



Liveability Versus Sustainability in Spanish Cities: First Evidences Using Synthetic Indicators

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Abstract

The aim of liveable, sustainable cities has become one of the major challenges for urban planning. However, achieving both goals at the same time is no easy task, particularly when liveability and sustainability may be defined by certain elements that tend to be in conflict. The main goal of this work is to analyse the relationship between liveability and environmental sustainability within the context of Spanish urban spaces. To this end, we propose two synthetic indicators: one for liveability and the other for urban environmental sustainability. Each of these indicators is constructed using a technique based on goal programming. A bivariate analysis is carried out using these indicators, which allows us to compare the extent to which Spanish cities are liveable and sustainable. This analysis should be useful for urban planners when taking and implementing policy decisions. By comparing cities with similar profiles using a benchmarking system, it becomes possible to judge the margin for improvement in one attribute without detriment to the other. This benchmarking system also allows us to reveal the specific dimensions of liveability or sustainability for which there is the greatest opportunity for improvement.

Keywords Urban liveability · Urban sustainability · Spanish cities · Synthetic indicators · Goal programming

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Introduction

Creating liveable, sustainable cities is an essential objective of urban planning. Specifically, one of the 17 goals of sustainable development (SDG) established by the United Nations for its 2030 Agenda (objective 11), mentions cities that are inclusive, safe, resilient, and sustainable. In consonance with this goal, the New Urban Agenda by the U.N. (United Nations, 2017) and the Urban Agenda for the EU (European Commission, 2019) were both passed in 2016. Spain published its own urban agenda (Spanish Ministry of Development, 2019), which was conceived of as a strategic document in line with its international counterparts. This mission statement acts as a reference framework for Spanish urban areas and proposes various policies, which are at once economic, social, and environmental.

These institutional goals are also reflected in the academic literature published over the last decade. Numerous studies have been carried out that analyse the various concepts that go to make up the idea of liveability (Morais et al., 2013; Saitluanga, 2014; Nissi & Sarra, 2016; Fu et al., 2019; Valcárcel-Aguiar & Murias, 2019) and environmental sustainability (Mcpherson et al., 2013; Kilkis, 2016; Zhang & Zhou, 2018) separately. However, in recent years, different authors have suggested that both of these concepts should be integrated into one overarching idea (Bithas & Christofakis, 2006; Mori et al., 2015; Zanella et al., 2015; Valcárcel-Aguiar et al., 2019) so that liveability becomes something durable in the long term.

However, this integration process is no simple matter. Liveability and sustainability contain markedly distinct elements, which may clash with one another. This, in turn, might impede simultaneous improvements in both indicators, (Ruth & Franklin, 2014; Gough, 2015). These difficulties impact the decision-making process, since the decisions that are taken in one sphere may have unpredictable effects on the other. Therefore, there is an imperative to empirically understand the relationship that exists between both concepts, particularly since there are hardly any studies that attempt to do so.

In the specific case of Spanish cities, it is often alluded to that their compact nature has helped to make them highly liveable without significantly affecting the environment (Rueda, 2012). However, in recent years cities have been growing whilst becoming more dispersed in nature, which has meant a cost in terms of environmental sustainability (the Ministry of the Environment, and Rural and Marine Environment and the Ministry of Development, 2011). This relatively recent change in the traditional patterns of population settlements makes it increasingly important to analyse how liveability and sustainability are related within the sphere of Spanish urban areas, especially since there appear to be no such academic studies that closely dissect this dynamic.

Within this context, the present work aims to analyse the relationship between liveability and environmental sustainability in Spanish urban areas. To do so, we propose two synthetic indicators: one for liveability and another for environmental sustainability in urban areas. Each of these indicators will be aggregated by using a technique based on goal programming. The construction of these

indicators allows us to carry out a bivariate analysis that aims to reflect how Spanish cities are performing in terms of these attributes.

While the conclusions obtained from a study of this kind are limited by the specific nature of the geographical sample, it is still feasible to obtain a relatively precise characterization of Spanish cities concerning their levels of liveability and urban sustainability and this, in turn, will provide a broader understanding of the complex relationships that exist between these two concepts. Also, this analysis should prove useful for those developing and implementing urban planning policy in cities in which one or both of these factors is considered to be sub-optimal. Thus, by using “reference” cities, i.e., cities that are similar in terms of profile, it is possible to carry out a benchmarking analysis, estimating the margins by which one of these attributes may be improved, without impinging negatively on the other. This benchmarking analysis also allows us to know the specific dimensions of liveability or sustainability that have the greatest possibilities for improvement in those cities.

The study is divided into five sections, followed by some conclusions. The second of these contains the theoretical foundations of the relationship that exists between the concepts of liveability and sustainability. This section focuses on aspects that concern the estimation of these two concepts, with particular emphasis on the overlapping of common features like the abstract and multidimensional nature of the same. The third section focuses on the synthetic indicators and the goal programming methodology used to estimate both liveability and sustainability. ‘[Relationship between liveability and environmental sustainability in Spanish cities](#)’ analyses the liveability and sustainability of 44 Spanish cities using the aforementioned methodology. The results of the study are contained in ‘[Results](#)’, together with their potential utility for urban planners. The final section presents the conclusions.

Theoretical Framework

The relationship between the notions of liveability and sustainability has been implicitly, theoretically studied in the urban literature (Newman, 1999; Shafer et al., 2000; van Kamp et al., 2003). Nevertheless, this relationship didn’t become an object of study in and of itself until the article published by Godschalk in 2004 in the *Journal of the American Planning Association*. As a starting point, this article takes the work of Campbell (1996) which highlights some of the contradictions within the goals of sustainable development, specifically, economic, social, and environmental objectives. Godschalk introduces the idea of liveability and presents three new relationships defined by the conflict that exists between liveability and the above-cited objectives. These are as follows: the growth management conflict, or the tension between economic growth and liveability; the conflict defined by gentrification, that is, social equity and liveability; and the green cities conflict, i.e., the natural environment and liveability.

