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Embedding environmental, economic and social indicators in the evaluation of the sustainability of the municipalities of Galicia (northwest of Spain)

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ABSTRACT

Cities today are dense networks of interchanging investments, information, goods and people, as well as centers of innovation and knowledge management. In such a complex framework of housing, social and economic interrelationships, cities become large consumers of resources and producers of greenhouse gases. Therefore, and in order to preserve resources and guarantee social services and the well-being of citizens, planning and policy actions are required that contribute to achieving sustainable growth. Beyond the environmental perspective, a socio-economic analysis is essential to make a comprehensive sustainability diagnosis of urban and rural systems. This paper presents a methodology for sustainability assessment, based on 38 indicators that include the three pillars of sustainability: social, economic and environmental. To carry out this assessment, 64 municipalities out of 313 located in Galicia (Northwest Spain) were selected and classified in three categories according to their population size (Medium Size, Small Size and Village). Moreover, two weighting methods have been considered (equal weighting and measured weighting attributed through Analytic Hierarchy Process method). The results show that most sustainable municipalities are located in the north of the region. On the other hand, regardless of the weighting method, 57% of the medium-sized municipalities are rated sustainable compared to 45% of those of the categories of Village and Small Size categories. Therefore, municipal size is relevant for measuring sustainability and there are no significant differences between the results obtained with the two weighting methodologies, indicating that the method developed is robust and could be applied to other municipalities and cities.

1. Introduction

The population of developed countries has experienced exponential growth since 1950 (Steffen et al., 2015), and the analysis of the statistics shows that about 50% of the population lives in urban areas (Ibrahim et al., 2018). The urban population is expected to multiply by 1.5 by 2045, which would mean a significant increase in the number of residents in urban areas, an additional 2 billion. Having this in mind, cities or urban settlements play a key role as driving forces of the global economy. Cities account for 85% of global gross domestic product (GDP) generation (World Bank, 2017), 75% of natural resources demand and 50% of global waste production (Ellen MacArthur Foundation, 2017). Therefore, urban systems are essential elements in global performance and are responsible for more than 70% of global greenhouse gas emissions (World Bank, 2018). Within this framework of growing expansion of the urban environment (López-Carreiro and Monzon, 2018), the quality and demand for resources (energy, water, nutrients), as well as socio-economic conditions in terms of living conditions, employment rates, cost of living are under increasing pressure (Ibrahim et al., 2018; Feleki et al., 2019). Bearing in mind the three pillars of sustainability: environmental, social and economic, the urban environment should not pose a threat to sustainable growth, but it could contribute positively if this development is properly managed by increasing productivity, materialising investment options, prioritising modernisation and posing new challenges to

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citizens, but always under intense policy coordination in the framework of sustainable development. However, none of these actions can be achieved simply by adding up individual initiatives. In this sense, adequate planning by national, regional and local governments, as decisive agents in urban development towards sustainability, is required (World Bank, 2018).

The Smart Sustainable Cities approach defined by Ibrahim et al. (2018) as "the desired goal for present and future urban development" emerged. According to this approach, a smart sustainable city is one that offers better living conditions to its citizens by providing solutions to a series of challenges that include people, economy, environment, mobility, governance and living (Bibri and Krogstie, 2017; Ibrahim et al., 2018).

However, currently cities and urban systems follow a non-holistic linear "take-make-dispose" model based on resource-intensive consumption rates along with the operation of inefficient processes that result in environmental impacts and economic losses (Ng et al., 2019). This is why the old approach of valuing waste arises with greater emphasis on the circular economy approach, so that it is proposed not only as an environmental strategy but also as an economic one. Governments are currently promoting the sustainable development of society and economy in the same way that environmental protection is achieved (Yuan et al., 2006).

In line with this concept, the analysis of urban metabolism emerges, which was defined within the discipline of urban ecology by Kennedy et al. (2017) as "*the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy, and elimination of waste*". This definition is closely related to the circular economy approach and requires an integrated examination of sustainability principles (Sodiq et al., 2019). Therefore, the analysis of socio-economic parameters in urban systems should be addressed to obtain a complete picture of the characterization of urban systems. In recent years, the interest in evaluating urban sustainability indices, as well as the choice of indicators to determine urban sustainability, has been extensively researched in the scientific field (Feleki et al., 2019). Nevertheless, the development of a sustainability index is complex since it requires stages of normalization and weighting scores (Tanguay et al., 2010). Another added difficulty relates to the fact that each pillar of sustainability comprises completely different aspects, being in some cases not quantitative. In this sense, the International Organization for Standardization (ISO) has paid attention to sustainable development in cities. ISO 37101 (2016) sets out the requirements for analysing the performance of city services and quality of life using a holistic approach and could be applied to any city, municipality or local government regardless of its development. This standard is related to ISO 37120 (2018), which establishes sets of indicators for assessing the sustainability in cities and communities.

Indicators provide information on the state of an area and its evolution over time (Science for Environment Policy, 2015). However, there is no consensus on the indicators considered in urban or regional sustainability studies (Macedo et al., 2017) although some attempts have been made in this direction (OCDE, 1993, 1995; Tanguay et al., 2010; Chrysoulakis et al., 2013; Goldstein et al., 2013; Petit-Boix et al., 2017; González-García et al., 2018). Difficulties in developing a consensual indicator that includes environmental, social and economic components are associated with variable interpretations that can be drawn from the definition of sustainability and the perception of evaluators, as this is an arbitrary process (Tanguay et al., 2010). This problem is aggravated by the fact that the set of indicators is often selected by purely qualitative methods, such as surveys of a group of experts or the general population. Therefore, the application of quantitative or semi-quantitative decision support systems could be useful in selecting an appropriate set of indicators (Chrysoulakis et al., 2013). In addition, the spatial dimension must also be considered for the most part due to the characteristics of the cities of the different regions (tourism, climate …), which may be completely different and, therefore, the set of indicators selected to analyse sustainability may be unsuitable (Feleki et al., 2019).

Therefore, the most important gap of this research is the description of the methodology to select indicators which is supported by the lack of consensus for the definition of sustainability, the arbitrariness of the indicators selecting methods, and the difficulty of applying the same set of indicators in different geographic areas. In this sense, the Leopold Matrix has proved to be an adequate tool to predict the impact of a project on the environment (Josimovic et al., 2014) and therefore to define potential improvement measures. If adapted, Leopold Matrix may become a decision support system based on the interaction between a parameter (e.g., an indicator in the context of urban sustainability) and a criterion.

Once indicators have been chosen, it remains difficult to integrate them in the form of a quantitative indicator for sustainability, that is, to construct a composite indicator or a mathematical combination of individual indicators representing different dimensions of a system (Saisana and Tarantola, 2002). Nardo et al. (2005) identified several tools for building composite indicators. First, Factor Analysis and Reliability/Item Analysis or Cluster Analysis can be applied to find similarities among indicators to determine whether the different dimensions of the sustainability are well balanced from a statistical point of view in the composite indicator. This step can be followed by an estimation of the unknown parameters or missing data. Then, normalization helps bring all the indicators to the same unit, so they can be combined and compared. Nardo et al. (2005) proposed several strategies to achieve this goal: ranking of indicators across countries, standardization (or z-scores), re-scaling, distance to a reference area, categorical scales, indicators above or below the mean, methods for cyclical indicators and percentage of annual differences over consecutive years. Among them, standardization is the most commonly used normalization tool, as it avoids the introduction of aggregation distortions stemming from differences in the average values of the indicators. Other normalization tools, such as re-scaling, are based on an internal comparison among the case study indicators considering the maximum and minimum value of the sample (Pollesch and Dale, 2016). Another version of re-scaling sets a reference or optimal parameter for benchmarking (Phillis et al., 2017). The two steps described above allow the data set to be aggregated to take sustainability into account if the same weighting is chosen among the indicators. In other words, if the relative importance of the different dimensions in their contributions to the sustainability performance of a system is identical. This assumption was followed in 45 out of 96 studies, against 51 in which a weight was applied based on statistics (21) or public/expert opinion (30) (Gan et al., 2017). The disparity is explained by the subjectivity of this step, as no evidence reflects that weighting should not be equal (Morse et al., 2011) and therefore, also the opposite. However, Wilson and Wu (2017) stated that egalitarian weighting becomes problematic when sustainable indicators are compared in time or space. The tools developed for weighting are broadly separated into those based on statistical models and those based on the benefit of the doubt approach (Nardo et al., 2005). Finally, data must be aggregated to obtain a single indicator representative of the sustainability. There are several techniques: additive methods, preference independence, multi-criteria analysis and geometric aggregation (Nardo et al., 2005). The present study evaluates the sustainability of 63 Galician municipalities, which have been selected between more than 300 municipalities of the region, after an exhaustive selection method described below. All the selected municipalities, despite having similar cultural and climatic backgrounds, present different demographic, economic and environmental patterns. Sustainability has been accounted through the application of an adapted Leopold Matrix for indicators selection, a re-scaling method for normalization, an Analytic Hierarchy Process (AHP) for weighting and an additive method for aggregation. A detailed description of the methodology and results achieved is given below. This analysis method is intended to be applicable for the assessment of different urban systems on the path to determining their sustainability.

