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Assessing the sustainability dimension at local scale: Case study of Spanish cities

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ABSTRACT

Nowadays, cities host most of the world population. As a result of human activities within their boundaries, most greenhouse gases emissions, natural resources consumption and waste generation are concentrated in urban areas. For these reasons, studies focusing on assessing the sustainability of cities have increased in recent decades. Bearing in mind the three pillars of sustainability (social, economic and environmental), this study aims to evaluate the level of sustainability of 31 representative Spanish cities through multiple sustainability indicators, which have been aggregated into a composite sustainability indicator that is reported by a three-letter code. Thus, each pillar of sustainability is represented by a letter A, B or C in the three-letter code, so that the letter A corresponds to the best rate and C to the worst.

Within the geographical and socio-demographic framework of Spain, the results show considerable differences between the cities in the south and the north of the country. Accordingly, most of the cities with the best sustainability scores according to the award of at least two A in the three-letters code are located in the north of the country. Examples of this category are Pamplona and L'Hospitalet de Llobregat (both ranked as AAA). Cities such as Murcia, Gijon, Badajoz and Huelva obtained the worst ranking with the CCC rating. For this group of cities, actions for the improvement of sustainability have been identified.

1. Introduction

The world urban population has grown exponentially since 1950. The causes of this accelerated population growth are multiple, the main one being the migration from rural to urban areas, which provide economic opportunities for citizens (Steffen et al., 2015). In addition to developing countries, this increase in the population of cities is really noticeable in countries with emerging economies, such as China, whose urban population has increased from 20% to 50% in the last 20 years (Bai et al., 2014). As a result, cities are currently undergoing urban expansion and therefore, the number of megacities worldwide (cities with more than 10 million of inhabitants) is increasing (Kennedy et al., 2014). In terms of urban planning and population distribution, data show that 60% of the global population will live in cities and urban systems in the next two decades (Ibrahim et al., 2018; John et al., 2019). This fact makes that cities generate more than 80% of the global Gross Domestic Product (GDP), but at the same time, they contribute more than 70% of the global Greenhouse Gas (GHGs) emissions affecting Climatic Change (WorldBank, 2019). Furthermore, urban areas consume 75% of natural resources, being highly dependent on surrounding ecosystems and generating half of global waste (Chrysoulakis et al., 2013) as well as they have a direct impact on the land use due to the urban surface is estimated to increase by 150% in 2050 (Artmann et al., 2019; Swilling et al., 2018). Furthermore, consumption of natural resources currently exceeds the biological capacity of the Earth to generate these resources, compromising the global society, economy and environment (Swilling et al., 2013). Additionally, despite the benefits of urban living associated to a greater access to services, other socio-economic factors are also observed: unemployment rates, cost of life, crime and poverty (Feleki et al., 2018; Phillis et al., 2017). In addition, socio-economic parameters such as inequality also affect the environment, which may lead to an increase in atmospheric emissions and water pollution (Boyce, 2018).

As a result, environmental problems arising from cities are at the heart of the Agenda 2030 action plan established by the United Nations in 2015, where, for the first time in history, all member countries are committed to addressing major societal challenges over the next 15 years. In this regard, 17 Sustainable Development Goals (SDGs) were

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defined, involving the three pillars of sustainability (social, economic and environmental). In more detail, the achievement of more sustainable cities is explicit in SDG number 11 (Sustainable Cities and Communities), which focuses on making cities and human settlements inclusive, safe, resilient and sustainable (United Nations, 2015). In this context, the approach to sustainable development in cities is a prime objective that policy-makers and governments must take into account (Dodds et al., 2012). However, the lack of consensus among scientists on the definition of sustainability in urban systems is significant (Berardi, 2013; Tanguay et al., 2010). Kennedy et al. (2007) define a sustainable urban system as one whose extraction of natural resources and waste generation does not exceed the capacity of the environment to regenerate these resources and to assimilate the waste produced.

Therefore, the sustainability of a city depends considerably on the human activities performed within its system boundaries, involving therefore agricultural, daily life, building, transport and industrial activities (Cui et al., 2019). These activities are addressed in the concept of urban metabolism (UM), introduced by Burgess (1925) to analyse the growth of a city from a sociologist approach. Afterwards, the concept of UM was adapted with the aim of quantifying material and energy flows within the limits of a city (Wolman, 1965). Although the references identifying the first works are documents from several decades ago, the concept of UM, to which socio-economic processes were incorporated into its definition (Kennedy et al., 2007), is still valid today, and thus, a better understanding of the links between societies and the mentioned flows is needed in order to identify the possibilities of fostering sustainability (Dijst et al., 2018). Moreover, UM can be combined with other assessment methodologies to obtain data about the status of an urban area, such as material flow analysis (MFA) – considered as a supporting tool to identify inventory data (mass and energy flows) –, life cycle assessment (LCA), which identifies environmental burdens arising from urban behaviour, input–output analysis (IOA), which includes economic parameters, and extended environmentally IOA – to combine both environmental and economic indicators. However, the concept of sustainability must be developed under three fundamental pillars, considering social, economic and environmental aspects but these methodologies only consider environmental issues, with the exception of IOA which includes economic data, and require additional information in order to contemplate all dimensions of the sustainability (Goldstein et al., 2013). The use of indicators and indices to analyse the sustainability of urban systems has intensified since the 1992 Earth Summit in Rio de Janeiro (Michael et al., 2014). In this sense, ISO 37120 (International Standardization Organization, 2014) proposes a set of standard indicators that will be used for the assessment of cities, municipalities or local governments. Furthermore, there are different initiatives to define Sustainable Development Indicators (SDI), which consider different approaches such as energy efficiency, optimization of the urban transport system and waste management, among others (Dizdaroglu, 2017). However, the selection and number of potential indicators considered vary considerably according to the point of view of evaluator (Tanguay et al., 2010). Designing a methodology to select the best set of indicators based on all dimensions of sustainability is a challenge, as it may depend on very different factors (i.e., the scale of study and data quality).

The analysis of SDI could be applied at national, regional, municipal, neighbourhood or building level (Berardi, 2013). Regarding the latter, it allows introducing advances in aspects such as the selection of construction materials and building practices, mainly from environmental and economic perspective (Cole, 2010). It is foreseeable that the social dimension has little relevance when the analysis is carried out at building level. However, a neighbourhood or city level approach should include socio-economic variables associated with the interactions of many social parameters (e.g. inequality) with the environment (Berardi, 2013; Boyce, 2018; Huang et al., 2006). Studies at the regional, national and global levels tend to pay more attention to economic indicators (Copus et al., 2004). On the contrary, studies at local level focus not only on economic but also on social and environmental indicators (Copus et al., 2004).

Beyond the three equitable pillars of sustainability mentioned above, some authors include an additional pillar that is the institutional dimension of development, which seeks to identify aspects such as governance, expenditures and public administration as socio-economic and policy-making information to be taken into account. These pillars can be divided in different categories – e.g. security, health, education, well-being, housing or demographic among others are into social dimension. However, depending on the study, some categories may be considered as opposed to others. This fact shows the lack of consensus about which of these categories and how many dimensions should be taken into account (Feleki et al., 2018; Tanguay et al., 2010).

Bearing in mind the selection of an adequate set of indicators, mathematical tools such the Leopold Matrix, which establishes the interaction between the magnitude of an effect on the environment and the relevance of that effect, can be useful (Josimovic et al., 2014). This model could be designed to establish a rating of indicators taking into account their characteristics of simplicity, availability and easy to calculate, (Feleki and Vlachokostas, 2018).

A large number of indicators provide more extensive and complementary information than establishing a single value, but the need to collect a large volume of data could complicate the understanding of the results. Thus, the use of indexes or scores (e.g., the air quality index that reports daily air quality by means of six different colours according to the level of health concern) is increasingly recognized as specifically useful for public communications (Feleki et al., 2018; Tanguay et al., 2010). This is the case of developing composite indicators based on the aggregation of different variables or indicators that make easier the understanding of sustainability results and reduce significantly the number of separated indicators (Dizdaroglu, 2017; Riedler and Lang, 2018). Nevertheless, aggregation of data may also imply a lack of valuable information or even the elaboration of simplistic policy conclusions. As a result, it is necessary to develop a methodological framework for selecting and assessing the indicators required to develop sustainable action plans and adequately summarize multi-dimensional issues (Copus et al., 2004).

A sustainability index is also based on the aggregation of selected indicators. Indicators can be aggregated with an equal weight, i.e. all indicators are given the same weight, or attribute greater contribution or weight to some indicators than others in the same index Contrary to equal weight, attributed weight allows to establish which indicators are more relevant (Gan et al., 2017). The weighting method considered plays a key role in the results achieved and attention should be paid to the correlation and compensability between indicators, aspects that should be perfectly defined in the description of the aggregation methodology in order to avoid double counting in the index (Becker et al., 2017).

Having in mind the relevance of weighting and aggregation, several weighting and statistical techniques could be considered such as conjoint analysis (CA), data envelopment analysis (DEA) or analytical hierarchy process (AHP), among others (Carbajal-Hernández et al., 2013; Nardo et al., 2008). On the other hand, the definition and establishment of thresholds as reference values to classify an item as sustainable or not in agreement with the corresponding index is a challenge for both scientists and politicians who require to be reliable since it can lead to differences in sustainability rankings (Feleki et al., 2018).

Taking into account the uncertainty and lack of consensus in the scientific field on the evaluation of cities from a sustainability approach, this study aims to define an aggregation methodology to be applied to a set of 31 Spanish cities distributed throughout the country and classified by size. In the aggregation method, the AHP methodology has been chosen as the weighting method for the definition of sustainability index. Finally, a color sustainability label has been designed for cities based on the development of a three-letters based scale that takes into account the results of the three pillars of sustainability.