After the publication of the above article, there have been many contributions that deal with the relationship between liveability and urban sustainability from a theoretical perspective (Howley et al., 2009; Allen, 2010; de Chazal, 2010; Newton, 2012; de Haan et al., 2014; Ruth & Franklin, 2014; Gough, 2015; van Assche et al.,

2010). In this sense, while the majority of these articles have focused on the areas of conflict that exist between these two concepts, they also tend to point out areas in which the two ideas overlap or share common ground.

In this vane, liveability and sustainability are both abstract, multidimensional constructs that attempt to say something about the relationship that exists between the population and the urban environment (van Kamp et al., 2003; de Chazal, 2010). They are both concepts that are popular with urban planners, particularly since they represent values and behaviours to which society as a whole tends to subscribe (de Haan et al., 2014; Gough, 2015). It is precisely this wide usage of the two concepts and their abstract nature that has generated so much confusion relative to their exact meanings, to such an extent that they are often used synonymously despite describing different realities (Veenhoven, 2000). Certain authors have focused on the different sources of conflict between the concepts of liveability and sustainability.

In the literature, the most salient of these sources of friction is perhaps the temporal horizon used by each (Gough, 2015). Specifically, liveability focuses on the more immediate needs of the population. For this reason, some authors such as de Haan et al. (2014) mention the anthropocentric nature of the notion of liveability. Sustainability, on the other hand, normally deals with a longer-term temporal horizon, since its focus lies on the needs of future populations. It should be underlined, however, that the satisfaction of these future needs makes it indispensable to fulfil certain minimum biological requirements in the present (Newman, 1999; Bithas & Christofakis, 2006). It is precisely for this reason that many authors focus on the environmental aspect of sustainability (Bithas & Christofakis, 2006; Newton, 2012; Ruth & Franklin, 2014), adopting, therefore, an “ecocentric” focus (de Haan et al., 2014).

This difference in the temporal horizon used to study liveability and sustainability is largely responsible for the leverage exerted by each when it comes to policy interventions (Allen, 2010; de Haan et al., 2014; Gough, 2015). In this sense, the emphasis on the present needs of urban dwellers inherent in the concept of liveability, needs that are more tangible and identifiable, makes the concept more attractive for public policymakers anxious to improve the public domain. Fundamentally there are two reasons for this. First, the potential benefits of these policies are perceived more clearly and more immediately by the general population (de Haan et al., 2014). Second, the higher specificity of the concept of liveability also makes it easier to apply policy strategies than when dealing with sustainability, which is much more abstract and difficult to operationalize (Gough, 2015).

In short, for the above reasons, policymakers and politicians often focus on strategies that aim to improve living conditions in the short-term rather than prioritizing their long-term sustainability. As a consequence, it might be that certain urban societies temporarily experience high levels of liveability at the expense of high levels of environmental decline (Ruth & Franklin, 2014).

Despite numerous theoretical efforts to differentiate and ring-fence notions of liveability and sustainability, there is a dearth of empirical literature that examines the relationship between the two. As far as we know, only Newton (2012) has analysed the relationship between liveability and environmental sustainability, specifically for big cities all over the world. Despite using data on a national

level to estimate urban sustainability, the results of this work allow us to intuit that cities that have high levels of liveability, have low levels of environmental sustainability. This study tries to analyse the relationship between both concepts by examining Spanish cities. To do so, we must start by looking at the commonly accepted definitions of both concepts.

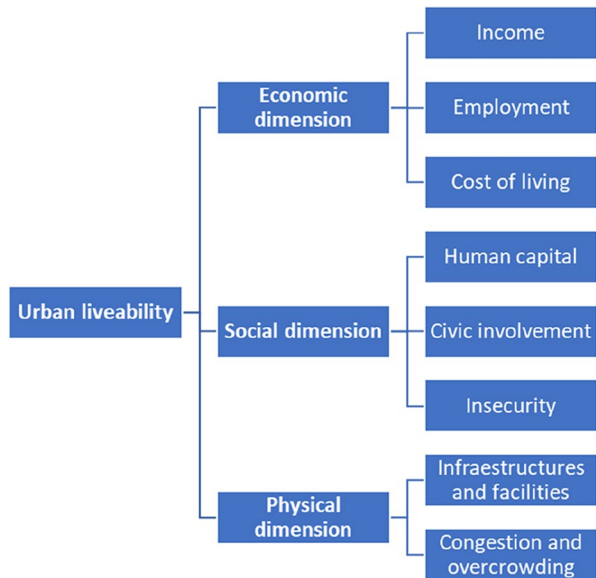
There is reasonable consensus as to a theoretical definition of urban liveability. In 2012 Newton defined the concept as a group of specific attributes of urban localization that contribute to an increase in the level of the individual's quality of life and the wellbeing of a society. Similarly, Gough (2015) interprets the liveability of a city to be the sum of the characteristics, both physical and social, of a particular place, that contribute to an improved quality of life for its inhabitants.

Concerning the "fuzzy" nature of environmental sustainability, there are important differences when defining the concept. Some analysts feel that the concept goes beyond the natural capital that is within reach of a city's inhabitants and the specific impact of these on the region in which they are located (Newton, 2012). Other analysts, such as Bettencourt and West (2010), consider that this kind of study should be framed in terms of local considerations. The analysis contained in this paper falls into the latter category. We take as our starting point the definition of environmental sustainability set out by Bithas and Christofakis (2006), in which the natural and biological existence of urban systems and the maintenance of their essential natural functions are assured. They add that, for this to occur, it is necessary to consider certain biological and environmental minimums. In this way, we hope to evaluate the negative impact that cities exert upon the environment, both in terms of the consumption of resources and in assimilating waste, whilst taking into account the necessity of establishing certain limits.

As highlighted above, the concepts of liveability and environmental sustainability are both multidimensional and abstract, which makes their quantification difficult and the direct measurement thereof, impossible. Within this context, the methodology of synthetic indicators is particularly useful to estimate this kind of concept. This is because they facilitate the evaluation of the various dimensions that go to make up the two concepts by using empirical variables, known as partial indicators. These variables are subsequently weighted and then aggregated into a single indicator.