This paper was structured in two main sections: a first section that describes the methodology followed to select the indicators, the municipalities, as well as the normalization, aggregation and weighting methods to obtain a final sustainability index and a second section based on the application of this methodology with the corresponding discussion of the results.

2. Description of methodology

Composite indicators are increasingly used in the field of sustainable development since they are useful instruments for policy-making and for communicating complex issues such as the degree of sustainability compliance (Nardo et al., 2005). The reason behind the use of composite indicators is justified by the fact that they are alternatives that integrate and complement the analysis of several different indicators separately (Tanguay et al., 2010). Nevertheless, it must be borne in mind that, because of their simplicity and sometimes arbitrariness, they can send ambiguous or non-robust messages (Nardo et al., 2005). Besides, the process of constructing composite indicators has some steps that necessarily involve subjective decisions, such as the selection of indicators, the consideration of missing values as well as the choice of normalization, weighting and aggregations methods (Mori and Christodoulou, 2012). Therefore, it is recommended to identify the sources of subjective judgement and to apply a sensitivity assessment to determine the degree of influence of these assumptions (Nardo et al., 2005).

This study has developed a methodology to select a sample of representative municipalities from all the provinces of the region under study. In addition, a set of indicators has been defined to study their sustainability. Mathematical methods of aggregation and weighting have been considered for data processing. Finally, sustainability results have been expressed through a label designed with three letters.

2.1. Selection of the sample

This study is located in Spain, a country with multiple commercial and leisure attractions (climate, culture, gastronomy and landscape) that make it an important destination for many Europeans. Accordingly, sustainability problems related to socioeconomic flows should be addressed. The selected case study includes a sample of Galician municipalities taken as representative of the 313 that make up the Galician region. Galician municipalities share culture, climate and legislation, but with major differences in their metabolism. In terms of diversity, some municipalities rely heavily on industry (Vigo, As Pontes de García Rodriguez), while others base their economy on the primary sector (Burela, Lalín) or tourism (Santiago de Compostela, Sanxenxo); some are experiencing a demographic boom (Oleiros, O Pedreiro de Aguiar), while others are suffering ageing population (Covelo, A Cañiza); most are environmentally proactive (Pontevedra), but there are exceptions (Ourense) according to information available from public data sources. The fact that municipalities in the same region present such different aspects makes them attractive for comparing their sustainability and identifying the spots to improve. In order to complete the task of collecting data, the Galician Federation of Municipalities and Provinces (FEGAMP[1]) has provided information and data sources, essential to complete a sustainability assessment.

2.1.1. Step 1

Once the scope of the initial selection has been established, the first task is to develop a quantitative and reproducible methodology based on the available data to carry out a first selection of cities among 313 Galician municipalities. To do so, the first step is to gather demographic data (population, singular entities of population, age range, city surface and population density) from each city. As a first action, all cities with more than 35,000 inhabitants were chosen on the basis that they are relevant economic and cultural centers for the region. These municipalities are the main cities of Galicia: A Coruña, Ferrol, Lugo, Pontevedra, Ourense, Santiago de Compostela and Vigo, and additionally, the medium-sized municipalities of Narón and Vilagarcía de Arousa. From now, the terms “city” and “municipality” are considered synonymous.

2.1.2. Step 2

An indicator based on the Population Density (PD)/Singular Entities of Population (SEP) ratio is defined and calculated for each city, considering PD as the number of registered inhabitants of the municipal area in km.[2] Both parameters are the most representative of the demographic situation of cities and will allow municipalities to be grouped into as many categories as desired within each province. Each municipality within each province of the region was ordered taking into account the corresponding PD/SEP ratio. In this sense, four rankings of municipalities corresponding to the provinces of A Coruña, Lugo, Pontevedra and Ourense were obtained. In each of these provinces, all municipalities were classified into four groups according to their PD/SEP ratio. Group 1 was formed with the municipalities with the highest values of the PD/SEP ratio (i.e., municipalities with a high population density and a low singular population density such as the municipality of Burela in the province of Lugo). Therefore, group 4 was formed with the municipalities with the lowest values of the PD/SEP ratio (i.e., municipalities with scattered populations such as the municipality of Castro Caldelas in the province of Ourense). Finally, the rankings of the provinces divided into four groups were distributed under a Gaussian distribution according to the following criteria:

- ✓ Municipalities are ranked from highest to lowest.
- ✓ No more than 70% of municipalities must be included in the central groups (groups 2 and 3) and the distribution must be adequate to obtain the minimum standard deviation. The system is solved by iterative calculation in Excel using the *Solver* tool. To do so, the target cell is defined: in this case is the sum of the standard deviations, which must be minimal. Then, the cells for iteration are selected (the percentage of cities contained in each group) and compliance with the restrictions (i.e., standard deviation and number of cities) is checked are introduced in the system. Finally, the initial iteration values are defined so that the system can reach the optimal solution in the form of the percentage of municipalities included in each group.
- ✓ Once the system is solved, the ranges of indicators for each group are simply determined by counting the number of cities belonging to each group from the highest value of the PD/SEP ratio to the lowest.

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

[2] http://www.meteogalicia.gal/web/index.action.

2.1.3. Step 3

Now, the cities are grouped into 4 different groups within each of the 4 provinces under study (A Coruña, Lugo, Ourense and Pontevedra), making a total of 16 groups containing 308 municipalities (excluding the 9 cities previously chosen). This number must be significantly reduced in order to be able to manage the data, avoiding losing the representativeness of the data relating to the demographic situation of the provinces. With this objective, each of the 4 groups contained in each province is studied individually. First, the PD/SEP indicator for each city is drawn together with the average PD/SEP ratio for the whole group on a spider web diagram. Second, a certain deviation from the mean (±30% in this study) is established and also represented in the spider web diagram. Finally, all municipalities whose proportion remains within the established range are pre-selected, considering a certain degree of deviation from the average. This process is repeated for each group, so that the number of potentially eligible cities is considerably reduced.

2.1.4. Step 4

The last step of the selection method consisted of applying the Leopold Matrix tool according to three criteria (see Table 1):

i) The availability of data being considered the most important. This table also shows the scale of values for quantifying each criterion. This tool allows to obtain quantitative results taking into account both the importance and magnitude of the indicator and being qualitatively assigned a value according to a scale. Quantitative results are obtained by multiplying the rows and the columns of the matrix. The criteria considered for the analysis are: Transparency and data availability for the municipality under study. An assessment is made of whether databases are available to compile the information needed for analysis.

ii) Administrative and demographic representativeness: The relevance of the municipality with respect to the region is evaluated, that is, if the municipality is the capital of the province, if there is court, firehouse, local police, national police, outpatient clinic, …public services which are not present in all municipalities.

iii) Environmental commitment: The environmental awareness of the municipality is marked taking into account whether it is proactive in environmental measures.

Once the Leopold Matrix was completed, the final score for each municipality was determined by multiplying the value assigned to each criterion. Subsequently, in order to obtain a similar number of municipalities per province, a threshold level of 8 points was established as the first requirement to be selected. All municipalities sharing the highest ratings were selected and a minimum of 1 city was established for groups 1 and 4 while a minimum of 3 municipalities was established for groups 2 and 3. However, large differences in the samples of selected municipalities per province are not desired since a similar order of magnitude is required between provinces, as well as a geographical distribution balance.

2.1.5. Step 5

Finally, the selected municipalities were classified into three categories according to their population: i) village - if it has less than 5,000 inhabitants; ii) small city - if it has a population between 5,000 and 50,000 inhabitants; and iii) medium city - if it has more than 50,000 inhabitants. The objective of this final classification is to avoid comparisons of sustainability results between cities and towns because of their inherent characteristics. In Fig. 1 the methodology of the selection of the sample was summarized.