2. Materials and methods

2.1. Description of the methodology

Building a composite indicator is a complicated procedure and requires multiple stages such as the definition of a theoretical basis, selection of representative indicators, collection of valuable data, normalization, weighting, establishment of thresholds and interpretation of results, among others (Nardo et al., 2008). Attention should be paid to the procedure, as the final conclusions depend directly on the selected set of indicators and must be coherent with the goal of the study. As earlier mentioned, composite indicators or indices are useful for policy-makers to assess the state of an urban area in a way that makes it possible to develop specific sustainability strategies (Feleki et al., 2018; Tanguay et al., 2010). However, the selection of an adequate set of indicators (or variables) and the estimation of the aggregation method must be carefully justified because of their effect on the global composite indicator (Gan et al., 2017). For this reason, this section introduces the developed methodology to assess the sustainability of cities, which will finally be applied to the Spanish set of cities to obtain the corresponding sustainability ranking. Given that the theoretical basis of the need to develop solid and well-founded strategies to define sustainability in urban systems has been detailed in the introductory section of this study, attention will be paid to the following stages of constructing a composite indicator.

2.1.1. Selection of representative indicators set

The methodology adopted in this study to select the indicators to be analysed is the one developed by González-García et al. (2019) to analyse sustainability in municipalities but applied to Spanish cities. According to this methodology, the selection process is divided into four stages. First, an exhaustive compilation of indicators from different specialized agencies and databases was carried out. Secondly, duplicated indicators were removed. Next, a Leopold Matrix (Valizadeh and Hakimian, 2019) was designed in order to reduce the number of indicators and select the most appropriated ones based on criteria such as prioritizing indicators with data available at city level and favouring indicators that appear most often in the different data sources. Table 1shows the criteria established in the aforementioned Leopold Matrix and the corresponding marks.

Following the methodology considered, only indicators with scores after the construction of the Leopold Matrix greater than 6 were selected for evaluation, in order to ensure high representativeness and availability. Thus, if an indicator appears on 3 data sources and data are available at national level, this indicator should have a score of 3 for frequency of occurrence in data sources and a score of 2 in data availability (see Table 1). Therefore, the final mark linked to this indicator should be obtained after multiplying the mentioned scores achieving a value of 6. Therefore, this indicator comply the selection criteria.

Finally, with the aim of achieving a suitable number of indicators, a panel of experts composed of 17 people from different specialties was selected in order to determine which indicators, previously selected with the Leopold Matrix, could be considered relevant in the study based on their own experience within the corresponding research fields. Thus, experts from the following areas of knowledge were consulted: Psychology (21%), Economic Sciences (32%) and Chemical and Environmental Engineering (47%). Further, in this group of experts there are members of the Galician Federation of Municipalities and Provinces (FEGAMP)[1] which are helpful in the terms of urban planning and governance. The fact of considering several experts and from different disciplines increases the impartiality of the method and restrains the selection of the most important indicators.

[1] http://www.fegamp.gal/

Table 1
Established marks for the construction of the Leopold Matrix (Adapted from González-García et al. (2019).

Criterion	Score	
Frequency of apparition in Data Sources	Appears on 3 or more sources	3
	Appears on 2 sources	2
	Appears on 1 source	1
Data Availability	City scale	3
	Regional or national scale	2
	No data	1

In this study and given that it focuses at city level, a further selection has been performed, removing from the list the pre-selected indicators no relevant for the case study. This is the case of the indicator "distance to continued attention points and hospitals", which could be representative at municipality level, but not at city level. However and in order to maintain the number of indicators in the set, an additional one has been introduced. This is the case of the "number of hospital beds". Consequently, Table 2 shows the final indicators to be considered in the sustainability assessment.

2.1.2. Normalization

Data collected from indicators may be in different units of measurement, making it difficult to compare and operate with the different values – e.g., the units corresponding of the indicator "number of hospital beds" are completely different, for example, with the indicator "population density". Thus, prior normalization of data is necessary before aggregating indicators.

There are different normalization methods (Ebert and Welsch, 2004; Nardo et al., 2008) and depending on the method selected, different results could be achieved. In this study, the method selected for normalization was Re-Scaling. Consequently, all the normalized values obtained for the different indicators should be between 0 and 1, corresponding 1 to the best value and 0 to the worst (Nardo et al., 2005). For example, if three cities are selected (City 1, City 2 and City 3) that report for two different indicators the values x_1, x_2 and x_3 (for a stimulant[2] indicator) and y_1, y_2 and y_3 (for a non-stimulant indicators) respectively, the normalized value for the City 1 should be obtained according to Eqs. (1) and (2) for a stimulant indicator and a non-stimulant indicator, respectively:

$$N_1^1 = \frac{x_1 - min(x_1;x_2;x_3)}{max(x_1;x_2;x_3) - \min(x_1;x_2;x_3)} \quad (1)$$

$$N_1^2 = \frac{max(y_1;y_2;y_3) - y_1}{max(y_1;y_2;y_3) - \min(y_1;y_2;y_3)} \quad (2)$$

where N_1^i is the normalized value corresponding to city 1 being i equal to 1 for a stimulant indicator and equal to 2 for non-stimulant one. The minimum between the values x_1, x_2 and x_3 corresponds to $\min(x_1; x_2; x_3)$ and the maximum, to $\max(x_1; x_2; x_3)$. The same nomenclature is used for y_1, y_2 and y_3. In this sense, the normalized values should be 1 for the best mark and 0 to the worst.

As the example shows, the re-scaling method compares values of different items (cities in this case) for one indicator, and transforms the maximum value of cities in the highest score and the minimum value into the lowest. Furthermore, this method makes it very difficult to establish a threshold for determining which values of each indicator are sustainable or not, because the most sustainable city in a ranking of

[2] Stimulant indicator is the one in which a high value is related with a positive impact (e.g. gross domestic product). Contrarily, a high value in a non-stimulant indicator should mean a negative impact (e.g. risk of poverty or unemployment rate)

Table 2
Set of indicators selected for analysis. Adapted from González-García et al. (2019).

Pillar	Indicator	Description	Unit
Social	Population graduated in secondary education	Percentage of population with at least secondary education with respect to the total population	PSE/Total Population
	Number of registered gender violence cases	Number of demands for gender violence	No of demands/1000 inhabitants
	Women unemployed	Percentage of unemployed women with respect to women at working age	Women unemployed/Women at working age
	Population rate at risk of poverty	Percentage of population which incomes are 50% lower than the average	%
	People per household	Result of dividing the population with the number of households in the municipality	Inhabitants/Number of Households
	Population that participated in the last municipal election	Total number of people that have vote in the las municipal elections	Account votes/electoral census
	Population under 16 years old	Percentage of people aged between 0 and 16 years	%
	Population older than 65 years old	Percentage of people with more than 65 years	%
	Population annual net growth	Growth population rate in the period from 2008 to 2017	%
	Ratio of immigrants	Percentage of people who have born in a foreign country registered in the census	%
	Population Density	Population / Municipality surface	Inhabitants/km^2
	Number of leisure facilities	Number of a entertainment establishments in the municipality	No. leisure facilities/1000 inhabitants
	Hospitals Beds per Habitants	Number of Hospitals Beds per inhabitants	No. Hospitals Beds/1000 inhabitants
	Total expense in social services	Total expense in social services per inhabitant	Expense in social services/inhabitant
Economic	GDP per capita	Gross Domestic product of the municipality per inhabitant	€/inhabitant
	City unemployment rate	Unemployment rate of people at working age	%
	Average household income	Income per person by number of people per household	€/household
	Number of permanent contracts signed per 1000 inhabitants	Number of contracts permanents signed in 2017	No. contracts/1000 inhabitants
	Number of businesses per 1000 inhabitants	Total number of business registered in the municipality	No. business/1000 inhabitants
	Municipal budget per inhabitant	Adjusted budget	€
	Non-financial total incomes	Non-Financial incomes in municipality per inhabitant	€/inhabitant
	Surplus/Deficit	Difference between net budgetary rights liquidated and recognised obligation per inhabitant	€/inhabitant
	Indebtedness	debt per inhabitant of the municipality	€/inhabitant
	Investment	Real investments per inhabitant	€/inhabitant
	Average rental price per m^2	Average monthly price of rental housing per square meter	€/m^2
	Average sale price per m^2	Average price of housing per square meter	€/m^2
	Number of hotel places	Number of places in hotels	No hotel places/1000 inhabitants
Enviromental	Ratio of public/private vehicles	Number of buses per tourism and motorbikes	%
	Ozone	Annual average concentration of the stratospheric ozone in air	µg/m^3
	NO_2	Annual average concentration of nitrogen dioxide in air	µg/m^3
	PM10	Annual average concentration of particles with a diameter less than 10 µm	µg/m^3
	Total domestic water consumption per dwelling	Domestic water consumption per year	m^3/households
	Total electrical use per capita	Electricity consumed per inhabitant and year	MWh/inhabitant
	Surface of green area	Surface of green zones within the total city surface	%
	Surface of pedestrian zone	Surface of pedestrian zones within the total city surface	%
	MSW collected	Amount of municipal solid wastes collected in the municipality	kg/inhabitant
	Non-Compliance Wastewater Treatment	Compliance with European regulations on water discharge	Adimensional
	Sustainability plan, participation in projects and awards	number of current urban sustainability plans	No. plans

cities could not be sustainable depending on the group of cities compared. Within the sample analyzed, there are cities that have been awarded the international recognition of sustainable city. These cities are Vitoria-Gasteiz and Pontevedra (Barral, 2015; Rioja-Andueza, 2019). Therefore, they have been considered as reference points in the analysis. Accordingly, the cities under comparison should be divided into groups that take into account similar characteristics, e.g., their population, with the aim of avoiding very different systems.