This methodology has numerous advantages for those making urban planning decisions. It allows them to bring together many of the elements of a complex reality and translate these into a single indicator, which is easier to interpret than a whole set of individual indicators. The suitability of this methodology as a means of evaluating the concepts that underlie this analysis is reflected in its widespread usage in literature in which urban liveability is assessed using synthetic indicators (Wang et al., 2011; Morais et al., 2013; Saitluanga, 2014; Nissi & Sarra, 2016; u et al., 2019) and for the sustainability of cities (Kilkis, 2016; Zhang & Zhou, 2018). Many authors have already focused on Spanish cities, estimating either liveability or sustainability using this methodology (Royuela et al., 2003; González et al., 2011; Reig-Martínez, 2016; Lozano-Oyola et al., 2019; Valcárcel-Aguiar & Murias, 2019; Valcárcel-Aguiar et al., 2019; Rama et al., 2020).

Fig. 1 Dimensions of urban liveability



This article uses synthetic indicators to analyse the relationship that exists between the two concepts in the case of Spanish cities. To this end, we first attempt to identify the theoretical dimensions that go to make up the concepts being evaluated to elaborate on the indicator.

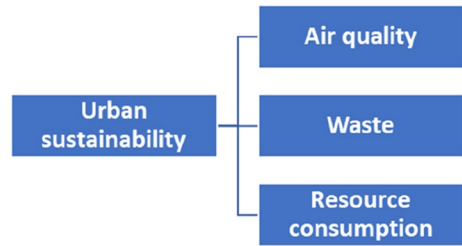
This study takes as its starting point the concept of urban liveability, which is made up of three basic dimensions, those that are most often considered in analyses of a similar kind (Shafer et al., 2000; Santos & Martins, 2007; Das, 2008). Figure 1 shows the dimensions that make up the concept of urban liveability.

It should be underlined that there is more than one way of achieving urban liveability. Although it is probably beneficial for there to be a certain balance among the dimensions that make up the concept (Shafer et al., 2000), it is still possible that different cities might be able to attain relatively good levels of liveability by emphasizing specific urban dimensions, which would partially make up for others that had a greater margin for improvement.

With respect to environmental sustainability, the theoretical framework of sustainability proposed in this study is based on the idea that urban agglomerations harm the natural environment (Berry, 1990), which, in turn, is the basis upon which the urban ecosystem develops. This impact takes the form of the excessive consumption of natural resources and an increase in the number and quantity of pollutants and waste that are generated. In consonance with these considerations, environmental sustainability is made up of three dimensions: air quality, the generation of waste, and the consumption of resources. Figure 2 represents the theoretical framework for environmental sustainability.

In this sense, and to ensure the viability of cities in the future, it is essential that the impact of urban activity in each of the dimensions of environmental sustainability does not exceed certain limits that are normally considered to be critical.

Fig. 2 Dimensions of urban environmental sustainability



Because of this, we consider it to be necessary to take a strong approach to sustainability in such a way that any negative performance in one of the aspects cannot be compensated for by an improvement in one of the others.

All of the dimensions of liveability and sustainability and the possibility of introducing some kind of compensatory mechanism, via which a negative score in one could be offset by a positive score in another, should be taken into consideration when estimating the synthetic indicators that are designed to measure both concepts. Based on these considerations, the aggregation of the partial indicators should be carried out utilizing a technique that allows us to consider a compensatory framework for urban liveability, but non-compensatory for environmental sustainability.

The aggregation, based on goal programming, is particularly suitable for this kind of scenario. On the one hand, this aggregation technique allows us to contemplate both the balance and the imbalance that might exist among the different partial indicators. On the other, the technique uses the concept of aspiration level, which is a concept with which urban planners are familiar. They create a representation of what planners and policymakers consider to be desirable levels for each of the indicators. As a consequence, indicators that are based on goal programming allow managers to incorporate aspiration levels for each of the variables used. This then helps to identify the objectives that should be reached and, when relevant, any deviation from said goals. Also, the results of the application are very simple to interpret and compare and offer numerous possibilities for their subsequent analysis such as benchmarking, which allows those cities with poorer levels of development to learn from the better performing cities.

Goal Programming and the Elaboration of Synthetic Indicators

The application of goal programming to the estimation of synthetic indicators has its origins in the article of Díaz-Balteiro and Romero (2004). Following this research, the goal concept was applied to the construction of composite indicators in an article by Blancas et al. (2010), albeit not as an optimisation process. The diverse advantages of this aggregation technique explain the fact that it had been used in several works in various fields (Lozano-Oyola et al., 2012; Molinos-Senante et al., 2016; Pérez et al., 2016; Blancas et al., 2018; Valcárcel-Aguiar and Murias, 2019; Valcárcel-Aguiar et al., 2019; Murias et al., 2020).

As it was explained, the aggregation of indicators based on goal programming used in this article does not involve an optimization procedure, so it is not necessary to define an objective function. This technique aggregates the deviation variables concerning aspiration levels. These aspiration levels will be defined for each partial indicator, and they represent an acceptable level of attainment for each partial indicator.

It is assumed that there is a series of N units, which are to be evaluated using M partial indicators: L positive partial indicators (the higher the value the better) and K negative partial indicators (or the lower the value the better), whereby $L + K = M$.

For each unit, there is a series of values for each of the partial indicators which aim to approximate the concept dimensions. The definitions are, therefore, as follows:

$$X_{il}^+ = \text{value of positive partial indicator } l \text{ for unit } i \quad \forall l = 1, 2, \dots, L \quad \forall i = 1, 2, \dots, N$$

$$X_{ik}^- = \text{value of negative partial indicator } k \text{ for unit } i \quad \forall k = 1, 2, \dots, K \quad \forall i = 1, 2, \dots, N$$

$$\mu_l^+ = \text{aspiration level for positive partial indicator } l \quad \forall l = 1, 2, \dots, L$$

$$\mu_k^- = \text{aspiration level for negative partial indicator } k \quad \forall k = 1, 2, \dots, K$$

Associated with each partial indicator and aspiration level, we can define a goal using the deviation variables. These represent the difference between the value of a partial indicator and its corresponding aspiration level, so they can be positive (p) or negative (n).