2.2. Selection of the indicators set

The selection of appropriate sustainable indicators is a crucial step in the development of a composite indicator to increase its scientific value and credibility. To this end, the procedure and the selection of criteria are carefully defined in order to ensure their transparency and strictness (Tanguay et al., 2010). First, an intensive literature search was carried out to list them, after which the indicators of four specialized agencies were considered, selected for their reliability and the integrity of their data sets: the United Nations (UN Global Goals, 2015), the European Commission (European Commission, 2017), the Organization for Economic Co-operation and Development (OECD, 2015), The World Bank (Anderson, 2009) and the Bank of Environmental Public Indicators (BPIA, 2017). The United Nations proposes a long list of indicators, embracing from gender equality to peace and justice (UN Global Goals, 2015).

Initially, the datasets summed up 214 indicators but were completed with 190 more according to those proposed by the Galician Statistics Institute (IGE) and the Spanish Public Database of Environmental Indicators (BPIA) for data availability reasons. Considering the social, economic and environmental dimensions of sustainable processes (Lozano, 2008; Tanguay et al., 2010), data were collected within each agency, and then all indicators were listed. After removing duplicates, the dataset contained more than 60 indicators, which should be reduced to be manageable. An adapted Leopold Matrix has been developed for this purpose. In the current study, the Leopold Matrix was designed taking into account social, economic and environmental indicators and criteria for selection. The criteria considered were: i) data availability for the system under study (no indicator is good if there is no information about it) and, ii) the frequency of occurrence in the datasets of the bodies consulted. The scale of values for quantifying the criteria is shown in Table 2.

Once the Leopold Matrix is completed, the final relevance of each indicator is determined by multiplying the semi-quantitative

Table 1
Scale of quantification of the Leopold Matrix criteria for the selection of municipalities.

Criterion	Mark	Description
Transparency and data availability	3	Data available from public sources
	2	Required internal sources or assumptions
	1	No data/High uncertainty
Administrative and demographic representativeness	3	Court/county or capital full services availability
	2	Essential services
	1	Lack of demographic representativeness
Environmental commitment	3	Frequent environmental activity
	2	Occasional environmental activity
	1	No proactive environmental activity

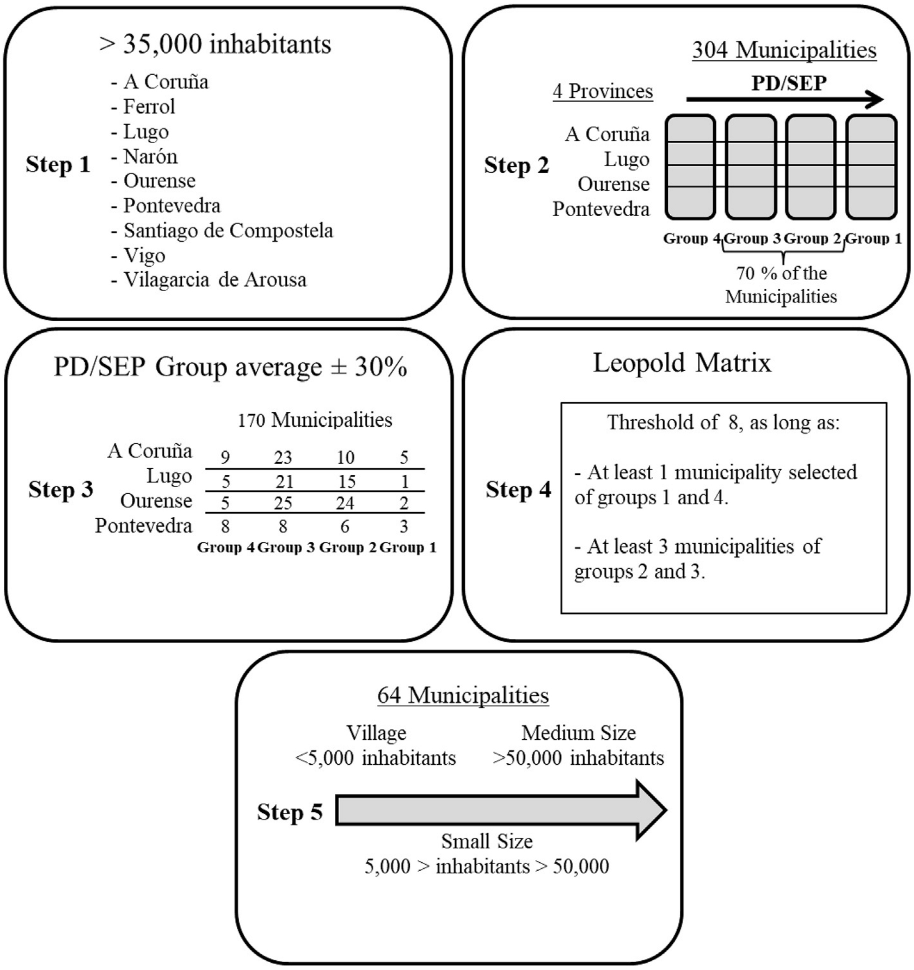


Fig. 1. Sample selection method steps: Step 1, big municipalities selection, Step 2, DP/SEP classification, Step 3, average DP/SEP groups selection, Step 4, Leopold Matrix application, Step 5, population Size of the selected municipalities selected.

Table 2
Scale for quantifying the criteria of the Leopold Matrix.

Data availability	3	Municipal scale
	2	Regional or national scale
	1	No data
Frequency [a]	3	Appears on 3 or more sources
	2	Appears on 2 sources
	1	Appears on 1 source

[a] Frequency of occurrence in the datasets of the bodies consulted.

value assigned to each criterion. All indicators whose relevance value is higher than or equal to 6 should be selected. Therefore, there must be at least one criterion with a score of 3.

Then, given that the number of indicators remains high, an additional criterion based on relevance to the case study (in this case, the study of municipalities and their sustainability) should be introduced. To this end, a panel of experts made up of 17 people from different specialties such as Chemical and Environmental Engineering (47%), Economic Sciences (32%) and Psychology (21%) was asked to assign independently to each selected indicator the value “1″ if it is considered relevant or “0″ if it is irrelevant. This panel of experts was made up of partners involved in a multidisciplinary project awarded by the Spanish Ministry of Economy and Competitiveness (CTQ2016-75136-P) as well as related stakeholders such as environmental consultants and associations of municipalities.

2.3. Normalization

As presented above, the data set selected comprises different types of indicators with very multiple units of measurement. When a group of indicators are not comparable with each other, for example, if they have different measurement units, it is necessary to perform a normalization step to express results with the same unit (Phillis et al., 2017). Selecting a suitable standardization method to apply to a specific topic is a difficult choice and should consider the properties of the data and the objectives of the composite indicator (Nardo et al., 2005). In the present study, the normalization method selected was re-scaling. As performed in Phillis et al. (2017), all indicators were normalized to obtain a dimensionless result, from 0 to 1; where 0 is the lowest sustainable value and 1 the highest one. To do so, it is important to define the direction of the indicator; a positive indicator means that the highest value of this indicator means the best sustainable performance, while a negative indicator encompasses worse sustainable performance. Ideally, the indicators should be normalized against benchmarks that, for each indicator, should reflect the target sustainable value as well as the unsustainable value. However, in practice, it is very difficult to define the sustainable and unsustainable edge of each indicator; therefore, the maximum and minimum values within the range of cities (per category that is, villages, small size cities and medium-sized cities, separately) were selected for the normalization procedure. Positive indicators were normalized according to equation (1) and negative indicators according to equation (2).

$$I_{qc} = \frac{x_{qc} - min_c(x_q)}{max_c(x_q) - min_c(x_q)} \tag{1}$$

$$I_{qc} = \frac{max_c(x_q) - x_{qc}}{max_c(x_q) - min_c(x_q)} \tag{2}$$

Where x_{qc} is the value for the municipality c and the indicator q, I_{qc} is the normalized value, and min_c (x_q) and max_c (x_q) are the minimum and the maximum value of x_q across all municipalities for the indicator q.

2.4. Aggregation and weighting

In the construction of a composite indicator, it is essential to combine the different indicators in a meaningful way into a few indexes. Aggregation is, together with weighing, the combination of normalized indicators into different indexes. Although different aggregation approaches are available in the literature, one of the most commonly used is to aggregate a set of indicators according to a related topic (Tanguay et al., 2010). Different aggregation methodologies are commonly used, including additive aggregation methods, geometric aggregation methods, and the non-compensatory aggregation method (Gan et al., 2017). This study considered the weighted arithmetic mean to calculate the final index obtained for each dimension of sustainability.