2.1.3. *Aggregation and weighting*

Once the values of indicators are normalized, they can be combined in order to build the composite indicator. Aggregation and weighting are methodologies that allow a set of normalized indicators to be transformed into a composite indicator or index (Gan et al., 2017). Aggregation determines the conceptual framework used in order to combine indicators of the three pillars either separately or together (Tanguay et al., 2010). There are different methods of aggregation: additive (e.g., arithmetic), multiplicative (e.g., geometric) or non-compensatory (e.g., multi-criteria analysis) aggregation methods. The most common is the additive aggregation method, being the arithmetic mean by far the most used (Gan et al., 2017).

On the other hand, weighting attributes a different weight for each indicator. However, it is common the use of a method attributing the same weight, and therefore, considering all indicators with equal relevance. Nevertheless, there are different methodologies such the analytical hierarchy process (AHP) or the principal components analysis (PCA), among others, which assign different relevance to the indicators (Gan et al., 2017).

In the present study, the selected indicators were classified into three groups according the three pillars of sustainability: social, economic and environmental; and the aggregating method selected was the weighted arithmetic mean. Bearing in mind the procedure described by González-García et al. (2019) for the selection of indicators, the same weights attributed to each one by these authors have also been considered in this study, regardless of the indicators replaced. These weights were obtained after the application of the AHP methodology. This weighting method has been widely used in the composition of different indices and is characterized by its ease of understanding and implementation. Furthermore, this method is capable of integrating different criteria and also simplifies complex hierarchy problems

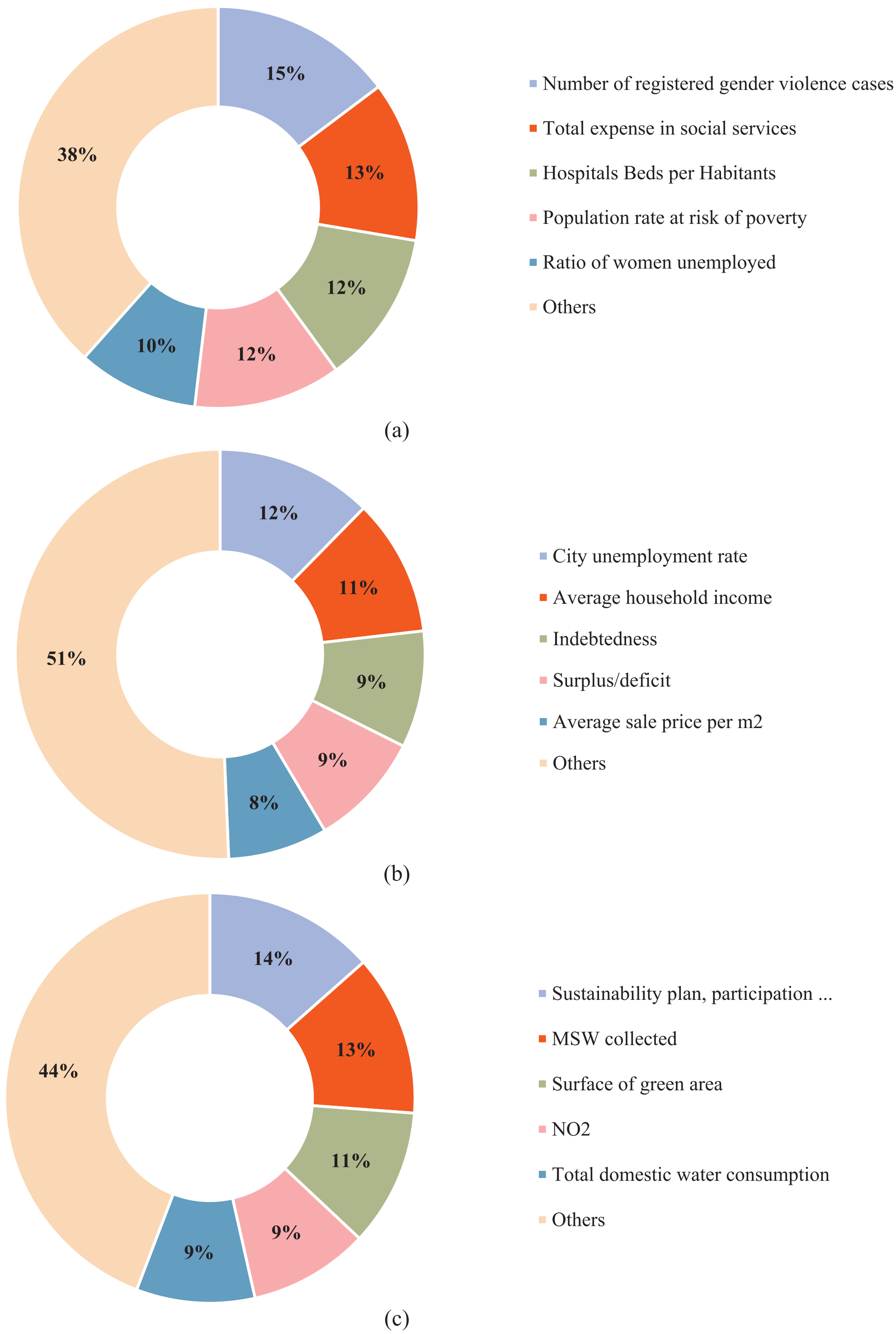

Fig. 1. Percentage distribution of the weights of the (a) social indicators, (b) economic indicators and (c) environmental indicators highlighting the five indicators with greater weight attributed by the AHP method.

(Sutadian et al., 2017). In AHP method the relevance of each indicator was evaluated over the others with scores between 0 and 9, being 9 the value corresponding to absolute importance, that is, that which should be predominant over the rest and 1 when both indicators present the same importance. The relative weights of the indicators were calculated using an eigenvector technique (Wind and Saaty, 2008). Finally, a priority vector was obtained with a weight assigned for each indicator between 0 and 1 for the indicators of each sustainability dimension. Fig. 1 details the distribution of the weights assigned to each indicator resulting from the AHP methodology.

2.1.4. Threshold establishment: rating letters for sustainability

After the aggregation and weighting stage, three composite indicators should be obtained for each city, taking into account the three pillars of sustainability. These composite indicators should have values ranging from 0 to 1. In order to establish thresholds within these composite indicators, they were divided for the quartiles into a Gaussian distribution. Cities whose value of the composite indicator, regardless of the sustainability pillar, was higher than that of the third quartile (Q_3), obtained an A rating. Cities with values between the first and third quartiles (Q_1 and Q_3 respectively) obtained a B rating. Finally, cities whose values were worse than Q_1 obtained a C rating. In this sense, the best values of composite indicators were designed with the letter A and the worst with C. For example, if the value of Q_3 was 0.65, and a city obtained a value of the social composite indicator of 0.68, this city has a mark of A in the social dimension. Therefore, a city had a code with 3 letters for each dimension of sustainability, and these letters can be A, B or C, depending on the value of the city in the corresponding composite indicator.

The present paper aims to define a sustainable city through this three-letter code. In this sense, it was established that a city with at least one A and no C in the code should be considered as sustainable city. Therefore, according with this criterion, the sustainability of a city depends on three independent values corresponding with the three pillars of sustainability. Consequently, this is in line with the concept of *strong sustainability* which considers that a poor result derived from low values in the environmental indicators cannot be compensated with satisfactory values in the economic or social ones (Cabello et al., 2019).

2.2. Case study

In the present study, a list of 31 Spanish cities has been proposed (Fig. 2) for analysis. Among the cities considered there are the ones with more than 250,000 ± 5,000 inhabitants that are Valencia, Seville, Zaragoza, Malaga, Murcia, Palma de Mallorca, Las Palmas de Gran Canaria, Bilbao, Alicante, Cordoba, Valladolid, Vigo, Gijon, L'Hospitalet de Llobregat, Vitoria-Gasteiz and A Coruña.

These cities are representative of 11 of the 17 autonomous communities that constitute Spain. Therefore, the most populated cities of the rest of autonomous communities were selected in order to consider representative cities in all regions. These cities were: Pamplona, Albacete, Santander, Logroño and Badajoz. It should be noted that Madrid and Barcelona: the two most populated and important Spanish cities in cultural, economic and political terms (Ricoa et al., 2019; Gómez-Losada et al., 2019), have not been taken into account due to the large differences in terms of number of inhabitants with respect to the rest of Spanish cities (the inhabitants of Barcelona are twice those of the third most populated Spanish city, i.e. Valencia, and Madrid is the third most populated city in the European Union).

However, some relevant cities at Spanish administrative level such as Oviedo, Santa Cruz de Tenerife, Santiago de Compostela and Toledo, have not been selected in the previously mentioned procedure. Therefore, they have been also included in the analysis. Moreover, some cities with small size were also selected to consider samples with different sizes of cities in all regions. These cities were Burgos, Huelva and Ourense. Finally, other criteria of selection were taken into account in order to complete the sample such as considering cities with an important historical heritage such as Tarragona and Lugo; as well as Pontevedra, a sustainable city at international level (Barral, 2015).

The selected cities present good geographical dispersion and are considered representative of all Spanish regions. Finally, these cities were classified into three groups according to their population: large (inhabitants > 350,000 ± 5000), medium (200,000 ± 5000 < inhabitants < 350,000 ± 5000) and small (inhabitants < 200,000 ± 5000). This classification avoids comparisons between cities with large differences in the number of inhabitants. Table 3 details the cities evaluated and some outstanding characteristics such as population size, population density and GDP.

