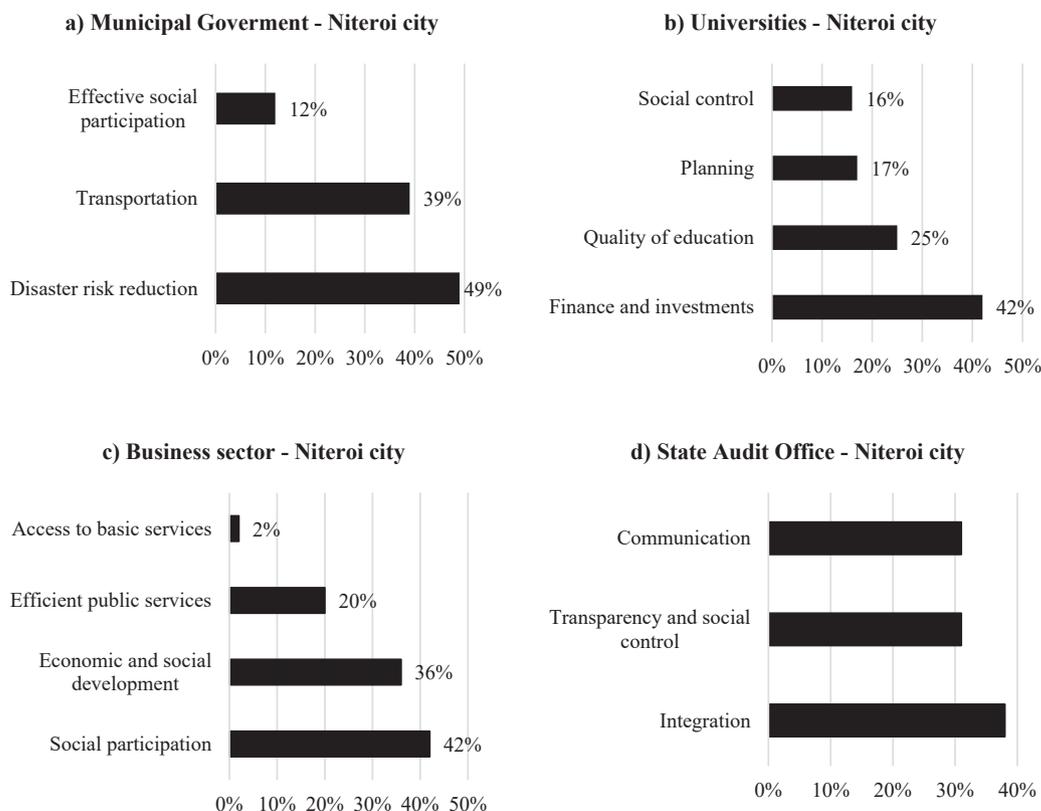
a) Municipal Goverment - Niteroi city

b) Universities - Niteroi city

c) Business sector - Niteroi city

d) State Audit Office - Niteroi city

Fig. 5. Stakeholder consolidated priorities in Niteroi city based on pairwise comparison (AHP).

a) Municipal Goverment - CIVAP

b) Scientific and technological community - CIVAP
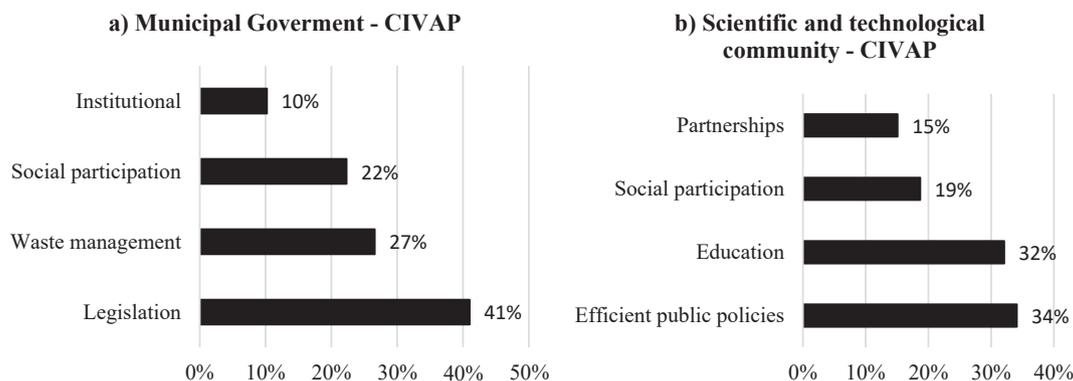
Fig. 6. Stakeholder consolidated priorities in CIVAP region based on pairwise comparison (AHP).