In terms of weighting, different weights can be assigned to the indicators to reflect their relative importance; therefore, give them more importance in the calculation of the final composite indicator. Several weighting techniques are available, including equal weighting, principal components analysis, public opinion, budget allocation or analytic hierarchy process (AHP) (Gan et al., 2017). In this study, two approaches were considered: the equal weighting as base case and the AHP methodology, which is considered as a simple and flexible technique that allows comparing several indicators with very different units, even if qualitative and quantitative data are considered. In addition, it implies that the weighing is carried out according to the experience and opinion of the experts in the field. In more detail, the AHP is a structured method that allows prioritising multiple criteria based on pairwise comparisons of elements (Saaty, 2008).

2.4.1. Step 1

The first step in this methodology is to translate a complex problem into a hierarchical structure consisting of an overall goal (i.e. identifying the most relevant indicators regarding the sustainability performance of a city), several criteria that contribute to this goal (i.e., the three dimensions of sustainability), and several attributes (i.e. the set of indicators).

2.4.2. Step 2

The panel of experts detailed in section 2.2 is asked to identify, given the pairs of indicators, which is the most important. Thereafter, they are also asked to provide their relative importance on a scale of 1–9 (Table 3).

2.4.3. Step 3

The third step is to calculate the relative weights of the indicators from the comparison matrix using an eigenvector technique (Saaty, 2008).

The main disadvantage of this method is that it is an arbitrary process and no weighting structure can rationally justify the attribution of a given weight (Gan et al., 2017). Moreover, the high number of matrices produced may limit the number of indicators selected. Some degree of inconsistency may also occur due to contradictions or careless errors during expert comparisons; however, the method may tolerate these inconsistencies if the consistency ratio is less than 0.1 (Nardo et al., 2005). According to it, the consideration of the equal weighting allowed us to compare the differences on the results.

Table 3
AHP measurement scale (Saaty, 2008).

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

2.5. Label with rating letters for sustainability reporting

At this stage, each dimension of sustainability has a score ranging from 0 to 1, and since obtaining a final sustainability score integrating all three dimensions could be controversial, it has been decided to avoid additional weighting procedures. Thus, three different letters (A, B and C) have been proposed to classify the municipalities. Accordingly, the A rating should correspond to the municipality with the best performance in each dimension and the C rating to the worst. Therefore, each municipality should be classified with a sustainability-city-label taking into account the combination of three letters (A/B/C). The reference scores used to establish the segregation between these letters were the quartiles obtained for each group of municipalities taking into account their population (i.e., village, small size and medium size). Therefore, to obtain an A rating, the dimension score must be higher than the Q3 value. In the same way, to obtain a B rating, the dimension score must be between Q1 and Q3. Consequently, C rating is acquired with a score lower than the Q1 value. Finally, the term “sustainable city” should be assigned to each municipality that has at least one A in the combination of letters but not one C.

3. Results

3.1. Sample selection

Following the description of the five steps previously reported for the selection of the municipalities under study, the sample was reduced from 313 to 64 cities. In Step 1, we selected the municipalities with more than 35,000 inhabitants, considered representative in Galicia: A Coruña, Santiago de Compostela, Ferrol, Narón, Pontevedra, Vilagarcía de Arousa, Lugo and Ourense. Table 4 displays a detailed description with characteristic information of these municipalities.

In Step 2, the PD/SEP ratio was calculated for each city and subsequently, the list of municipalities was classified into four groups according to their ratio and the criteria detailed in Section 2.1. Consequently, the Gaussian curve was built considering the previously detailed restrictions shown in Fig. 2.

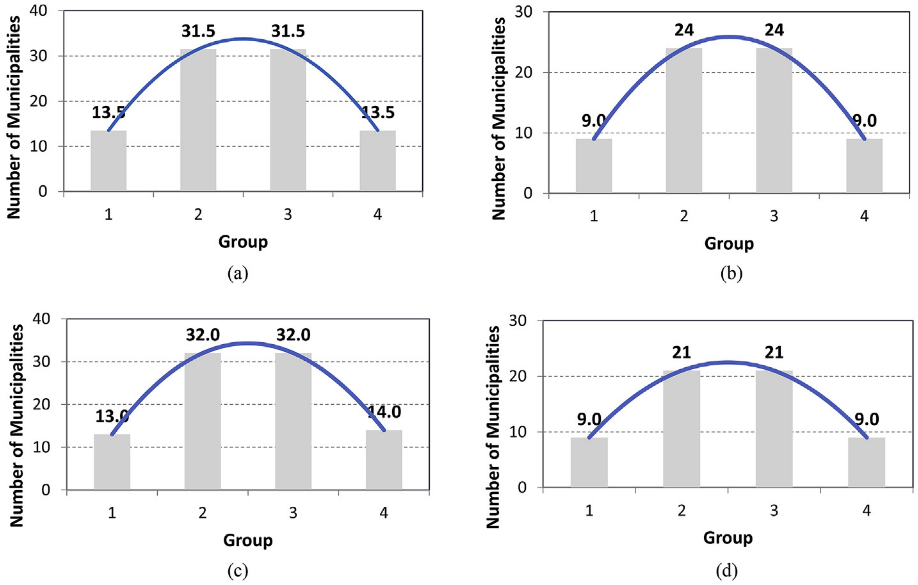
Cities by group and province were then assessed individually taking into account the PD/SEP ratio and the corresponding deviation from the mean score, set at ±30%. Cities and values are represented in a spider web diagram (Step 3) in the Supplementary material in the Figures SM1 to SM4.

As a result of the above steps, the number of potentially eligible

Table 4
Main characteristics of the Galician municipalities included in the case study.

Municipality	Population	Pop. density	Population growth[a]	Household avg. income	GDP	Weather	Other
	(Inhabitant)	(Inhabitants.km^{-2})	(%)	(€.dwelling^{-1})	(€.inhabitant^{-1})		
Vigo	292,817	2,638	−1.49	35,428	24,416	Coastal Atlantic	Industrialized coastal city
Coruña (A)	244,099	6,378	−0.83	36,712	24,987	Coastal Atlantic	Main administrative city
Ourense	105,636	1,223	−1.95	29,648	19,720	Inland Atlantic	Third highest aging index in Galicia
Lugo	97,995	295	0.27	30,292	21,800	Inland Atlantic	Very low population density
Santiago de Compostela	96,456	437	0.80	35,788	32,637	Coastal Atlantic	Capital of Galicia, with high tourism rate
Pontevedra	82,671	683	0.18	35,040	21,253	Coastal Atlantic	Environmentally proactive
Ferrol	67,569	818	−6.38	29,201	20,356	Coastal Atlantic	Sharp decline in recent years
Narón	39,280	576	1.33	27,649	15,401	Coastal Atlantic	Periphery of Ferrol
Vilagarcía de Arousa	37,479	840	−1.64	27,035	15,848	Coastal Atlantic	Industrialized coastal city

[a] Population growth from 2011 to 2016.



(a) (b)

(c) (d)

Fig. 2. Fitting of the Gaussian function for the case study. a) A Coruña; b) Lugo; c) Ourense; d) Pontevedra.

cities is reduced from 308 to 170 (43, 41, 55 and 22 municipalities in A Coruña, Lugo, Ourense and Pontevedra respectively), including cities with more than 35,000 inhabitants. However, despite being a considerably smaller number, it remains unmanageable. Furthermore, it should be borne in mind that in the case of the municipalities corresponding to group 1 of Lugo province, none of them are within the established deviation (see Fig. 4a). This is due to the high PD/SEP ratios for Burela and Rábade, exceptional cases in Galicia and the result of a past political issue.

These municipalities have experienced economic growth due to a specific economic situation. This is the case of Burela, which experienced an economic growth of the fishing sector in which European economic aid was key to the positioning of its fishing port (MAPA, 2013). In the case of Rábade, the economic growth is due to the fact that the arrival of the railway between Madrid and A Coruña allowed the creation of large merchandise warehouses. For this reason, they have a small municipal area and a unique entity of population. Consequently, the municipality with the DP/ESP ratio closest to the limit was selected for analysis.

Then, in order to obtain a similar number of municipalities per province, the Leopold matrix procedure described in Step 4 was applied. A threshold value of 8 was the first approximation to reduce the number of representative cities for analysis. As already mentioned, no great differences are desired in the samples of the municipalities selected per province, since an order of similar magnitude should be desired. Consequently, it was necessary to discard some municipalities from the selected list (for example, in the province of A Coruña or Ourense). Thus, the final selection took into account intrinsic aspects such as the presence of a representative industry (as is the case of As Pontes de García Rodríguez, where the leading company in the electricity sector in Spain is located) or tourist/cultural aspects (such as Quiroga, which is an important municipality in wine tourism).