2.3. Inventory data

Once the set of indicators and cities to be studied had been established, a compilation of data for each indicator was conducted for each city. For this purpose, the consultation of data was carried out considering local sources: websites of the municipalities; regional sources: websites of the different regional statistics institutes, website of

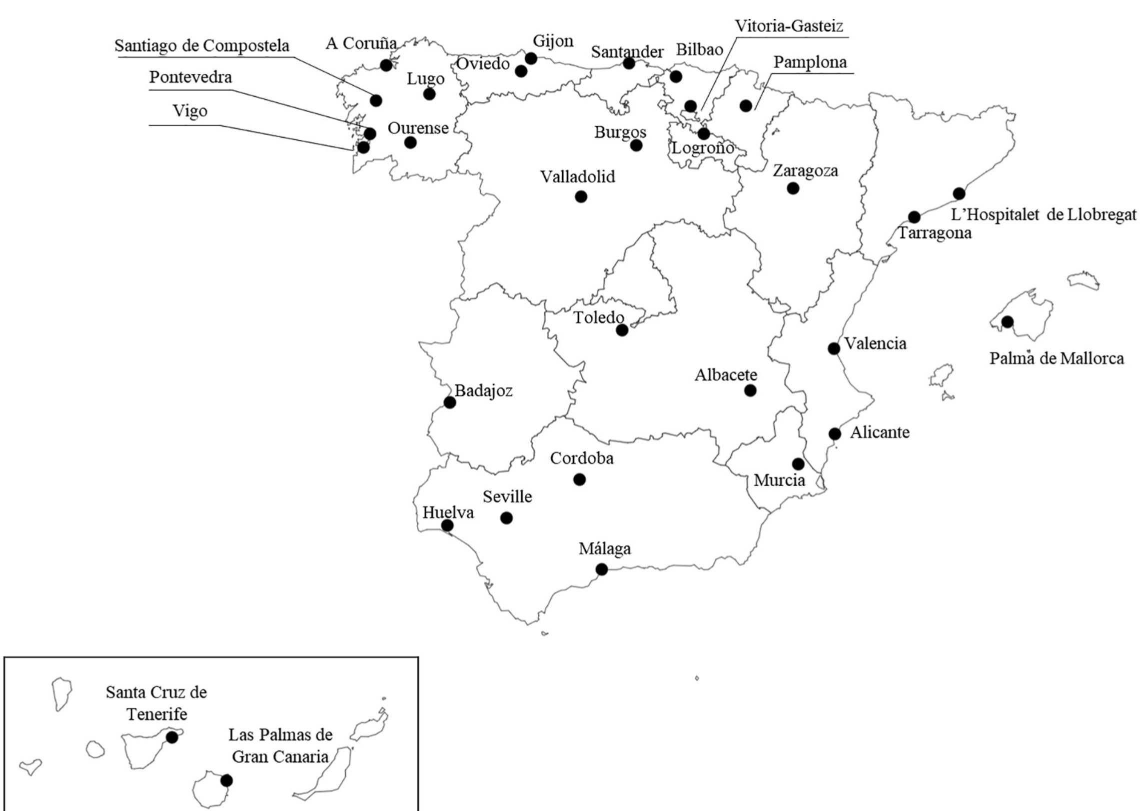

Fig. 2. Location on the map of the Spanish cities considered in the study.

Table 3
Cities considered for assessment and main characteristics. Data of population size correspond to 2017.

	Population size	Population density	GDP	
	(number of inhabitants)	(inhabitants·km^{-2})	(€·inhabitant^{-1})	(Source) Year
Large Size				
Valencia	787,808	5852	22,153	(1) 2014
Seville	689,434	4876	18,461	(2) 2015
Zaragoza	664,938	683	17,153	(3) 2011
Malaga	569,002	1439	17,021	(3) 2015
Murcia	443,243	503	19,227	(2) 2016
Palma de Mallorca	406,492	1949	27,994	(3) 2015
Las Palmas de Gran Canaria	377,650	3756	19,248	(2) 2015
Bilbao	345,110	8438	30,890	(3) 2012
Medium Size				
Alicante	329,988	1640	18,191	(2) 2015
Cordoba	325,916	260	16,724	(3) 2015
Valladolid	299,715	1514	22,492	(2) 2014
Vigo	292,986	2685	24,416	(3) 2014
Gijon	272,365	1499	31,773	(3) 2014
L'Hospitalet de Llobregat	253,782	20,466	23,200	(1) 2016
Vitoria - Gasteiz	246,976	876	32,252	(3) 2012
A Coruña	244,099	6458	24,987	(3) 2014
Oviedo	220,301	590	38,656	(3) 2014
Santa Cruz de Tenerife	203,692	1353	19,217	(2) 2015
Pamplona	197,138	7803	29,100	(3) 2015
Small Size				
Burgos	175,623	1640	27,205	(2) 2016
Albacete	172,816	141	19,067	(2) 2015
Santander	171,951	4947	15,826	(3) 2014
Logroño	150,979	1906	26,044	(2) 2015
Badajoz	150,543	105	15,748	(2) 2015
Huelva	145,115	953	18,125	(2) 2017
Tarragona	131,507	2272	41,900	(3) 2017
Ourense	105,636	1220	19,720	(3) 2014
Lugo	97,995	294	21,800	(3) 2014
Santiago de Compostela	96,456	440	32,637	(3) 2014
Toledo	83,741	361	17,169	(2) 2015
Pontevedra	82,671	684	21,253	(3) 2014

(1) City council website; (2) National Statistics Institute (Statistics National Institute, n.d.); (3) Regional Statistic Institute.

regional governments and institutions (e.g. air quality data are available from meteorological agencies); national sources: Statistics National Institute (Statistics National Institute, n.d.), national government (Accountability, 2016; Government of Spain, 2016) and national institutions (Directorate General of Traffic, 2016; Electoral Commission, 2015; Public Service of State Employment, 2017), as well as data collected from Spanish ministerial offices and services (Ministry of Development, 2018; Ministry of Health Social Services and Equality, 2017). In addition, data were obtained from on-line observatories such as Datosmacro (Expansion, n.d.), Idealista (Idealista, 2016), Spanish companies guide (Universia, 2019) and the Ais group (Ais Group, 2016). Mention has also been made of data from cities that do not comply with the regulations on wastewater treatment, information compiled through a newspaper article published in El País (Planelles, 2018).

Regarding information corresponding to leisure facilities, it was estimated by means of a Google search in the different Spanish cities taking into account different leisure options: leisure centers, theatres and concert halls, cinemas, art galleries, museums, sport centers, gyms, golf clubs, swimming pools, ice skating rinks, spas, thematic parks, children parks and bowling alleys. In addition, when geographical data were not available in the mentioned sources, "Google Earth Pro (7.3.2.5776)" (2019) was used to calculate data regarding the surface of cities (km^2), green areas (km^2) and pedestrian areas (km^2), according to the limited traffic areas of each city. Tables SM1-SM9 in the Supplementary Material summarize the information compiled for each city together with the corresponding year, source and scale, depending on whether it is local, regional or national data.

3. Results and discussion

3.1. Ranking of cities

After compiling the inventory data for each indicator, the mathematical methodology detailed in Section 2.1 has been applied in order to obtain a composite indicator for each city and sustainability dimension. This composite indicator is the result of aggregating the corresponding values and the attributed weights. As a result, cities were rated between 0 and 1. The values of the first and third quartiles between cities in the same size category were then calculated. Table 4 displays the values for the composite indicators of cities classified by size. The distance between quartiles indicates the difference between cities within the same size category. For example, in the medium size category the difference between the quartiles for the economic factor is 0.069, while in the small size category it is 0.258. This implies that, in economic terms, medium-sized cities are more similar to each other than smaller cities.

Finally, the assignment to each city of a three-letter code was conducted taking into account the values indicated in Table 4. Thus, cities with a score higher than the third quartile have been rated as A in the corresponding dimension of sustainability. Cities with values between the first and the third quartiles have been rated as B, and consequently, cities with values below the first quartile have been classified as C. For example, Toledo, classified within the Small Size category, obtained a score of 0.743 in the social composite indicator, a value clearly higher than that corresponding to the third quartile (0.644). Thus, Toledo was ranked as A in the social dimension. Following this approach Toledo

Table 4
Values for the composite indicators associated to each city for the three sustainability dimensions and corresponding quartiles.

Large size			
City	Social	Economic	Environmental
Valencia	0.386	0.425	0.746
Seville	0.414	0.365	0.643
Zaragoza	0.514	0.383	0.629
Malaga	0.303	0.333	0.494
Murcia	0.375	0.307	0.415
Palma de Mallorca	0.565	0.545	0.455
Las Palmas de Gran Canaria	0.451	0.415	0.698
Bilbao	0.526	0.637	0.554
First quartile value	0.378	0.341	0.465
Third quartile value	0.523	0.515	0.684
Medium Size			
City	**Social**	**Economic**	**Environmental**
Alicante	0.313	0.435	0.601
Cordoba	0.405	0.326	0.586
Valladolid	0.491	0.460	0.624
Vigo	0.482	0.399	0.483
Gijon	0.347	0.335	0.446
L'Hospitalet de Llobregat	0.569	0.607	0.682
Vitoria-Gasteiz	0.662	0.448	0.502
A Coruña	0.557	0.449	0.505
Oviedo	0.517	0.432	0.552
Santa Cruz de Tenerife	0.450	0.468	0.416
Pamplona	0.688	0.516	0.774
First quartile value	0.405	0.399	0.483
Third quartile value	0.569	0.468	0.624
Small Size			
City	**Social**	**Economic**	**Environmental**
Burgos	0.516	0.553	0.577
Albacete	0.617	0.272	0.364
Santander	0.434	0.639	0.399
Logroño	0.749	0.518	0.459
Badajoz	0.311	0.242	0.388
Huelva	0.301	0.230	0.349
Tarragona	0.616	0.493	0.522
Ourense	0.493	0.475	0.468
Lugo	0.612	0.394	0.601
Santiago de Compostela	0.653	0.563	0.437
Toledo	0.743	0.566	0.500
Pontevedra	0.573	0.424	0.643
First quartile value	0.449	0.303	0.390
Third quartile value	0.644	0.561	0.564

obtained a three-letter code AAB (social-economic-environmental). Having in mind the criterion described in Section 2.1.4 to define a city as sustainable (sustainable cities are those that in the letter code obtain at least one A and no C), Toledo can be considered as a sustainable city.