The interpretation of the deviation variables will depend on the type of partial indicator (positive or negative). In the case of a positive partial indicator X_{il}^+ , the variable n_{il}^+ would be undesirable, since it would express a weakness in the partial indicator, while the variable p_{il}^+ would be desirable since it would indicate a strength. As a result, the goals can be formulated as follows:

$$X_{il}^+ + n_{il}^+ - p_{il}^+ = \mu_l^+, \quad \text{where } n_{il}^+, p_{il}^+ \geq 0; \quad n_{il}^+ \cdot p_{il}^+ = 0 \quad \forall l = 1, 2, \dots, L$$

In contrast, in the case of a negative partial indicator X_{ik}^- the deviation variable p_{ik}^- would be undesirable, since it expresses a weakness in this partial indicator, while n_{ik}^- would be desirable, expressing a strength. As such, the goals can be formulated as follows:

$$X_{ik}^- + n_{ik}^- - p_{ik}^- = \mu_k^-, \quad \text{where } n_{ik}^-, p_{ik}^- \geq 0; \quad n_{ik}^- \cdot p_{ik}^- = 0 \quad \forall k = 1, 2, \dots, K$$

Henceforth, to avoid any confusion caused by the type of partial indicators in the interpretation of the deviation variables, we will refer to desirable deviation variables or strengths, and to undesirable deviation variables or weaknesses. The strengths are expressed as S_{im} and consist of the positive deviation variables p_{il}^+ in the case of positive partial indicators and the negative deviation variables n_{ik}^- in the case of negative partial indicators. The weaknesses are expressed as W_{im} and consist

of the negative deviation variables n_{ij}^+ in the case of positive partial indicators and the positive deviation variables p_{ik}^- in the case of negative partial indicators.

It should be noted that the deviation variables might be difficult to compare since the partial indicators can be measured on different scales. To remedy this, the deviation variables will be expressed in relative terms: as a percentage of their corresponding aspiration levels.

Once the deviation variables have a common scale they must be weighted according to the importance of partial indicators. Weighting is a delicate stage in the process of constructing a synthetic indicator. An accurate assignation of weights would require a strong agreement among stakeholders. However, it is not always possible to reach this agreement, and from an analytical point of view different strategies are used, such as identical weights, or resorting to the use of quantitative methods. These methods can be statistical techniques without using expert opinion, or techniques that do involve interaction with experts or stakeholders, eventually recurring to the support of Multicriteria Decision Analysis methods.

After assigning the weights (ω_m), the deviation variables can be aggregated into a single synthetic indicator as it is expressed below:

$$SI_i = \sum_{m=1}^M \frac{\omega_m (S_{im} - W_{im})}{\mu_m} \quad \forall i = 1, 2, \dots, N$$

$$\text{where } \sum_{m=1}^M \omega_m = 1$$

The aggregation of the partial indicators allows us to globally assess the performance of each unit with respect to the aspiration levels previously defined.

Relationship Between Liveability and Environmental Sustainability in Spanish Cities

The layout of most Spanish cities is consistent with the Mediterranean urban model whose structure is traditionally compact. Certain authors have pointed out that this characteristic is largely responsible for high levels of liveability without having significant environmental consequences (Rueda, 2012). However, the economic and demographic dynamism of the second half of the 20th century and, in particular, the real estate boom that reached its peak at about the turn of the century, has favoured more dispersed urban growth. This has led to serious deficiencies in environmental sustainability (Spanish Ministry of the Environment, and Rural and Marine Environment and the Ministry of Development, 2011; García, 2016).

In this sense, the models of urban development that are more widely scattered and characterized by lower population densities, are generally less economically and environmentally efficient because of higher energy requirements, the construction and maintenance costs of their infrastructure, and the costs of providing public services (Spanish Ministry of Development, 2019). These models increase physical distances

between destinations, which often makes using private transport unavoidable, a dynamic that impinges negatively on urban sustainability (IDAE, 2008).

It should also be mentioned that Spain is a country that is especially susceptible to the effects of climate change (Estrela et al., 2012), a phenomenon affected by the activity taking place in urban areas, whose consequences subsequently impact living conditions. Therefore, improving the liveability of the cities should not be undertaken without considering how these improvements might affect the environment and how achieving some kind of balance might be possible.

Within this context, and with a view to improvements in the urban planning of Spanish cities, analysing the relationship that exists between liveability and urban sustainability using specifically urban indicators that respect the theoretical requirements for each of the concepts is of great utility. Also, this analysis constitutes a basis upon which to replicate studies that look at the urban contexts that exist in other countries. This would provide further evidence to bolster the theoretical debate taking place concerning this dynamic.

The relationship between urban liveability and environmental sustainability is studied by analysing 44 Spanish cities which are provincial capitals and or the capitals of the autonomous regions. To do so, we compare the results obtained in the two synthetic indicators calculated by using the theoretical framework presented in ‘Theoretical Framework’ and the aggregation technique given in ‘Goal Programming and the Elaboration of Synthetic Indicators’.

We now go on to briefly develop some of the most relevant aspects of the estimation of the synthetic indicators for the case of Spanish cities.

Urban Liveability Index (ULI)

The synthetic index for urban liveability used in this article is based on that which is calculated by Valcárcel-Aguir and Murias (2019), which is called Urban Liveability Index (ULI). These authors take as their starting point the three dimensions set out in the theoretical framework: economic, social, and physical. Since these are very wide-ranging dimensions, the authors also consider more specific subdimensions gleaned from a revision of previous works. These subdimensions will be estimated by using a series of objective partial indicators; these can be seen in Table 1.

The key statistics of partial indicators considered for the ULI in this case of study are presented in Table 2.