Tables 1–4 of the Supplementary Material (SM Tables 1–4)

Table 5
Classification of municipalities according to their population.

Category	Municipalities
Medium Size	Vigo, Coruña (A), Ourense, Lugo, Santiago de Compostela, Pontevedra, Ferrol.
Small Size	Betanzos, Oleiros, Sada, Narón, Rianxo, Muros, Melide, Ordes, Santa Comba, Pontes de García Rodríguez (As), Arzúa, Sarria, Castro de Rei, Vilalba, Ribadavia, Verín, Pereiro de Aguiar (O), Celanova, Moaña, Grove (O), Vilagarcía de Arousa, Vilanova de Arousa, Sanxenxo, Tomiño, Ponteareas, Salvaterra de Miño, Silleda, Cañiza (A), Lalín, Estrada (A)
Village	Aranga, Cabanas, Cerdido, Laxe, Muxía, Cabanas, Zas, Monterroso, Mondoñedo, Vicedo (O), Pedrafita do Cebreiro, Pobra do Brollón (A), Quiroga, Fonsagrada (A), Rábade, Carballeda de Avia, Monterrei, Pobra de Trives (A), Cortegada, Coles, Castrelo de Miño, Castrelo do Val, Baños de Molgas, Lobeira, Rairiz de Veiga, Ramirás, Vilariño de Conso, Covelo

show the final list of municipalities selected for the study. Data are collected from 64 municipalities, distributed as follows: 20 municipalities in A Coruña, 12 municipalities in Lugo, 17 municipalities in Ourense and 15 municipalities in Pontevedra.

Finally, the previously selected municipalities were classified into three categories according to their population in Step 5: i) village (less than 5,000 inhabitants); ii) small-sized city (5,000–50,000 inhabitants); and iii) medium-sized city (more than 50,000 inhabitants). Table 5 displays the classification by category of inhabitants and Fig. 3 shows its corresponding geographical distribution throughout the Galician community.

3.2. Selection of the indicator set

The selection of the set of indicators was developed following the steps described in Section 2.2. The use of the Leopold Matrix considering the criteria based on data availability and frequency of occurrence in the datasets allowed the list of indicators to be reduced from more than 200 to 60. As this number remained unmanageable, relevance was included as an additional criterion by the panel of experts in charge of selecting the set of indicators, which reduced the final list to 29. Considering the differences between municipalities, four indicators were considered in the economic field: non-financial total incomes (€·inhabitant^{-1}), municipal budget (€·inhabitant^{-1}), surplus/deficit (€·inhabitant^{-1}) and ratio of public/private vehicles (%). The latter considers for the public vehicles the number of buses and for private vehicles, only passenger cars and motorbikes.

Four specific indicators for medium-sized municipalities were added to the selection in order to better understand their behaviour even though they had not been considered in the original proposal. These indicators were: i) average rental price per m^{-2} (€), ii) average selling price per m^{-2} (€), iii) number of hotel beds and, iv) number of sustainability plans, participation in projects or sustainability awards received.

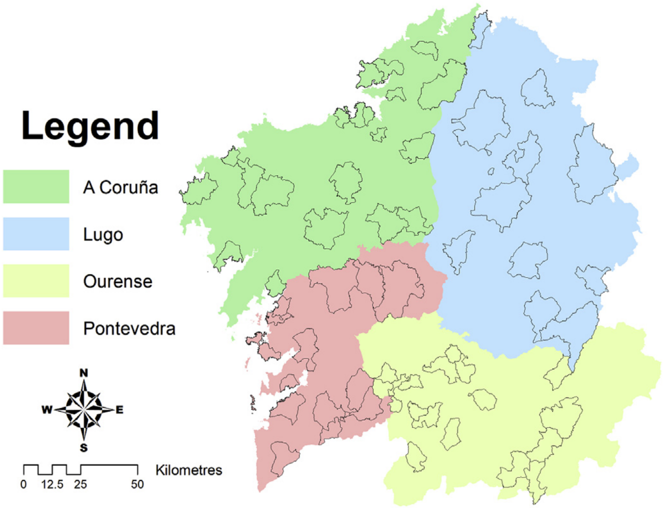


Fig. 3. Distribution of the selected municipalities per province.

It was observed that some Galician municipalities with more than 15,000 inhabitants did not meet the requirements demanded by the European Commission for wastewater treatment. Having this issue in mind, a semi-quantitative indicator was included with the marks “0″ or “1″ whether or not they meet the requirements.

The final list of indicators proposed for analysis is displayed in Tables 6 and 7, including a brief description for each indicator.

3.3. Inventory data

Following the selection of municipalities and the set of indicators, it was necessary to collect the information necessary for the sustainability analysis. Different official datasets were consulted, such as the Galician Statistics Institute (IGE), Google maps and the Spanish Statistics Institute (INE), Meteogalicia,[2] Directorate General of Traffic of Spain ,[3] Ministry of Development[4] and Ministry of Interior[5] as well as specific information provided by FEGAMP. Tables 5–7 in the Supplementary Material (SM Tables 5–7) summarize the information collected for each municipality classified in terms of village, small-sized city and medium-sized city. Tables 8–10 in the Supplementary Material (SM Tables 8–10) displays the detailed data gathered and estimated for the social indicators set for each municipality. Tables 11–13 in the Supplementary Material (SM Tables 11–13) display the detailed data collected and estimated for the economic and environmental indicators set for each municipality.

In the case of the indicator of MSW collected, data are available only at regional level. For this reason, the indicator was not considered in the present study. However, it could be considered in order to compare Spanish municipalities from different regions.

3.4. Ranking of municipalities

As described in Section 2.3, once the set of indicators has been established and the corresponding values have been collected, the indicators must be normalized since they present multiple different units unmanageable to obtain a final score, ratio or label. In this study, the normalization step was based on re-scaling. Thus, all indicators (economic, social or environmental) reported a value between 0 and 1. To this end, they were normalized per municipal category with respect to the reference values that, for each indicator, should reflect the maximum and minimum values within the range of cities included in the category. Next, the indicators were evaluated separately per sustainability dimension for each

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[3] http://www.dgt.es/es/.

[4] https://www.fomento.es.

[5] http://www.interior.gob.es.

Table 6
List of indicators selected to assess urban sustainability, common to all the municipalities regardless their size.

Criterion	Indicator	Description	Unit
Social	Population graduated in secondary education	Number of inhabitants with secondary education overcome	PSE/total population
	Number of registered gender violence cases	Number of registered gender violence cases recorded in the municipality along the year	Nº of gender violence cases/1000 inhabitants
	Number of women unemployed	Total amount of women with working age without an employment contract	Women unemployed/women at labour age
	Population rate at risk of poverty	Percentage of population that earn a salary 50% lower than the average	P<50%/total population
	Number of households	Average number of people that live in the households of the municipality	Inhabitants/number of households
	Population that participated in the last municipal election	Total number of people that deposit a valid vote in the municipal elections that took place in 2015	Accounted votes/electoral census
	Population under 16 years old	Inhabitants under 16 years	P < 16/total population
	Percentage of population older than 65 years old	Percentage of population over 65 years. A high percentage indicates a high aging population index	%
	Population annual net growth	Growth population rate in the period 2011–2016	%
	Foreign immigrants	Number of inhabitants born abroad, registered in the electoral register	Nº of No-EU immigrants/1000 inhabitants
	Population density	Number of inhabitants/Total municipality surface	Inhabitants/km^2
	Number of leisure facilities	Number of entertainment establishments in the municipality	Nº of leisure facilities/1000 habitants
	Distance to continued attention points and hospitals	Distance, in km, between the city hall and the closer hospital/surgery	km
	Total expense in social services	Total expense in social services and employment policies	€/Inhabitant
Economic	GDP per inhabitant	GDP of the municipality/Number of total inhabitants	€/inhabitant
	City unemployment rate	Number of unemployed population/Total active population	%
	Average household income	Gross income of the municipality/Total number of households	€/household
	Number of permanent contracts signed	Total amount of permanent contracts signed throughout the year	Number contracts/1000 inhabitants
	Number of business	Total number of companies with registered office in the municipality	Number companies/1000 inhabitants
	Municipal budget	Adjusted budget	€
	Non-financial total incomes	Chapters I-VII of the municipal budget	€/inhabitant
	Surplus/Deficit	Difference between net budgetary rights liquidated and recognised obligation	€/inhabitant
	Indebtedness	Financial debt of the municipality	€/inhabitant
	Investment	Chapter VI of the municipal budget. It measures the investment effort	€/inhabitant
Environmental	Ratio of public/private vehicles	Division between the number of busses and the number of passenger cars and motorbikes	%
	Ozone	Average ozone concentration in the air	µg/m^3
	NO$_2$	Average NO$_2$ concentration in the air	µg/m^3
	PM10	Average PM$_{10}$ concentration in the air	µg/m^3
	Total domestic water consumption	Volume of water consumed in the households (m^3) per year	m^3/household
	Total electrical use	Amount of electricity (MWh) consumed per inhabitant per year	MWh/inhabitant
	Surface of green area	Total surface (in km^2) corresponding to the green area of the municipality/total surface	%
	Surface of pedestrian zone	Total surface (in km^2) corresponding to the pedestrian zone in the municipality/total surface	%
	MSW collected	Amount (in tonnes) of Municipal Solid Waste (MSW) collected in the municipality	kg/inhabitant

Table 7
List of potential indicators selected to assess urban sustainability, exclusive for medium size municipalities.