Accordingly, all cities have obtained a three-letter code between AAA and CCC resulting in 27 possible combinations, of which only 7 should define a city as sustainable. The first letter corresponds to the social aspect, the second to the economic variable and the third to the environmental one. According to the results, 13 of the 31 studied cities have been identified as sustainable, most of them being small-sized cities. However, the best scores have been obtained in the cities corresponding to the medium-sized category, with two cities ranked with a triple A code (AAA). This is why the C rank is concentrated in fewer cities in the small towns: Alicante has two C and Huelva and Badajoz have three C each. Therefore, the number of sustainable cities was higher. In addition, there is much more dispersion in the values of the composite indicators of the small cities, which indicates that the differences between them are much greater. In the case of medium-sized cities, the dispersion is much less than in the case of small cities, except in the cases where it was rated AAA: Pamplona and L'Hospitalet de

Table 5
Cities studied with their corresponding three-letter code.

Big Size		Medium Size		Small Size	
Valencia	BBA	Alicante	CBB	Burgos	BBA
Seville	BBB	Cordoba	BCB	Albacete	BCC
Zaragoza	BBB	Valladolid	BBA	Santander	CAB
Malaga	CCB	Vigo	BBB	Logroño	ABB
Murcia	CCC	Gijon	CCC	Badajoz	CCC
Palma de Mallorca	AAC	L'Hospitalet de Llobregat	AAA	Huelva	CCC
Las Palmas de Gran Canaria	BBA	Vitoria-Gasteiz	ABB	Tarragona	BBB
Bilbao	AAB	A Coruña	BBB	Ourense	BBB
		Oviedo	BBB	Lugo	BBA
		Santa Cruz de Tenerife	BAC	Santiago de Compostela	AAB
		Pamplona	AAA	Toledo	AAB
				Pontevedra	BBA

Llobregat, which are outlined in all the composite indicators. Thus, there is a greater number of cities between quartiles 1 and 3, and therefore fewer sustainable cities.

On the other hand, there are four cities that have been classified as CCC: Murcia, Gijon, Badajoz and Huelva. Moreover, all the cities under study with the letter A in the environmental score achieve the sustainability category as detailed in Table 5. The rationale behind this finding could be cities with an important environmental commitment, are usually those whose citizens have a certain welfare state, otherwise, the municipality and citizens would give priority to economic and social development. On the contrary, there are some cities with an A in the letter code corresponding to social or economic aspects which do not achieve the category of sustainable city. These were the cases of Palma de Mallorca, Santa Cruz de Tenerife or Santander, whose letter codes were AAC, BAC and CAB respectively. The first two are cities with high tourist influence, which brings great economic benefits, but which demands a large consumption of electricity and water and generates large amount of waste. On the other hand, the reason why Santander has not been classified as sustainable is due to depopulation. Furthermore, in the case of Palma de Mallorca although its code has two A, according to established criteria, does not reach the category of sustainable. In this sense, a balance between social, economic and environmental indicators is required to be sustainable. Table 5 details the different three-letter codes of the selected Spanish cities.

Bearing in mind that each composite indicator depends on multiple indicators, it should be necessary to identify these indicators with the lowest scores in order to propose for improvement. Table 6 shows the cities ranked as CCC as well as the indicators that obtained a value of 0 after the normalization step.

In the case of the four cities ranked as CCC, it is important to note how close they are to the threshold established by the first quartile. It is thus possible to identify the indicators on which they have the lowest scores in order to propose actions to improve the global performance. The main differences between the first quartile value and the composite indicator obtained correspond to the social composite indicator for the cities of Badajoz and Huelva. The rationale behind these results is due to the notable differences in the values achieved in the social indicators. However, the social composite indicator in the case of Murcia is similar to that of the first quartile. The same happened for the environmental composite indicator in the case of Badajoz. These differences or similarities indicate how close one city is to acquiring a B score on some of the sustainability dimensions. Fig. 3 presents the values of the first quartile and the values of the composite indicators for the cities that have rated CCC.

In the case of Murcia, the social indicators “people per dwelling” and “population density” are related to the size of the city and whether or not it is a compact population. However, Murcia has the smallest

Table 6
Cities with rating CCC and the indicators whose relative values after normalization were 0.

	Murcia	Gijon	Badajoz	Huelva
Social Indicators	People per dwelling. Population Density. Number of leisure facilities per 1000 inhabitants. Total expense in social services.	Ratio of population under 16 years old. Hospitals Beds per inhabitants.	Ratio of immigrants. Population Density. Number of leisure facilities per 1000 inhabitants. Total expense in social services.	Number of registered gender violence cases per 1000 inhabitants Ratio of women unemployed Population rate at risk of poverty.
Economic Indicators	Average household income. Non-financial total incomes. Average rental price per m^2. Average sale price per m^2. Number of hotel places.	Number of permanent contracts signed per 1000 inhabitants.	GDP per inhabitant. Non-financial total incomes. Surplus/deficit. Investment.	City unemployment rate Number of permanent contracts signed per 1000 inhabitants. Indebtedness.
Environmental Indicators	Ratio of public/private vehicles. Surface of green area. Sustainability plan, participation in projects and awards.	Surface of green area. MSW collected. Non-Compliance Waste Water Treatment.	Ratio of public/private vehicles. Total domestic water consumption.	Ozone. PM10.

green area despite its surface is relatively large. Consequently, the city should take into account the incorporation of both elements in future urban planning strategies to achieve a sustainable category. In economic terms, it highlights indicators related to the price of housing. These indicators are stimulant indicators, that is high rental and sale housing prices indicate the high purchasing power in the city. This reality is explained by the low values of the "average household incomes" and "non-financial total incomes" that refer to tax collection.

Gijon is one of the few cities that do not comply with wastewater discharge limits. Moreover, it is the medium-sized city with the highest production of waste and must also improve the extension of green areas in terms of environmental indicators. Consequently, the city should take these aspects into account in its improvement strategy and pay attention to the design of better urban planning having in mind both wastewater and solid waste management.

On the other hand, although Gijon has been ranked as C in the economic pillar, it has only obtained the lowest value in one economic indicator. The reason for this result is due to the small difference between the quartiles in the case of economic indicators in medium-sized cities, which means that cities with few differences in some values of the indicators have a remarkably different result in the letter ranking. Moreover, bearing in mind the social pillar, Gijon is the medium-sized city with the lowest number of hospital beds as well as with the lowest population ratio under 16 years of age.

Badajoz and Huelva, as shown in Fig. 3, have the greatest challenges within social indicators. In the case of Badajoz with the lowest "ratio of immigrants" within the category of small cities, it could imply a low number of inhabitants of working age, which may also explain, together with the low number of companies, the low GDP per inhabitant and the low level of attraction as a working pole. Moreover, the low expenditure on social services is easily related to municipal budget indicators, which are also shown in Table 6.

Regarding Huelva, it is the small city with the highest number of registered cases of gender-based violence and the highest ratio of unemployed women. It therefore requires the promotion of gender equality projects by city policy-makers.

In addition, some of these indicators have a high weight attributed by the AHP methodology. This is the case of the number of registered cases of gender violence or the total expenditure on social services in the case of social indicators, the urban unemployment rate as an economic indicator or the MSW collected within the environmental indicators. This makes it more difficult for cities with low relative values in these indicators to achieve sustainable city status.

According to geographical distribution, most sustainable cities are located in the north, especially the geographical area in which Bilbao, Vitoria-Gasteiz, Pamplona, Logroño and Burgos are located. On the one hand, Bilbao and Vitoria-Gasteiz belong to the Basque country and this region has an independent fiscal management; thus, the expenditure on social services is the highest of all cities. Logroño also stand out for its expenditure on social services and ranks as the first for the small-sized city group. In the case of Burgos, it is the city with not only the lowest unemployment rate of the small cities, but also it has a large surface of green zones. Pamplona, on the other hand, has the smallest population at risk of poverty in medium-sized cities, a low number of unemployed people and a large number of sustainability plans. Therefore, Pamplona together with L'Hospitalet de Llobregat are a good example of balance between the three dimensions of sustainability. In addition, cases such Toledo and L'Hospitalet de Llobregat could be positively affected due to the proximity of both cities to Madrid and Barcelona respectively.

Contrary, the worst sustainability results were obtained mainly in the south. This is due to the high rate of unemployment registered in the regions of Andalusia, Murcia and Extremadura, as well as the high ratio of population at risk of poverty. Moreover, in Andalusia the low number of permanent contracts signed indicates a low quality of jobs. This is in part because tourism is a key economic factor in the south of Spain, which is characterized by being a seasonal sector with precarious