outcomes (Grafakos et al., 2015). Significantly, to the best of my knowledge, although not conclusive, those results are relevant because the analysis of SDG 11 based on MAMCA has not been previously performed in Brazilian municipalities or other cities.

Based on the results, it is also important to acknowledge the interlinkages and interdependencies among goals to guarantee an integrated implementation of SDGs. In this study, key stakeholders focused on the need for integrating SDG 11 targets with other goals: SDG 4 (Quality education), SDG 8 (Inclusive and sustainable economic growth), SDG 16 (Peace, justice, and strong institutions), and SDG 17 (Partnerships and means of implementation). Significantly, integration among the means of implementation themselves has been highlighted as a factor of success of Agenda 2030 (Stafford-Smith et al., 2017).

In terms of limitations, there are some concerns to take into account. First, most of data required to measure progress towards SDG 11 will have to be generated through municipal government, which is not well

structured for data collection and analysis. Second, the narrow representability of the business sector and the lack of NGO participation were key limitations in this research. Furthermore, the difficulty in promoting social participation at local levels, and the lack of systematic data collection and reporting by Brazilian municipalities, have been reported as barriers for successful achievement of goal 11 (Almeida et al., 2018). Considering the difficulties associated with SDG reporting when it is coordinated at the national level (Patel et al., 2017), the indicators identified in this research can be helpful for informing progress to the national level. Moreover, the available indicators have great potential to evaluate the achievement of SDG 11 targets and can be applied to different types of cities.

3. Conclusions

This research concludes that the adopted methodology can support

local decision-makers to build a more effective implementation of SDG 11 in Brazilian municipalities by mainly providing an overview of major urban issues based on a multi-stakeholder view. The definition of alternatives to be analysed (step 1) and the selection of stakeholders (step 2) are critical steps in the methodology to legitimise the outcomes. The selection of key stakeholders was a limitation in this study. Regarding the choices and the weights of the criteria (step 3), the technique adopted in this research was suitable but other approaches could be tested. Overall, the MAMCA facilitated communication and deeper analysis by distinct stakeholders, indicating the most important issues regarding SDG 11 implementation. Also, through the methodology it was possible to identify convergences and conflicts between key stakeholders, which should be considered in the further development of local policies and decision making.

The identification of criteria, indicators and measurement methods (step 4) is very useful and can facilitate implementation and evaluation of local policies. The developed indicators can also be used as a starting point to assess the contribution of local policies already deployed in the city to SDG 11 achievement. Also, the indicators can be used to build the municipal baseline and contribute to national achievements and reporting. Therefore, the use of indicators based on a multi-stakeholder view can support the municipal government in identifying new opportunities for sustainable urban development, enabling more systemic and holistic views to facilitate formulation of local policies.

The Analytical hierarchy process (AHP) used to develop step 5 was very suitable and facilitated the analysis of different stakeholders' points of view. Regarding the outcomes (step 6 and 7), although the results are insightful, considering that a broad participation was not possible to achieve, a validation phase including new local stakeholders' views should be incorporated for further refinement and improvement of indicators. In this phase, more indicators could be added or eliminated. Significantly, considering the distinct realities in the country, it's likely that the set of indicators developed in this research would not suit all municipalities, requiring some adjustments.

Finally, the results revealed that existing systems of indicators will not be able to demonstrate progress towards achieving SDG 11 targets at local levels. It is necessary to adjust existing indicators and organize a consistent and frequent method to gather and evaluate data as well as mobilize civil society towards the importance of SDGs' achievements. Moreover, data and the updated frequency that facilitates to monitor evolutions.

Declarations

Author contribution statement

Ana C. L. Almeida: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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