The synthetic index will be elaborated by using the goal programming technique as a linear aggregation of the previously weighted relative strengths and weaknesses. Weighting and aspiration levels must be established beforehand by the urban planner in accordance with the characteristics and objectives of the cities being assessed.

$$ULI_i = \sum_{m=1}^{13} \frac{\omega_m (S_{im} - W_{im})}{\mu_m} \quad \forall i = 1, 2, \dots, 44$$

In the case of the Spanish cities analysed, the choice of the weighting system was conditioned by different factors. Some authors highlight the need for a

Table 1 List of partial indicators for the ULI and data sources

Dimensions	Sub-dimensions	Partial indicators	Abbreviation	Units	Database
Economic	Income	Average net disposable income	INC	Euros	Urban indicators (Spanish Statistical Institute, 2011)
	Employment	Unemployment rate	UNE	Percentage	Urban indicators (Spanish Statistical Institute, 2011)
	Cost of living	Residential price	PRI	Euros	Urban indicators (Spanish Statistical Institute, 2011)
Social	Human capital	Population (ages 25–64) with higher education	HUK	Percentage	Urban indicators (Spanish Statistical Institute, 2011)
	Civic involvement	Population that volunteers	SOK	Percentage	Population and housing census (Spanish Statistical Institute, 2011)
	Insecurity	Amount of crimes	CRI	Crimes/1000 inhabitants	Crime Statistics System (Ministry of the Interior, 2013)
Physical	Infrastructures and facilities	Supply of hospital beds	HEA	Beds/1000 inhabitants	National Hospital Catalogue (Ministry of Health, 2011)
		Supply of reading seats in libraries	EDU	Reading seats/1000 inhabitants	Spanish public libraries in figures (Ministry of Education, 2011)
		Supply of cinema seats	LEI	Cinema seats/1000 inhabitants	Urban Audit (Eurostat, 2011)
		Commutes in public transport	TRA	Percentage	Urban Indicators (Spanish Statistical Institute, 2011)
		Congestion and overcrowding	GRE	m ² /inhabitant	Urban Information System (Ministry of Public Works, 2009)
		Average commute time	COM	Minutes	Urban Indicators (Spanish Statistical Institute, 2011)
		Average home size	HOU	m ² /person	Urban Audit (Eurostat, 2011)

The National Statistics Institute does not provide data on income for Pamplona, Bilbao, Donostia/San Sebastián and Vitoria. The data for Pamplona was obtained from the Navarre Statistics Institute and in the case of the three Basque cities, it was approximated using gross disposable income per household from the Basque Statistics Institute (EUSTAT)

Table 2 Descriptive statistics of partial indicators for the ULI

Partial indicators	Mean	Median	Maximum	Minimum	Standard deviation
INC	31,725.58	31,273.20	61,300.00	22,532.94	5555.39
UNE	0.20	0.19	0.31	0.11	0.05
PRI	161,684.46	151,018.32	312,296.74	116,600.16	37,332.53
HUK	0.32	0.30	0.45	0.24	0.05
SOK	0.03	0.03	0.04	0.02	0.00
CRI	47.52	43.65	98.55	24.12	15.15
HEA	7.49	7.23	15.73	4.19	2.55
EDU	4.44	4.03	9.61	1.39	1.94
LEI	23.85	23.65	48.33	9.68	8.18
TRA	12.41	10.98	27.72	4.65	5.09
GRE	21.15	20.60	51.23	1.29	10.53
COM	20.01	19.20	31.21	17.34	2.64
HOU	35.87	35.75	39.72	31.51	1.98

balance between the economic, social, and physical dimensions (Shafer et al., 2000). Besides, in the absence of external information from experts or policy makers of what could be the more suitable weighting scheme, the use of identical weights allows to obtain a first approach of the performance of these cities in terms of liveability. For this reason, we have chosen to assign identical weights to the three main dimensions of liveability, which are shared equally among the partial indicators of which these dimensions are constituted. This choice is made without prejudice to the future inclusion of more precise information derived from expert opinion.

With respect to aspiration levels, given that there is no universally agreed-upon normative or expert criteria, these have been established in accordance with empirical analysis (Cicerchia, 1999). In particular, and in line with other works (Blancas et al., 2010; Valcárcel-Aguiar & Murias, 2019; Valcárcel-Aguiar et al., 2019), the aspiration level assigned for each of the 13 partial indicators was the arithmetical mean of the observations for the 44 Spanish cities analysed.

Environmental Sustainability Index (ESI)

To approximate environmental sustainability, an index is proposed which we shall simply call the Environmental Sustainability Index (ESI). Based on the theoretical framework introduced in ‘Theoretical Framework’, the ESI will be made up of three dimensions: air quality, generation of waste, and the consumption of resources. Each of these dimensions will be approximated by using a partial indicator, as is shown in Table 3.

As in the case of the Urban Liveability Index, the main statistics of partial indicators considered for the Environmental Sustainability Index are summarised below (Table 4).

Table 3 List of partial indicators for the ESI and data sources

Dimensions	Partial indicators	Abbreviation	Units	Database
Air quality	Average annual concentration of PM ₁₀	AIR	Mcg/m ³	Air Base (European Environment Agency, 2011)
Waste	Generation of solid waste per inhabitant	WAS	kg/inhabitant/day	Spanish Sustainability Observatory (Spanish Sustainability Observatory, 2005)
Resource consumption	Domestic electricity consumption per inhabitant	ELE	MWh/inhabitant/day	Spanish Sustainability Observatory (Spanish Sustainability Observatory, 2005)

It should be underlined that the dimensions that make up the concept of environmental sustainability are essential for the continuity of consumption and production processes in urban areas, and human life in general (Dietz & Neumayer, 2007; Ekins et al., 2003). For this reason, to better approximate the concept, it is necessary to consider certain minimum environmental requirements for each of these dimensions to guarantee environmental sustainability (Bithas & Christofakis, 2006; Mori et al., 2015).

Again, goal programming will be used in order to aggregate the partial indicators of environmental sustainability. Nevertheless, since this article rests upon the idea of strong sustainability, it is necessary to use a non-compensatory approach. Hence, if a city has no weaknesses reflected in any of the partial indicators for environmental sustainability, the score for the synthetic indicator will be the weighted sum of the relative strengths. However, if a city has weaknesses at least in one of the partial indicators, the score for the synthetic indicator will be the weighted sum of the relative weaknesses and will have a negative sign.

$$ESI_i = \begin{cases} \sum_{m=1}^3 \frac{\omega_m \cdot S_{im}}{\mu_m} \text{ if } \sum_{m=1}^3 W_{im} = 0 \\ - \sum_{m=1}^3 \frac{\omega_m \cdot W_{im}}{\mu_m} \text{ if } \sum_{m=1}^3 W_{im} \neq 0 \end{cases} \quad \forall i = 1, 2, \dots, 44$$