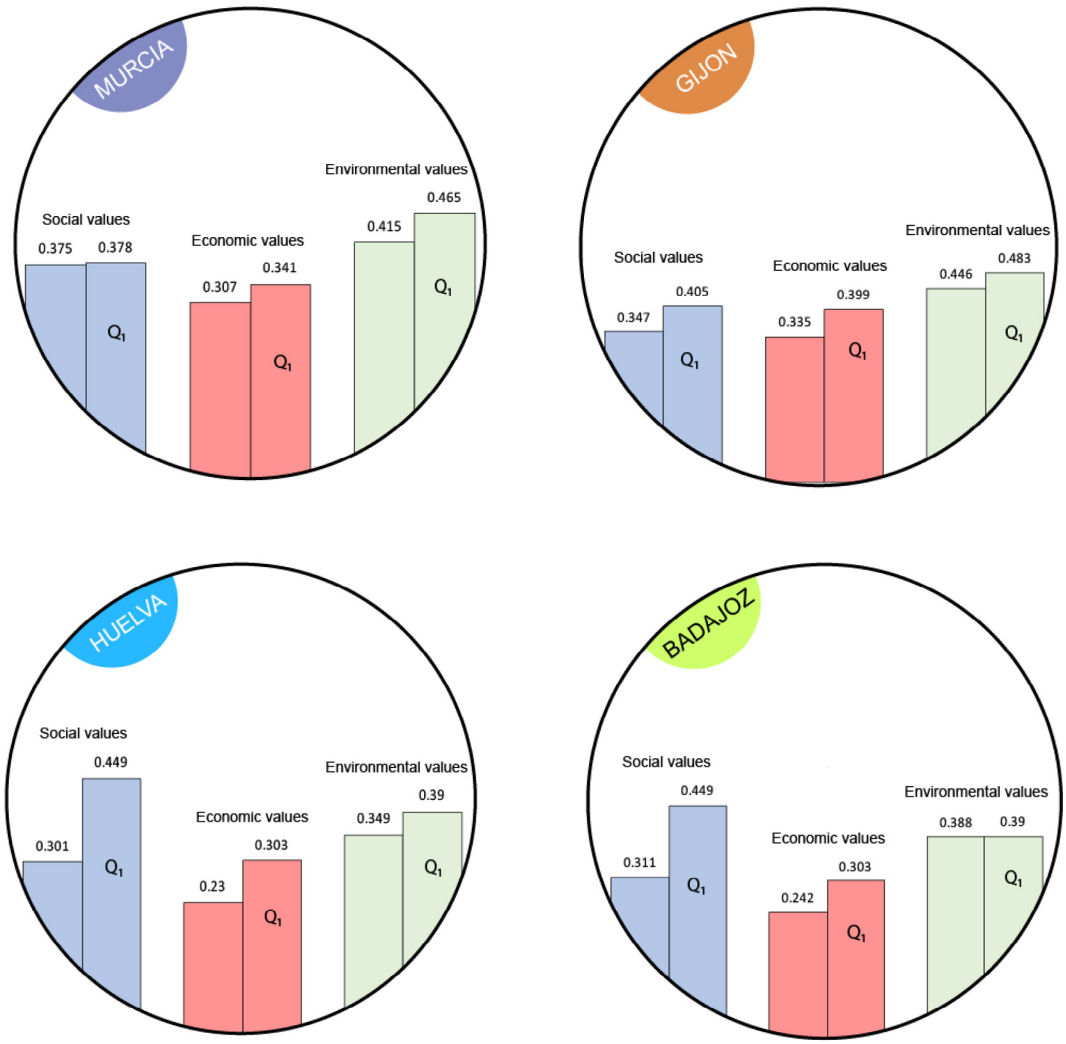

Fig. 3. Composite indicators and first quartile values of the cities rated as CCC.

jobs (Martí et al., 2017). The geographical distribution of cities can be seen in Fig. 4.

This inequality in terms of sustainability between the north and south of the country is associated with historical reasons. Regional differences in education in the preindustrial era between the north and the south of Spain are linked to higher illiteracy rates in the south of the country. Accordingly, there was greater industrial development in the northern regions (Beltrán-Tapia and Martinez-Galarraga, 2018). Thus, in regions such as Andalusia (south of Spain), most of the gross value added comes from the agricultural sector. On the contrary, in other regions such as the Basque country (north of Spain), the main economic power is the industry, which generates much more wealth and, consequently, increases indicators such as GDP and income per capita (Beltrán-Tapia and Martinez-Galarraga, 2018; Tirado et al., 2016). More recently, although Andalusia has made significant socio-economic progress since Spain joined the European Union, it remains one of the least developed regions in Europe (Cabello et al., 2019.). In addition, its coastal areas have suffered more from the consequences of the economic crisis on tourism (a key sector in its economy) than other areas that affect other sectors indirectly (Cabello et al., 2019).

The criterion for defining sustainability proposed by this study is a non-compensatory one, therefore good results in the environmental pillar do not compensate for poor results in the economic and social one. This consideration may affect some cities, such as Malaga, whose city council has a solid environmental program with experience of more than 20 years (City council of Malaga, 2017), but because it has a high rate of unemployment and poverty, it does not qualify as sustainable in this study. In addition, cities with a low ranking are taking measures and actions to achieve a more sustainable city status. This is the case of Murcia, where the University of Murcia launched a dissemination project in collaboration with the city council and other institutions with the aim of raising awareness and disseminating the different SDGs of the Agenda 2030 (University of Murcia, 2019). In the same line, Gijon developed a mobility plan in 2004 focused on the promoting of more sustainable mobility systems in the city center (City council of Gijon, 2014). Seville, which also has its own mobility plan, has established a series of objectives and strategies to achieve sustainable city status by 2030. Examples of these measures are the generation of employment and economic development and the fight against poverty and social inequalities, among others (City Council of Seville, 2019). Finally, Zaragoza has implemented several actions within the framework of Agenda 21, within four specific objectives: Integrating nature in the city and its Area of Influence, improving air quality, promoting the development of clean technologies and adopting operational systems for waste management and improving water quality, reducing its inappropriate use and promoting its study (City Council of Zaragoza, 2005).

3.2. Relevance of the study

Concern about assessing urban sustainability has grown since the Rio 1992 summit, from which the Agenda 21 program emerged

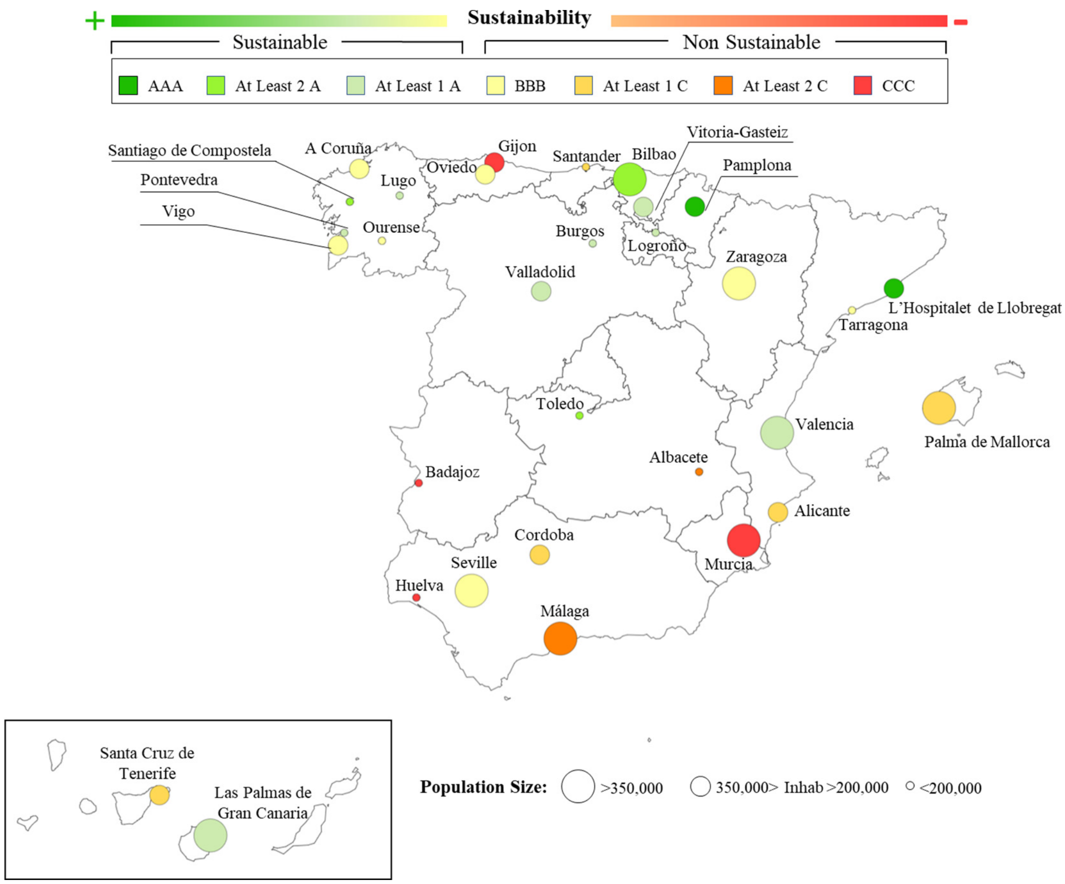

Fig. 4. Representation of results in colour categories where the lowest values in terms of sustainability that achieved a CCC score were represented in dark red and the best values, with a AAA score, were represented in dark green.

(Tanguay et al., 2010). Moreover, in 2015 the 193 member states of the United Nations agreed on complying with the 2030 Agenda Action Plan with one target goal focused on driving cities towards sustainability (United Nations, 2015). As a result, several studies focusing on the assessment of indicators in cities have been carried out in the last years (Feleki et al., 2018). Furthermore, standardization organizations have recently developed regularization work in the field of smart cities for sustainable development (Marsal-Llacuna, 2016). In addition, outside the scientific field, different city rankings have been published in several journals at both Spanish and European levels, which identify not only the quality of life of their inhabitants but also the socio-economic and environmental impact of the activities carried out in their surroundings (Batten, 2019; El País, 2019; Mercer, 2018). These rankings, further to being a way of comparing a city with others, may contain useful information for interested parties and policy makers on the road to the conception of a city more attractive for people, tourism and business (Mercer, 2019).

However, there are still challenges for the society and researchers, such as the definition of the concept of a sustainable city, as well as the identification of the best indicators set to assess the sustainability (Feleki et al., 2018). Furthermore, the established indicators could be different for each case study because not all cities control the same data due to the differences that may exist between the regions where each city is located (e.g., different climate, culture, …) (Braulio-Gonzalo et al., 2015). With these issues in mind, this study contributes, first, to the application of the Leopold Matrix designed to select a suitable set of indicators for the case study; and second, to propose a definition of sustainable city through a three-letter code that requires a certain balance in the three pillars of the sustainability to be accredited as a sustainable city. The latter does not coincide with other studies (Batten, 2019; Siemens, 2012), where cities are classified in a ranking with a score integrated by the three main pillars of sustainability but not with the same weight, i.e. a high value in the economic pillar can compensate a low value in the environmental one, and the city should be classified as sustainable.