Criterion	Indicator	Description	Unit
Economic	Rental price	Average price rental price per m^2	€/m^2
	Sale price	Average sale rental price per m^2	€/m^2
	Hotel beds	Number of total hotel places available in the municipality/1000 inhabitants	Number of places/1000 inhabitants
Environmental	Environmental activity	Number of sustainability plans, participation in projects and awards received in the municipality according to its environmental awareness	Number of issues
	Non-Compliance Waste Water Treatment	Compliance or not with the guidelines established by the European Commission in terms of wastewater treatment	Adimensional

municipality and considering two different weighting procedures: an equal weighting for all of them (per dimension) and a measured weighting after the application of AHP methodology.

3.4.1. *Equal weighing*

Tables 8–10 displays the scores per sustainability dimension for each municipality included for analysis in the category of village, small and medium size cities, respectively, considering equal weighting.

After estimating the sustainability scores, the next procedure was to assign the rating method scales for the cities from AAA to CCC taking into account the previously estimated values (the first letter corresponds to the social dimension, the second to the economic and the third to the environmental). Therefore, the

Table 8
Social, Economic and Environmental scores for municipalities included in the category “village”.

Municipality	Social	Economic	Environmental
Aranga	0.401	0.494	0.570
Cabanas	0.570	0.418	0.433
Cerdido	0.414	0.421	0.581
Laxe	0.456	0.165	0.639
Muxía	0.504	0.419	0.739
Zas	0.466	0.411	0.539
Fonsagrada (A)	0.404	0.392	0.606
Mondoñedo	0.509	0.349	0.698
Monterroso	0.497	0.357	0.579
Pedrafita do Cebreiro	0.455	0.413	0.595
Pobra do Brollón (A)	0.346	0.264	0.590
Quiroga	0.410	0.300	0.552
Rábade	0.545	0.390	0.566
Vicedo (O)	0.545	0.390	0.566
Baños de Molgas	0.385	0.300	0.383
Carballeda de Avia	0.451	0.171	0.564
Castrelo de Miño	0.422	0.235	0.391
Castrelo do Val	0.385	0.261	0.413
Coles	0.584	0.470	0.343
Cortegada	0.415	0.258	0.562
Lobeira	0.288	0.304	0.369
Monterrei	0.349	0.198	0.491
Pobra de Trives (A)	0.519	0.278	0.594
Rairiz de Veiga	0.384	0.173	0.405
Ramirás	0.382	0.285	0.412
Vilariño de Conso	0.511	0.656	0.589
Covelo	0.311	0.286	0.606
Third Quartil value	0.499	0.405	0.582
First Quartile value	0.377	0.255	0.404

Table 9
Social, Economic and Environmental scores for municipalities included in the category “small size”.

Municipality	Social	Economic	Environmental
Arzúa	0.478	0.462	0.576
Betanzos	0.566	0.338	0.327
Melide	0.483	0.339	0.612
Muros	0.362	0.346	0.697
Narón	0.581	0.309	0.421
Oleiros	0.662	0.458	0.392
Ordes	0.485	0.397	0.377
Pontes de García Rodríguez (As)	0.506	0.596	0.460
Rianxo	0.439	0.319	0.497
Sada	0.624	0.291	0.323
Santa Comba	0.453	0.402	0.398
Castro de Rei	0.371	0.421	0.554
Sarria	0.478	0.391	0.515
Vilalba	0.517	0.375	0.520
Celanova	0.351	0.279	0.435
Pereiro de Aguiar (O)	0.483	0.406	0.454
Ribadavia	0.454	0.369	0.595
Verín	0.456	0.332	0.523
Cañiza (A)	0.262	0.280	0.587
Estrada (A)	0.486	0.319	0.547
Grove (O)	0.478	0.451	0.413
Lalín	0.449	0.404	0.415
Moaña	0.550	0.267	0.406
Ponteareas	0.530	0.215	0.422
Salvaterra de Miño	0.442	0.268	0.511
Sanxenxo	0.483	0.408	0.421
Silleda	0.496	0.446	0.520
Tomiño	0.519	0.238	0.517
Vilagarcía de Arousa	0.588	0.295	0.409
Vilanova de Arousa	0.492	0.408	0.392
Third Quartil value	0.511	0.400	0.520
First Quartile value	0.443	0.288	0.404

Table 10
Social, Economic and Environmental scores for municipalities included in the category “medium size”.

Municipality	Social	Economic	Environmental
A Coruña	0.691	0.548	0.372
Ferrol	0.355	0.038	0.508
Lugo	0.637	0.407	0.657
Ourense	0.428	0.476	0.581
Pontevedra	0.654	0.421	0.630
Santiago de Compostela	0.686	0.659	0.447
Vigo	0.509	0.399	0.209
Third Quartil value	0.672	0.537	0.617
First Quartile value	0.420	0.391	0.364

municipality with the AAA sustainability label should be considered sustainable in all its dimensions. On the contrary, a CCC label should be far from sustainable patterns. According to the established criteria, a municipality which presents a combination of classification letters including at least one C or none A is labelled as unsustainable. Table 11 displays the municipalities with the corresponding rating levels. Of the initial list of 64 cities, 30 were identified as sustainable, corresponding to 12 villages, 14 small size cities and 4 medium size cities. Of the entire sample, only 2 municipalities acquired the best combination of letters (AAA). Surprisingly, none of the medium-sized cities were able to reach the triple A rating. Two cities (A Coruña and Santiago) were classified as AAB and Pontevedra and Lugo as BBA.

According to the results from the rating system, 57% in the “medium size” municipalities and 45% of sustainable municipalities included in the categories “village” and “small size” attained an A rating in the environmental dimension.

In addition, taking into account the values given in Tables 8–10, the distance between the value of each municipality and the value of the quartiles is indicative of how close or far a municipality of the A rating is. For example, As Pontes de García Rodríguez has a rating of B in the social dimension, but its value is 0.506 with respect to the value of 0.511 of the third quartile, being very close to the rating A in this dimension.

3.4.2. Measured weighing after AHP application

The AHP method establishes a pairwise comparison that determines how long one parameter is more important than another (Saaty, 2008). This model of analysis was used to formulate and analyse unstructured problems in different fields of science (Veisi et al., 2016). In addition, there are several studies that use the AHP method with the aim of assigning weights to different indicators (Hermann et al., 2007; Ismail, 2012; Carbajal-Hernández et al., 2013).

The panel of experts from different specialities (Chemical and Environmental Engineering, Economic Sciences and Psychology) were asked to evaluate according to their experience, the relative weights of the different indicators within each sustainability dimension. Thus, an eigenvector was built being the scores displayed in Table 12.