As with the previous synthetic indicator, all of the dimensions are assigned identical weightings, ensuring that all of the partial indicators have the same weights. With regard to the establishment of the aspiration levels, certain external reference points can be incorporated into the indicators. In the indicator labelled “mean annual concentration of PM₁₀” a level of 40 mcg/m³ was established, this being a maximum level set

Table 4 Descriptive statistics of partial indicators for the ESI

Partial indicators	Mean	Median	Maximum	Minimum	Standard deviation
AIR	25.01	23.07	36.69	14.17	5.51
WAS	1.27	1.26	1.75	0.80	0.20
ELE	5.40	5.12	9.45	2.28	1.43

by European Directive 2008/50/CE of the European Parliament and its Council on the 21st of May 2008. The aspiration level for the indicator entitled “generation of solid waste per inhabitant” was set at 1.4 kg of solid waste per inhabitant per day, and the “domestic electricity consumption per inhabitant” was set at 10 MWh per person per year, maximum outputs recommended by the Spanish Ministry of the Environment and Rural and Marine Affairs (2010) in the publication *Municipal System of Sustainability Indicators*.

Results

Table 5 presents the values for the synthetic indicators of liveability and urban sustainability for the 44 cities analysed.

As can be seen, the urban liveability index (ULI) contains positive values for some of the cities and negative values for others. To the extent that the construction of this indicator allows us to balance strengths and weaknesses, the value or score will be positive when the strengths outweigh the weaknesses, and vice-versa. Therefore, the greater the score obtained by a city, the greater the liveability for the residents.

The environmental sustainability index (ESI) can also contain both positive and negative values. However, in contrast to the liveability index, there is no compensatory mechanism to balance the strengths and weaknesses that compose the ESI. As a consequence, a positive value in the indicator reflects that the city has strengths in all of its partial indicators. The higher the score for each city, the greater the environmental sustainability. In contrast, negative values in the index indicate the existence of weaknesses in at least one of the partial indicators. Similarly, the lower the value of the indicator, the greater the city’s unsustainability.

Using the information gleaned from both of the synthetic indicators and, to study the relationship between liveability and urban sustainability, we carry out a bivariate analysis, which allows us to classify the 44 Spanish cities into four groups. These groups divide the sample according to whether the analysis finds the cities to be sustainable or not, and their level of liveability compared to the mean score for the whole of the sample. These results can be seen in Fig. 3.

The cities in group I, located in the first quadrant of the graph, are the best performers: they fulfil the minimum environmental requirements for the three partial indicators that make up the environmental sustainability index while, at the same time, performing better than average in those aspects that relate exclusively to liveability. In this sense, the policies and practices carried out in the cities that fall into this group should be seen as an example for the cities in the other groups.

Specifically, group I contains 19 cities, most of which are located in the North of Spain. With the two exceptions of A Coruña and Donostia/San Sebastián, all are inland. Most of the cities are rather small (fewer than 300,000 inhabitants), except for Zaragoza. The distribution pattern for the cities in group I, based on the typology of their functional urban areas (ESPON, 2003),¹ differs very little from the sample

¹ A functional urban area (FUA) is made up of an urban centre and the outskirts thereof. The latter area is economically integrated with the centre by means of its labour market, for example.

Table 5 Scores for the ULI and the ESI for the cities analysed

Cities	ULI	ESI
Albacete	0.0459	0.3111
Alicante	-0.0613	0.3512
Almería	-0.1538	0.4265
Badajoz	-0.0739	0.4799
Barcelona	-0.0831	-0.0167
Bilbao	-0.0848	0.1688
Burgos	0.0763	0.3659
Cáceres	0.1166	0.4715
Cádiz	-0.0658	0.2515
Castellón de la Plana	-0.0483	0.2933
Ciudad Real	0.1403	0.3345
Córdoba	-0.0727	0.3217
Coruña, A	0.0407	0.2575
Donostia	0.1423	0.2457
Girona	0.0205	-0.0167
Granada	-0.0222	-0.0238
Guadalajara	0.0059	-0.0238
Huelva	-0.1973	0.2228
Jaén	0.0096	0.3795
León	0.0286	0.3928
Lleida	0.0445	0.2820
Logroño	0.0421	0.3685
Madrid	-0.0313	0.3117
Málaga	-0.1469	-0.0548
Murcia	-0.0545	0.2569
Ourense	0.0301	0.4498
Oviedo	0.0304	0.2007
Palencia	0.0477	0.3746
Palma de Mallorca	-0.1003	-0.0833
Palmas de Gran Canaria, Las	-0.0953	0.3865
Pamplona	0.2412	0.3225
Pontevedra	-0.0196	0.4432
Salamanca	0.0270	0.3888
Santa Cruz de Tenerife	-0.1019	0.3787
Santander	0.0256	-0.0476
Santiago de Compostela	0.1438	-0.0423
Sevilla	-0.1099	-0.0024
Tarragona	-0.0479	0.1777
Toledo	0.2240	-0.0238
Valencia	-0.0480	0.3627

Table 5 (continued)

Cities	ULI	ESI
Valladolid	0.0286	0.3916
Vitoria	0.0376	0.3085
Zamora	0.0514	0.3810
Zaragoza	0.0180	0.2650

as a whole. However, on looking at the economic characteristics of the functional areas (ESPON, 2003) of which these cities form part, it is highly significant that of the five highly industrialized cities in the sample, three are to be found in this group: Donostia, Pamplona, and Vitoria.

The cities that perform worst are those contained in group III, which is represented by the third quadrant. These cities, besides being “unsustainable”, perform worse than average on the liveability index. Hence, the margin for improvement for this group of cities is substantial.

Geographically, all of the latter cities are to be found in the south and east coast regions. The mean population size of these cities is over 700,000, indicating that they are clearly large compared to the rest of the sample. Specifically, this city-profile is linked to a separate category within the Spanish urban system, since these areas are MEGAs and functional national or transnational areas, following the ESPON categories.

Group IV corresponds to the fourth quadrant and contains five cities: Girona, Guadalajara, Santander, Santiago de Compostela, and Toledo. The cities within this group have scores that are higher than the mean in terms of urban liveability but fail to satisfy the minimum environmental conditions established by the analysis.