In addition, the classification of cities according to their size avoids comparing large cities with small ones since they may have very different socio-economic realities, such as municipal budget, investment, etc. which also affect the environmental behaviour of the cities. In this sense, the challenges and sustainability plans that can be projected from the results of this study are oriented towards reaching goals within the limits of their size category. This study shows the current sustainability picture of the most representative Spanish cities. However if the time is managed as an additional variable, as well as to study cities for different years, the trend of each city can be seen in a sustainability dimension. For this purpose, collecting and monitoring data at city level is a key factor in sustainability assessment (Ibrahim et al., 2018), as good data quality improves the representativeness and plausibility of results.

In relation to the results obtained at the present study, they are in line with other study available in the literature (Siemens, 2012), where the cities ranked at the top in the sustainability scale were Bilbao, Logroño, Pamplona and Vitoria-Gasteiz, which have reported good results in our study despite not having used the same set of indicators (see Table 5). However, there are some differences compared to this study due to the use of different indicators, and the way the ranking was scored. In this document the scoring criterion is considered a three-letter code which is a non-compensatory system; however, in the Siemens study (2012) the scoring criterion is based on a compensatory procedure. Thus, a low score in an indicator can be compensated by a good result on another. Bearing it in mind, that is the reason why cities such as Malaga or Zaragoza which have a good score the study conducted by Siemens (2012), did not reach the category of sustainable city using the three-letter code. Moreover, the three letter code designed allows to identify the strengths and weaknesses of a city in a simple and fast way. Therefore, the stakeholders and policy makers, using a retrospective analysis, can easily identify the indicators which need to be improved to reach the category of sustainable city.

4. Conclusions

Assessing sustainability at the city level remains a challenge. Many studies focus on environmental aspects. However, sustainability implies three dimensions: social, economic and environmental. Therefore, the use of sustainability indicators can be considered as a potential assessment method that incorporates non only environmental but also socioeconomic factors. With the point to achieve the goals set out in the Agenda 21, the use of sustainability indicators has grown in recent years. However, there are different gaps in this type of analysis, such as the identification of the adequate set of indicators, the scale of application (city, metropolitan area…) and the lack of consensus on the definition of sustainability, which makes it difficult to establish sustainability thresholds. In addition, data collection and monitoring are essential, but not all cities have equivalent level of data, which makes it very difficult to determine the real state of a city.

This study develops a methodology to assess sustainability in cities considering a set of Spanish cities as case study to demonstrate its applicability. For this purpose, a set of indicators covering the three pillars of sustainability for the set of cities classified by size was selected and measured. Moreover, each indicator was assigned a different weight as a result of the application of the AHP methodology. A three-letter code was developed to define the concept of sustainability, so that in order to reach the category of sustainability, a balance between the three pillars should be required. The results show that the cities located in the north of the country achieve better scores than the ones located in the south. The rationale behind these differences is associated with economic factors (such as higher unemployment rates and fewer permanent contracts in the south of the country) and social issues derived from the economic ones, such as a high poverty rate in the south.

This three-letter code may be useful to get a quick idea of the state of a city, but policy makers should need a retrospective analysis to know which indicators achieve the worst scores in a certain city. In this sense, sustainability plans and projects could be developed to improve the category of that city from a sustainability approach.

CRediT authorship contribution statement

Manuel Rama: Data collection, data calculation, results presentation, Writing - original draft preparation. **Sara González-García:** Methodology, Supervision, Writing - reviewing manuscript. **Elena Andrade:** Methodology, Supervision, Validation. **Maria Teresa Moreira:** Methodology, Supervision, Writing - reviewing manuscript. **Gumersindo Feijoo:** Methodology, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolind.2020.106687.

References

Accountability, 2016. Consultation of institutions and accounts (in Spanish). http://www.rendiciondecuentas.es/es/consultadeentidadesycuentas/buscarEntidades/ (accessed June, 2019).
Ais Group, 2016. Spanish poverty town to town (in Spanish). https://www.ais-int.com/datos-sociodemograficos-economicos-habits-municipios/es/ (accessed June, 2019).
Artmann, M., Inostroza, L., Fan, P., 2019. Urban sprawl, compact urban development and green cities. How much do we know, how much do we agree? Ecol. Indic. 96, 3–9. https://doi.org/10.1016/j.ecolind.2018.10.059.
Bai, X., Shi, P., Liu, Y., 2014. Realizing China's urban dream. Nature 509, 158–160.
Barral, S., 2015. Pontevedra receives the UN award in Dubai (in Spanish). La Voz Galicia.
Batten, J.J., 2019. Citizen Centric Cities. The Sustainable Cities Index 2018.
Becker, W., Saisana, M., Paruolo, P., Vandecasteele, I., 2017. Weights and importance in composite indicators: Closing the gap 80, 12–22. DOI:10.1016/j.ecolind.2017.03.056.
Beltrán-Tapia, F.J., Martinez-Galarraga, J., 2018. Explorations in Economic History Inequality and education in pre-industrial economies: Evidence from Spain 69, 81–101.
Berardi, U., 2013. Sustainability assessment of urban communities through rating systems 1573–1591. DOI:10.1007/s10668-013-9462-0.
Boyce, J.K., 2018. The environmental cost of inequality. Sci. Am. 319, 72–77. https://doi.org/10.1038/scientificamerican1118-72.
Braulio-Gonzalo, M., Bovea, M.D., Ruá, M.J., 2015. Sustainability on the urban scale: proposal of a structure of indicators for the Spanish context. Environ. Impact Assess. Rev. 53, 16–30. https://doi.org/10.1016/j.eiar.2015.03.002.
Burgess, E.W., 1925. The Growth of the City: An Introduction to a Research Project [El crecimiento de la ciudad: Una introducción a un proyecto de investigación]. Urban Ecol. An Int. Perspect. Interact. Between Humans Nat. XVIII, 71–78. DOI:10.1007/978-0-387-73412-5_5.
Cabello, J.M., Navarro-Jurado, E., Rodríguez, B., Thiel-Ellul, D., Ruiz, F., 2019. Dual weak–strong sustainability synthetic indicators using a double reference point scheme: the case of Andalucía, Spain. Oper. Res. 19, 757–782. https://doi.org/10.1007/s12351-018-0390-5.
Carbajal-Hernández, J.J., Sánchez-Fernández, L.P., Villa-Vargas, L.A., Carrasco-Ochoa, J.A., Martínez-Trinidad, J.F., 2013. Water quality assessment in shrimp culture using an analytical hierarchical process. Ecol. Indic. 29, 148–158. https://doi.org/10.1016/j.ecolind.2012.12.017.
Chrysoulakis, N., Lopes, M., San José, R., Grimmond, C.S.B., Jones, M.B., Magliulo, V., Klostermann, J.E.M., Synnefa, A., Mitraka, Z., Castro, E.A., González, A., Vogt, R., Vesala, T., Spano, D., Pigeon, G., Freer-Smith, P., Staszewski, T., Hodges, N., Mills, G., Cartalis, C., 2013. Sustainable urban metabolism as a link between bio-physical sciences and urban planning: the BRIDGE project. Landsc. Urban Plan. 112, 100–117. https://doi.org/10.1016/j.landurbplan.2012.12.005.
City council of Gijon, 2014. Gijón Sustainable Urban Mobility Plan. https://movilidad.gijon.es/page/13901-pmus-2004-2016 (accessed March, 2019).
City council of Malaga, 2017. Malaga. Sustainable city (in Spanish). http://medioambiente.malaga.eu/opencms/export/sites/sostenibilidad/.content/galerias/documentos/malaga-sostenible.pdf (accessed March, 2019).
City Council of Seville, 2019. Objectives and Strategies. Seville 2030 (in Spanish). https://www.sevilla.org/planestrategico2030/documentos/sevilla-2030/plan-estrategico-sevilla-2030/objetivos-y-estrategias-sevilla2030.pdf (accessed March, 2019).
City Council of Zaragoza, 2005. Zaragoza and sustainable development. http://www.zaragoza.es/contenidos/medioambiente/agenda21/publicaciones_anteriores/Agenda21.pdf (accessed March, 2019).
Cole, R.J., 2010. Building environmental assessment in a global market. Int. J. Sustain. Build. Technol. Urban Dev. 1, 11–14. https://doi.org/10.5390/SUSB.2010.1.1.011.
Copus, A., Smith, J., Lloyd, J., Zografos, C., 2004. Study on indicators of sustainable development at the local level.
Cui, X., Wang, X., Feng, Y., 2019. Examining urban metabolism: a material flow perspective on cities and their sustainability. J. Clean. Prod. 214, 767–781. https://doi.org/10.1016/j.jclepro.2019.01.021.
Dijst, M., Worrell, E., Böcker, L., Brunner, P., Davoudi, S., Geertman, S., Harmsen, R., Helbich, M., Holtslag, A.A.M., Kwan, M.P., Lenz, B., Lyons, G., Mokhtarian, P.L., Newman, P., Perrels, A., Ribeiro, A.P., Rosales Carreón, J., Thomson, G., Urge-Vorsatz, D., Zeyringer, M., 2018. Exploring urban metabolism—towards an interdisciplinary perspective. Resour. Conserv. Recycl. 132, 190–203. https://doi.org/10.1016/j.resconrec.2017.09.014.
Directorate General of Traffic, 2016. Vehicle fleet (in Spanish). http://www.dgt.es/es/.
Dizdaroglu, D., 2017. The Role of Indicator-Based Sustainability Assessment in Policy and the Decision-Making Process: A Review and Outlook. DOI:10.3390/su9061018.