Tables 14–16 in the Supplementary Material (SM Tables 14–16) display the scores per sustainability dimension for each municipality in the category of village, small-sized and medium-sized cities, respectively, considering the priority vector obtained for each indicator after the application of the AHP procedure. In accordance with the scores obtained per sustainability dimension and after the estimation of the corresponding quartiles, Table 13 summarizes the municipalities with the corresponding rating levels. Slight differences have been identified with regard to the ranking achieved with equal weighting. Of the initial list of 64 cities, 25 were identified as sustainable corresponding to 13

Table 11
Sustainability rating levels for the Galician municipalities under study. Gray boxes identify the ones tagged as sustainable.2

A Coruña

Village	Label	Small Size	Label	Medium Size	Label
Aranga	BAB	Arzúa	BAA	Coruña (A)	AAB
Cabanas	AAB	Betanzos	ABC	Ferrol	CCB
Cerdido	BAB	Melide	BBA	Santiago de Compostela	AAB
Laxe	BCA	Muros	CBA		
Muxía	AAA	Narón	ABB		
Zas	BAB	Oleiros	AAC		
		Ordes	BBC		
		Pontes de García Rodríguez (As)	BAB		
		Rianxo	CBB		
		Sada	ABC		
		Santa Comba	BAC		

Lugo

Village	Label	Small Size	Label	Medium Size	Label
Fonsagrada (A)	BBA	Castro de Rei	CAA	Lugo	BBA
Mondoñedo	ABA	Sarria	BBB		
Monterroso	BBB	Vilalba	ABA		
Pedrafita do Cebreiro	BAA				
Pobra do Brollón (A)	CBA				
Quiroga	BBB				
Rábade	ABB				
Vicedo (O)	ABB				

Ourense

Village	Label	Small Size	Label	Medium Size	Label
Baños de Molgas	BBC	Celanova	CCB	Ourense	BBB
Carballeda de Avia	BCB	Pereiro de Aguiar (O)	BAB		
Castrelo de Miño	BCC	Ribadavia	BBA		
Castrelo do Val	BBB	Verín	BBA		
Coles	AAC				
Cortegada	BBB				
Lobeira	CBC				
Monterrei	CCB				
Pobra de Trives (A)	ABA				
Rairiz de Veiga	BCB				
Ramirás	BBB				
Vilariño de Conso	AAA				

Pontevedra

Village	Label	Small Size	Label	Medium Size	Label
Covelo	CBA	Cañiza (A)	CCA	Pontevedra	BBA
		Estrada (A)	BBA	Vigo	BBC
		Grove (O)	BAB		
		Lalín	BAB		
		Moaña	ACB		
		Ponteareas	ACB		
		Salvaterra de Miño	CCB		
		Sanxenxo	BAB		
		Silleda	BAA		
		Tomiño	ACB		
		Vilagarcía de Arousa	ABB		
		Vilanova de Arousa	BAC		

Table 12
Priority vector according to the experts.

Pillar	Indicator	Priority vector	
		Medium size	Small size/Village
Social	Population graduated in secondary education	0.034	
	Number of registered gender violence cases	0.147	
	Number of women unemployed	0.097	
	Population rate at risk of poverty	0.119	
	Number of households	0.035	
	Population that participated in the last municipal election	0.027	
	Population under 16 years old	0.052	
	Percentage of population older than 65 years old	0.054	
	Population annual net growth	0.050	
	Foreign immigrants	0.053	
	Population density	0.040	
	Number of leisure facilities	0.038	
	Distance to continued attention points and hospitals	0.123	
	Total expense in social services	0.129	
Economic	GDP per inhabitant	0.062	0.056
	City unemployment rate	0.124	0.164
	Average household income	0.108	0.118
	Number of permanent contracts signed	0.077	0.094
	Number of business	0.061	0.079
	Municipal budget	0.076	0.083
	Non-financial total incomes	0.062	0.059
	Surplus/Deficit	0.091	0.079
	Indebtedness	0.092	0.111
	Investment	0.064	0.158
	Rental price	0.064	
	Sale price	0.079	
	Hotel places	0.042	
Environmental	Ratio of public/private vehicles	0.088	0.077
	Ozone	0.073	0.122
	NO_2	0.108	0.111
	PM10	0.100	0.129
	Total domestic water consumption	0.107	0.130
	Total electrical use	0.107	0.148
	Surface of green area	0.124	0.101
	Surface of pedestrian zone	0.087	0.182
	Environmental activity	0.051	
	Non-Compliance Waste Water Treatment	0.154	

villages, 8 small-sized cities and 4 medium-sized cities. Only one additional village (Monterroso) was identified as sustainable as difference to the previous weighting approach. Nevertheless, six municipalities in the "small size" category lost the condition of sustainable with the measured weighting approach (Ribadavia, Verín, O Grove, Lalín, Sanxenxo and Vilagarcía de Arousa). Regardless the weighting approach considered Muxía and Vilariño de Conso acquired the triple A rating but one additional municipality in the category of "Village" (Pedrafita do Cebreiro) and two municipalities in the category of "Small size" (Arzúa and Melide) achieved this score with the measured weighting approach. However, again, none of the medium-sized cities were able to achieve this mark and minor differences in letter combinations were identified in these municipalities regardless of the weighting approach.

The most important differences were identified in the "small size" category, where it was observed some outstanding differences in the rating of some municipalities. This is the case of Oleiros that was not labelled as sustainable when the indicators were equally pondered (see Table 11, rating AAC) and, with the application of the measured weights, it changed to the triple A rating (see Table 13).

Finally, the results have been analyzed per province. Table 14 shows the number of sustainable municipalities identified per province with both weighting methods. In the case of the northern provinces (A Coruña and Lugo) the number of sustainable municipalities is higher than in the southern provinces (Ourense and Pontevedra). There rationale behind this result is mainly associated with economic factors. One can be explained by the fact that municipalities in the south, despite having a larger number of inhabitants, have a municipal budget similar to that of municipalities in the north. In addition, the weighting method significantly affects the results in the two southern provinces, with 12 municipalities identified as sustainable by equal weighting and only 6 when measured weighting is applied. Therefore, attention should be paid on the selected weighting method to identify and report the sustainability results since discrepancies on the results could be identified. Accordingly, more research should be required in the definition of the most favorable weighting method.

3.5. *Relevance of study*

Sustainable cities are related to the creation of spaces for social, business and technological development. Research on sustainable cities is maturing and new challenges are emerging associated with small municipalities or villages, whose assessment is still incipient. A small municipality or village is an ecosystem of limited size driven by specific mechanisms and dynamics that are the product and result of interactions at multiple levels (Visvizi and Lytras, 2018). Rural areas account for 28.2% of the European population (Eurostat, 2018). Nowadays, population is moving towards large urban systems (Ibrahim et al., 2018) and villages are depopulating at a worrying rate (Wang et al., 2019). The depopulation of small municipalities involves a number of social, economic and demographic problems related to the lack of specific services, such as

Table 13
Sustainability rating levels for the Galician municipalities under study. Gray boxes identify the ones tagged as sustainable.3

A Coruña

Village	Label	Small Size	Label	Medium Size	Label
Aranga	BAA	Arzúa	AAA	Coruña (A)	AAB
Cabanas	AAB	Betanzos	ABC	Ferrol	CCB
Cerdido	BAA	Melide	AAA	Santiago de Compostela	AAB
Laxe	BCA	Muros	CBA		
Muxía	AAA	Narón	ABB		
Zas	BAB	Oleiros	AAC		
		Ordes	BBB		
		Pontes de García Rodríguez (As)	BAB		
		Rianxo	BBB		
		Sada	ABC		
		Santa Comba	AAC		

Lugo

Village	Label	Small Size	Label	Medium Size	Label
Fonsagrada (A)	BBA	Castro de Rei	CAA	Lugo	BBA
Mondoñedo	ABA	Sarria	BBB		
Monterroso	BBA	Vilalba	ABA		
Pedrafita do Cebreiro	BBA				
Pobra do Brollón (A)	CBA				
Quiroga	BBB				
Rábade	ABB				
Vicedo (O)	ABB				

Ourense

Village	Label	Small Size	Label	Medium Size	Label
Baños de Molgas	CBC	Celanova	CCB	Ourense	BBB
Carballeda de Avia	BCB	Pereiro de Aguiar (O)	BAB		
Castrelo de Miño	BCC	Ribadavia	BCA		
Castrelo do Val	BBC	Verín	BBB		
Coles	BAC				
Cortegada	CBB				
Lobeira	CBC				
Monterrei	CCB				
Pobra de Trives (A)	ABA				
Rairiz de Veiga	BCB				
Ramirás	BBB				
Vilariño de Conso	AAA				

Pontevedra

Village	Label	Small Size	Label	Medium Size	Label
Covelo	CBA	Cañiza (A)	CBA	Pontevedra	BBA
		Estrada (A)	BBA	Vigo	CBC
		Grove (O)	BBB		
		Lalín	BAC		
		Moaña	BCB		
		Ponteareas	BCB		
		Salvaterra de Miño	CCB		
		Sanxenxo	BBB		
		Silleda	ABB		
		Tomiño	BCB		
		Vilagarcía de Arousa	BBB		
		Vilanova de Arousa	BCC		

Table 14
Number of sustainable municipalities per province.