In contrast to groups I and III, there is no specific pattern to the geographical distribution for group IV. However, in terms of population, the cities in the group may be considered to be quite small, and with the exception of Santander none of them has more than 100,000 inhabitants. Of these five small cities, three are at the head of local/regional functional areas and two are at the head of transnational/national functional areas. Most of the cities in this group are characterized by having diversified economic specializations.

Finally, group II, which represents the second quadrant, contains those cities that fulfil the minimum environmental requirements but have scores that are lower than average for the sample in liveability. This group contains 15 of the 44 cities in the sample. Most of these areas are located in the south and the east of Spain, although there are two cities from the north, Bilbao and Pontevedra, and also Madrid, in the centre of the peninsula. These cities have an average population above 450,000 inhabitants and most of them are at the head of transnational/national functional areas.

Those who manage the urban areas of the cities that belong to this group should focus on improving aspects of urban liveability that have weaknesses. Further, and in consonance with the findings of experts including Godschalk (2004), Howley et al. (2009), Allen (2010), Chazal (2010), Ruth and Franklin (2014) and Gough (2015), liveability and sustainability might be concepts that are effectively in conflict with

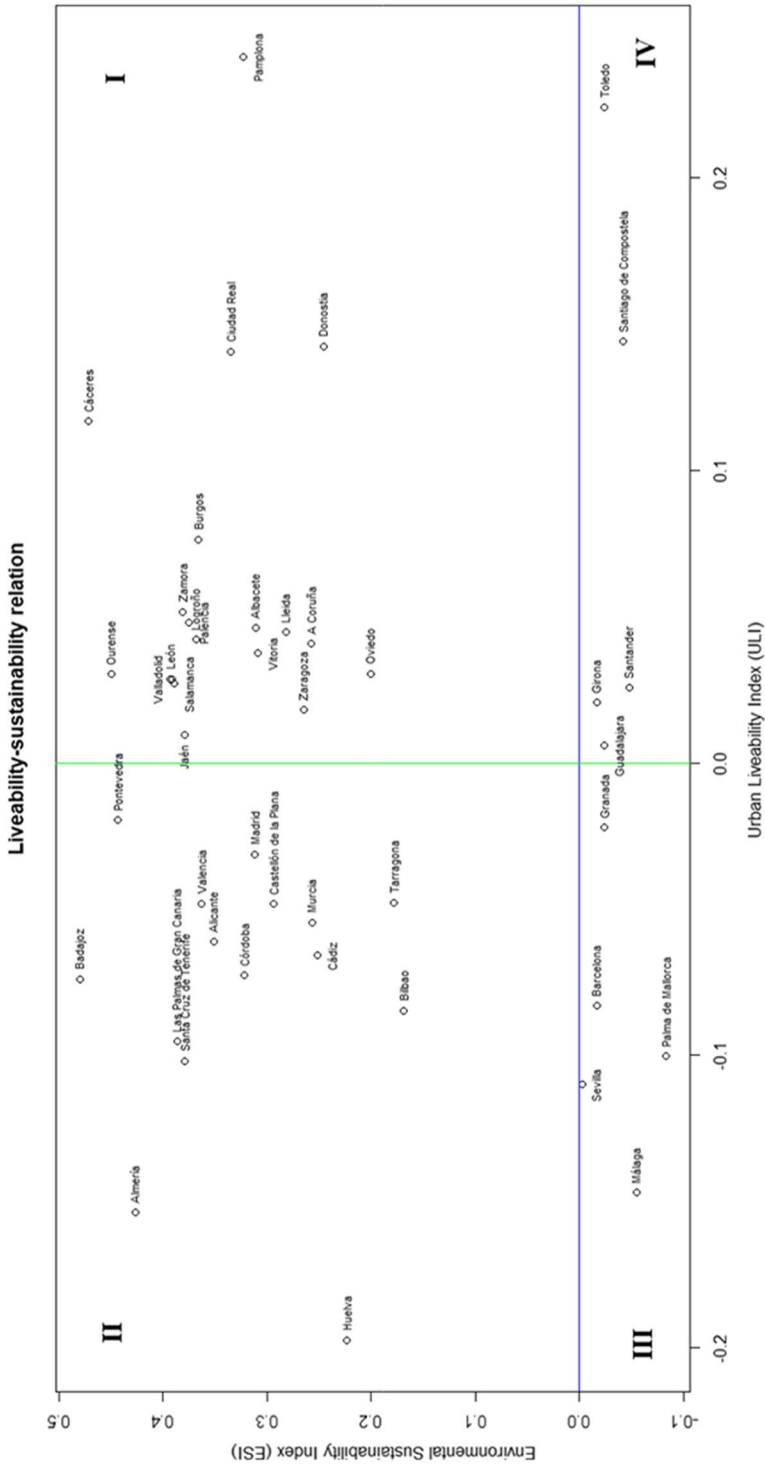


Fig. 3 Bivariate analysis of the cities according to urban sustainability and liveability

each other, so any improvements in the conditions of liveability should be carried out whilst monitoring any possible impacts upon the evolution of sustainability.

In short, results show that cities belonging to regions of the north coast or inland have a better performance, being mostly sustainable and presenting liveability levels higher than average (group I). On the contrary, among the cities belonging to regions located on the eastern and southern coast of Spain, only two can be categorized in group I: Lleida, in the region of Catalonia, and Jaén, in the region of Andalusia.

In addition, and from a theoretical point of view, city size has demonstrated to have a relevance in the benefits and costs of agglomeration (Royuela & Suriñach, 2005) which determine urban liveability and sustainability. City size has also an important role in the contextualization of liveability and sustainability agendas (Way, 2016). Attending to city size, large cities in the sample seem to present worse results, especially in terms of the liveability they offer their citizens. Of these cities, only Zaragoza is placed among the cities of group I, which constitute a reference by obtaining in both indicators results above levels established for the bivariate analysis. Medium-sized cities (between 100,000 and 500,000 inhabitants) and small cities (less than 100,000 inhabitants) are represented in group I in a similar proportion to the general sample. However, in the case of medium-sized cities, the presence of group II cities (sustainable, but with liveability levels lower than average) stands out, and in the case of small cities, it is the presence of group IV cities (with liveability higher than average but not sustainable) which is considerable.