Dodds, F., Schneeberger, K., Ullah, F., Le Blanc, D., 2012. Review of implementation of Agenda 21 and the Rio Principles, Sustainable development in the 21st century.
Ebert, U., Welsch, H., 2004. Meaningful environmental indices: a social choice approach. J. Environ. Econ. Manage. 47, 270–283. https://doi.org/10.1016/j.jeem.2003.09.001.
El País, 2019. Ranking of the best cities to live (in Spanish). https://elpais.com/elpais/2019/03/25/album/1553530190_109859.html#foto_gal_1 (accessed June, 2019).
Electoral Commission, 2015. Electoral results (in Spanish). http://www.juntaelectoralcentral.es/cs/jec/elecciones/Locales_mayo2015?p=1379061494795 (accessed 9.20.05).
Expansion, n.d. Datosmacro. https://datosmacro.expansion.com/ (accessed June, 2019).
Feleki, A.E., Vlachokostas, C., 2018. Characterisation of sustainability in urban areas: an analysis of assessment tools with emphasis on European cities.
Feleki, E., Vlachokostas, C., Moussiopoulos, N., 2018b. Characterisation of sustainability in urban areas: an analysis of assessment tools with emphasis on European cities. Sustain. Cities Soc. 43, 563–577. https://doi.org/10.1016/j.scs.2018.08.025.
Gan, X., Fernandez, I.C., Guo, J., Wilson, M., Zhao, Y., Zhou, B., Wu, J., 2017. When to use what: Methods for weighting and aggregating sustainability indicators. Ecol. Indic. https://doi.org/10.1016/j.ecolind.2017.05.068.
Goldstein, B., Birkved, M., Quitzau, M.B., Hauschild, M., 2013. Quantification of urban metabolism through coupling with the life cycle assessment framework: Concept development and case study. Environ. Res. Lett. 8. https://doi.org/10.1088/1748-9326/8/3/035024.
Gómez-Losada, Á., Santos, F.M., Gibert, K., Pires, J.C.M., 2019. A data science approach for spatiotemporal modelling of low and resident air pollution in Madrid (Spain): implications for epidemiological studies. Comput. Environ. Urban Syst. 75, 1–11. https://doi.org/10.1016/j.compenvurbsys.2018.12.005.
González-García, S., Rama, M., Cortés, A., García-Guaita, F., Núñez, A., Louro, L.G., Moreira, M.T., Feijoo, G., 2019. Embedding environmental, economic and social indicators in the evaluation of the sustainability of the municipalities of Galicia (northwest of Spain). J. Clean. Prod. 234, 27–42. https://doi.org/10.1016/j.jclepro.2019.06.158.
Google, 2019. Google Earth Pro (7.3.2.5776).
Government of Spain, 2016. Ranking of expenses in Social Services and social promotion (in Spanish).
Huang, S.L., Lee, C.L., Chen, C.W., 2006. Socioeconomic metabolism in Taiwan: emergy synthesis versus material flow analysis. Resour. Conserv. Recycl. 48, 166–196. https://doi.org/10.1016/j.resconrec.2006.01.005.
Ibrahim, M., El-Zaart, A., Adams, C., 2018. Smart sustainable cities roadmap: readiness for transformation towards urban sustainability. Sustain. Cities Soc. 37, 530–540. https://doi.org/10.1016/j.scs.2017.10.008.
Idealista, 2016. Evolution of the price of housing for rent (in Spanish).
International Standardization Organization, 2014. ISO 37120 Sustainable development in communities: City indicators for service delivery and quality of life.
John, B., Luederitz, C., Lang, D.J., von Wehrden, H., 2019. Toward sustainable urban metabolisms. From system understanding to system transformation. Ecol. Econ. 157, 402–414. https://doi.org/10.1016/j.ecolecon.2018.12.007.
Josimovic, B., Petric, J., Milijic, S., 2014. The use of the Leopold matrix in carrying out the EIA for wind farms in Serbia. Energy Environ. Res. 4. https://doi.org/10.5539/eer.v4n1p43.
Kennedy, C., Cuddihy, J., Engel-yan, J., 2007. The Changing Metabolism of Cities 11. DOI:10.1007/s00125-014-3420-8.
Kennedy, C., Stewart, I.D., Ibrahim, N., Facchini, A., Mele, R., 2014. Developing a multi-layered indicator set for urban metabolism studies in megacities. Ecol. Indic. 47, 7–15. https://doi.org/10.1016/j.ecolind.2014.07.039.
Marsal-Llacuna, M.L., 2016. City indicators on social sustainability as standardization technologies for smarter (Citizen-Centered) governance of cities. Soc. Indic. Res. 128, 1193–1216. https://doi.org/10.1007/s11205-015-1075-6.
Martí, P., Nolasco-Cirugeda, A., Serrano-Estrada, L., 2017. Assessment tools for urban sustainability policies in Spanish Mediterranean tourist areas. Land Use Policy 67, 625–639. https://doi.org/10.1016/j.landusepol.2017.06.015.
Mercer, 2018. The cities with the highest quality of life in the world (in Spanish).
Mercer, 2019. City attractiveness. https://mobilityexchange.mercer.com/city-benchmarking-and-consulting (accessed June, 2019).
Michael, F.L., Zainon, Z., Figueroa, M.J., 2014. Review of urban sustainability indicators assessment e Case study between Asian countries. Habitat Int. 44, 491–500. https://doi.org/10.1016/j.habitatint.2014.09.006.
Ministry of Development, 2018. Appraised value of the dwelling (in Spanish).
Ministry of Health Social Services and Equality, 2017. National Catalog of Hospitals (in Spanish), Estadísticas e Información Sanitaria. DOI:978-84-7670-723-4.
Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., 2005. Tools for composite indicators building. Inst. Prot. Secur. Citiz. Econom. Stat. Support to Antifraud Unit I-21020 Ispra 134. DOI:10.1038/nrm1524.
Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., 2008. Handbook of Contructing Compsoite Indicators: Methodology and user guide. DOI:10.1787/9789264043466-en.
Phillis, Y.A., Kouikoglou, V.S., Verdugo, C., 2017. Urban sustainability assessment and ranking of cities. Comput. Environ. Urban Syst. 64, 254–265. https://doi.org/10.1016/j.compenvurbsys.2017.03.002.
Planelles, M., 2018. Spain faces a millionaire fine for purifying urban waters badly. El País.
Public Service of State Employment, 2017. Registered unemployment and contracts by municipality (in Spanish). https://www.sepe.es/HomeSepe.
Ricoa, Anna, Martínez-Blancoa, Julia, Montlleó, Marc, Rodríguez, Gustavo, Tavares, Nuno, Albert Arias, J.O.-S., 2019. Carbon Footprint of tourism in Barcelona. Tour. Manage. 70, 491–504. https://doi.org/10.1016/j.tourman.2018.09.012.
Riedler, B., Lang, S., 2018. A spatially explicit patch model of habitat quality, integrating spatio- structural indicators. Ecol. Indic. 94, 128–141. https://doi.org/10.1016/j.ecolind.2017.04.027.
Rioja-Andueza, I., 2019. Vitoria, from green capital of Europe to “global green city” (in Spanish). eldiario.es.
Siemens, 2012. 25 Ciudades Españolas Sostenibles 68.
Statistics National Institute, n.d. Statistics National Institute (in Spanish). https://www.ine.es/welcome.shtml (accessed June, 2019).
Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., Ludwig, C., 2015. The trajectory of the anthropocene: the great acceleration. Anthr. Rev. 2, 81–98. https://doi.org/10.1177/2053019614564785.
Sutadian, A.D., Muttil, N., Yilmaz, A.G., Perera, B.J.C., 2017. Using the Analytic Hierarchy Process to identify parameter weights for developing a water quality index 75, 220–233.
Swilling, M., Robinson, B., Marvin, S., Hodson, M., Allen, A., Herrero, A.C., Landman, A., Ratanawaraha, A., Revi, A., Truffer, B., Binz, C., Janisch, C., Conway, D., Daste, D., Pieterse, E., Morais, G.W. De, Choi, G.W., Adelekan, I., Dávila, J., Seppälä, J., Singh, K., Coenen, L., Peltonen, L., Tavener-smith, L., Lwasa, S., Swanepoel, S., Broto, V.C., Pengue, W.A., 2013. City-Level Decoupling.
Swilling, M., Hajer, M., Baynes, T., Bergesen, J., Labbé, F., Musango, J.K., Ramaswami, A., Robinson, B., Salat, S., Suh, S., Currie, P., Fang, A., Hanson, A., Kruit, K., Reiner, M., Smit, S., 2018. The weith of cities.
Tanguay, G.A., Rajaonson, J., Lanoie, P., 2010. Measuring the sustainability of cities: An analysis of the use of local indicators 10, 407–418. DOI:10.1016/j.ecolind.2009.07.013.
Tirado, D.A., Díez-Minguela, A., Martinez-Galarraga, J., 2016. Regional inequality and economic development in Spain, 1860 e 2010. J. Hist. Geogr. 54, 87–98. https://doi.org/10.1016/j.jhg.2016.09.005.
United Nations, 2015. Transforming our world: the 2030 Agenda for Sustainable Development.
Universia, 2019. Spanish companies guide. https://guiaempresas.universia.es/ (accessed June, 2019).
University of Murcia, 2019. ODSesiones. https://www.um.es/web/17odsesiones/proyecto/que-es (accessed June, 2019).
Valizadeh, S., Hakimian, H., 2019. Evaluation of waste management options using rapid impact assessment matrix and Iranian Leopold matrix in Birjand, Iran. Int. J. Environ. Sci. Technol. 16, 3337–3354. https://doi.org/10.1007/s13762-018-1713-z.
Wind, Y., Saaty, T.L., 2008. Marketing applications of the analytic hierarchy process. Manage. Sci. https://doi.org/10.1287/mnsc.26.7.641.
Wolman, A., 1965. The metabolism of cities. Sci. Am. 213, 178–190. https://doi.org/10.1038/scientificamerican0965-178.
WorldBank, 2019. Urban development. Overview. http://www.worldbank.org/en/topic/urbandevelopment/overview (accessed June, 2019).