	Sustainable Municipalities	
	Equal Weighting	Measured Weighting
A Coruña	11	10
Lugo	7	8
Ourense	5	3
Pontevedra	7	3

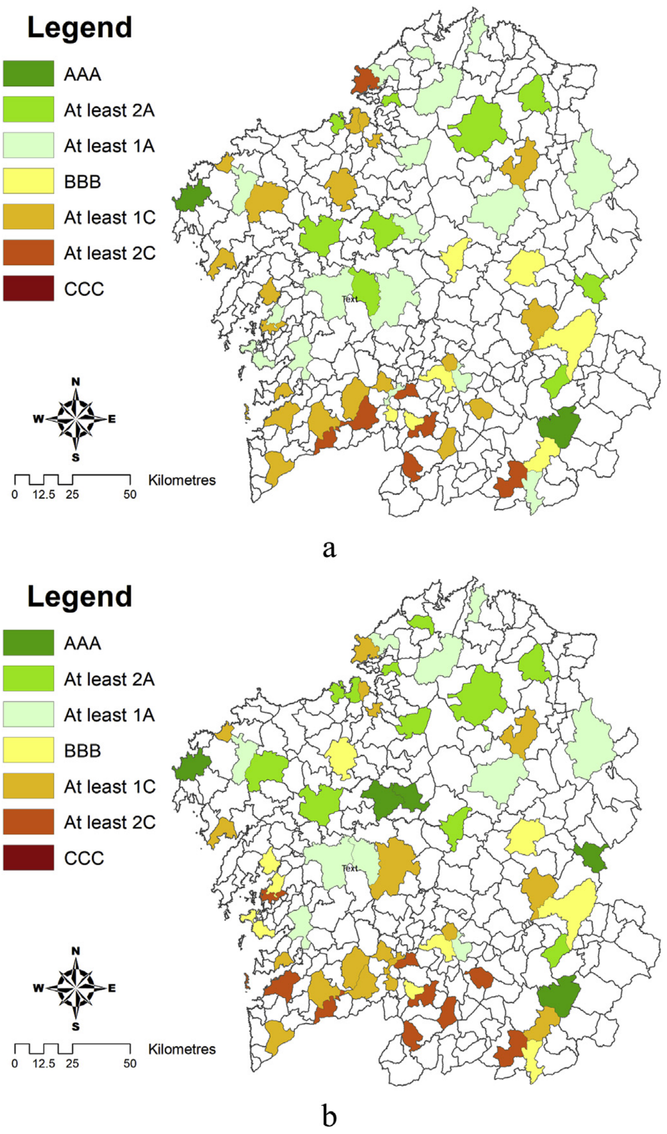
secondary schools, courts or health and leisure centers, which affect the availability of services, well-being and quality of life, supported by the fact that the costs of providing services are also much higher when the population is distributed in many small settlements rather than concentrated in larger ones (Ubels et al., 2019). For this reason, the European Commission established a Bled Declaration for a smarter future for rural areas in the European Union (European Commission, 2018) and launched the EU Action for Smart Villages (European Commission, 2017). The main objective is to develop rural areas where people want to live, work and benefit from local services, tourism, etc. Rural communities need jobs, basic services and connectivity, as well as proactive entrepreneurship (Zou et al., 2020).

Spain is experiencing, along with other southern European countries such as Greece, Portugal and Italy, significant population losses in rural areas (European Network for Rural European Netwrok for rural development, 2018; World Bank, 2018). Although depopulation rate is higher in the interior of the country, attention has been paid to Galicia (Northwest Spain) since this Spanish region leads the rural population decline since 2008 (small municipalities lose 25 rural inhabitants per day), driven mainly by the economic crisis[6] and the lack of jobs.

The Galician region is divided into 313 municipalities with different social, economic and environmental characteristics. These municipalities can make essential contributions to solving many of the major social challenges, such as climate change or the sustainable supply of food, biomass and energy (Esteve-Llorens et al., 2019; Roibás et al., 2018). In the same way that their tourism and culture can motivate employment and investment in these areas (Otero-Giráldez et al., 2012).

Most sustainability indicator studies only consider highly populated urban areas, but this perspective needs to be adapted to more variable ranges of cities, towns and villages. Only in this way is it possible to reflect the real situation of the area under study and, in this sense, to become aware of the needs of each of the municipalities (Anisimova, 2020). A sustainable municipality must guarantee equal access to municipal services, encourage the participation of its citizens in social activities, create local value chains and establish sustainable procurement principles, based on its strengths and resources, as well as the development of new opportunities. However, they should demand good governance, rural development policies and citizen participation, fighting against the centralization of public services and exploiting trade unions with other small towns and cities (Ibrahim et al., 2018; Ubels et al., 2019). Therefore, the evaluation of sustainability in Galician municipalities could be considered interesting, putting into practice a methodology developed and with potential to be applied in other Spanish autonomous communities. On the other hand, this methodology could be applied considering time as a variable, with the objective of identifying trends in the municipalities.

Fig. 4 represents graphically the distribution of sustainable and unsustainable municipalities considering a color code and taking into account the two approaches of weighting indicators. The location of a municipality on different rating scales depends to a large extent on its intrinsic characteristics, as well as on the criteria chosen for the rating (i.e. the three-letter rating must have at least an A rating and no C rating to achieve the sustainable denomination). According to the results, the proposed method for assessing the sustainability of municipalities appears to be sufficiently robust. Regardless the weighting for the indicators, no major differences in the results have been detected in municipalities of the categories "village" and "medium size" as displayed in Fig. 4. On the contrary, the weighting approach affects the labelling of sustainable in small-sized municipalities. This issue is related with these municipalities that have only one letter A in the three letter combination derived from equal weighting approach. The rationale behind these results is because these municipalities achieve a low normalized value in indicators with a high measured weight (i.e., number of registered gender violence cases per 1,000 inhabitants, city unemployment



a

b

Fig. 4. Distribution and graphical classification of Galician municipalities according to their sustainability score. a) Equal-weighting, b) Measured weighting according to AHP methodology.

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[6] https://www.farodevigo.es/galicia/2016/01/04/galicia-lidera-caida-poblacion-rural/1379739.html (accessed October 2018).

rate, investment, average household income and ozone concentration in air). This combination makes them susceptible to lose the condition of sustainable. On the other hand, municipalities of southern Galicia occupy a worse position in terms of sustainability than those of the north due to the low values in the municipal budget per inhabitant.

Accordingly, and although some assumptions might be necessary mostly related to the municipalities that should be part of the sample and with specific indicators representative of the region, the methodology could be useful for policy-makers and governments in acquiring strategies to revitalize municipalities under a sustainable approach. For example, a better distribution of the municipal budget in the south of the region. The methodology considers a series of indicators concerned with the sustainability of cities or municipalities, which provide information on local conditions, allowing comparisons within the sample. Although there have been no problems with the collection of information from the different indicators, as public data sets (in some cases, local and regional data) were used, limitations caused by the accessibility of the data in other regions may appear.

4. Conclusions

Research on the assessment of sustainable cities is maturing. However, new challenges arise associated with small municipalities or villages, whose assessment is still incipient. However, there is still no consensus on the definition and quantification of the sustainability of a given population, incorporating concepts such as quality of life, equity, social inclusion and environmental issues. This study deals with the development of a methodology to evaluate the sustainability of municipalities, based on the analysis of indicators related to the social, economic and environmental dimensions. Consequently, the main reason for our study is to find a method for the selection of both municipalities and indicators that allows a wide possible coverage of the integrated components of sustainable development and the categories that compose them, while minimizing the number of indicators retained, as well as the number of representative municipalities. The sustainability of municipalities was modeled and measured at scale considering different weighting approaches, although this issue had a minor influence on the classification of sustainable municipalities, except for small-sized ones. A city-sustainability label was designed based on the combination of three letters in order to rank municipalities according to their scores. The sustainability scores show important differences between the Galician municipalities of the North and the South, where the low values of the municipal budget per inhabitant adversely affect the sustainability.

Although different weighting approaches were proposed (equal weighting and measured weighting based on experts' opinion), no outstanding differences in the letters combination were identified regardless the approach in municipalities under the categories "village" and "medium size". Further research could fill current research gaps in methodological terms, and efforts should focus on their application to large cities and municipalities located in other countries.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2019.06.158.

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