Finally, and closely related to population size issues, the city function may have an important role (Royuela & Suriñach, 2005). In this sense, the Spanish cities which are MEGA obtain poor results (three in group III and two in group II). Likewise, cities with transnational/national influence mostly show liveability levels lower than average. Among them, there are cities in group I (sustainable and liveable), although in a slightly lower proportion than that of the sample. On the contrary, almost three-quarters of the cities with regional/local influence belong to group I, potentially acting as a reference for cities that are not sustainable, or that present a level of liveability below the average.

Based on the classification of the cities into groups using bivariate analysis and on some of their characteristics, a benchmarking analysis should be particularly useful for urban planners in cities that fall into groups II and IV, i.e., those cities which have a bad performance in one of the two attributes tested (liveability or sustainability). Benchmarking allows urban planners the opportunity to find a city of group I (liveable and sustainable) which can act as a reference. Reference cities present a similar value in one of the attributes but they are clearly better in the other one, showing that it is possible to achieve better values in the latter attribute without sacrificing the good performance in the former one. Within this group of reference cities, we have opted to provide as an example the city that is more similar in some of the previously analysed characteristics, which are also discussed on the scientific literature, such as their population size or the relevance of their functional urban area (FUA) (Royuela & Suriñach, 2005; Way, 2016).

Reference cities allows cities in groups II and IV to estimate their margin for improvement in that attribute whose performance is poor, but without detriment to the attribute whose performance is acceptable. In a second stage of this

analysis, it also allows urban planners in the cities that belong to groups II and IV to be aware of the specific dimensions of urban liveability or sustainability on which they should prioritize their efforts to improve.

In order to study the functioning of the benchmarking analysis, Table 6 shows some examples of cities from group II, i.e., cities which are sustainable, but they score below the mean in terms of liveability. For each of these, another city from group I was identified to act as a “reference” following the previously explained procedure. Therefore, the reference city presents a similar level of sustainability but a higher level of liveability than the city from group II, and they also share demographical and functional aspects. This analysis makes it possible to measure the margin for improvement in liveability in these cities in group II, without negatively affecting urban sustainability.

Based on the information given in Table 6, it can be seen that for the cities in the sample, there is a significant margin for improvement in liveability. Such is the case of Murcia, which can be compared with A Coruña, or the case of Castellón when compared to its reference city of Vitoria. In other cities in the sample, the margins for improvement are even more important, because the reference cities with which they can be compared have urban liveability levels that are especially high. This is the case of Córdoba and Alicante, which may be compared to Pamplona (the city with the best ULI score), or the Andalusian cities of Huelva and Cádiz, which may be compared to the Basque reference city of Donostia/San Sebastián (the second most liveable city in terms of its ULI score which is also sustainable).

Benchmarking among the cities from group II and their reference cities might provide important qualitative information, enabling the former cities to become precisely aware of those areas of potential improvement in liveability and orientating planning and economic efforts accordingly. To illustrate the utility of this

Table 6 Cities with a margin for improvement in liveability and some reference counterparts

Cities with a margin for improvement in liveability				Reference cities			
City	ULI	Populat	FUA	City	ULI	Populat	FUA
Badajoz	- 0.0739	151,214	Regional/local	Cáceres	0.1166	95,616	Regional/local
Córdoba	- 0.0727	328,326	Transnational/ national	Pamplona	0.2412	195,943	Transnational/ national
Alicante	- 0.0613	329,325	Transnational/ national	Pamplona	0.2412	195,943	Transnational/ national
Cádiz	- 0.0658	124,014	Transnational/ national	Donostia	0.1423	185,512	Transnational/ national
Huelva	- 0.1973	147,808	Transnational/ national	Donostia	0.1423	185,512	Transnational/ national
Murcia	- 0.0545	437,667	Transnational/ national	A Coruña	0.0407	245,053	Transnational/ national
Tenerife	- 0.1019	204,476	Transnational/ national	Burgos	0.0763	178,864	Transnational/ national
Castellón	- 0.0483	176,298	Transnational/ national	Vitoria	0.0376	240,753	Regional/local

type of analysis, the cities of Cádiz and Huelva were selected, and the city of Donostia as their reference, as can be seen in Fig. 4.

Figure 4 allows us to analyse the relative deviations from the aspiration level for each of the partial indicators of urban liveability and sustainability for the three cities. While the three partial indicators for urban sustainability for the three cities reflect similar strengths, the same is not true for the indicators of liveability. Specifically, both Cádiz and Huelva have significant weaknesses in the indicators for health infrastructure and unemployment, in contrast to Donostia where these are recorded as strengths. In addition to these indicators, the Andalusian city of Huelva has important weaknesses in the indicators for transport and leisure. In the latter indicator, Huelva has a wide margin for improvement when compared to Donostia, for which leisure is a considerable strength. Also, even if these cities which score particularly badly fulfil the aspiration levels for some indicators, there is often still a margin for improvement. For example, Cádiz fulfils the aspiration level for leisure infrastructure, but its reference city, Donostia, has strengths in this indicator which are proportionally even greater.

Table 7 echoes the results of Table 6, but in this case, the focus is on improving sustainability. Three cities from group IV are selected as an example. Therefore, these cities have liveability scores that are higher than average but fail to fulfil the minimum requirements for sustainability. Each of these cities was assigned a reference city whose population and area of urban influence are comparable. In the case of the reference cities, while the liveability scores were similar to those of their counterparts, they were, in contrast, deemed to be sustainable. It may be asserted that environmental sustainability should be the main objective for these group IV cities. Nevertheless, this analysis goes further since it informs urban planners and city administrators how to fulfil the minimum requirements for sustainability, without incurring high costs on liveability in the short-term.

As in the case of cities with a margin for improvement in liveability, which were previously analysed, benchmarking also allows to identify the environmental sustainability indicators for the cities that have a margin for improvement in this attribute. One example of this type of analysis is shown in Fig. 5 in which the comparative differences between A Coruña and Santander are highlighted.

Fig. 4 Comparative analysis of the relative deviations of the partial indicators for urban sustainability and liveability. Donostia, Cádiz and Huelva

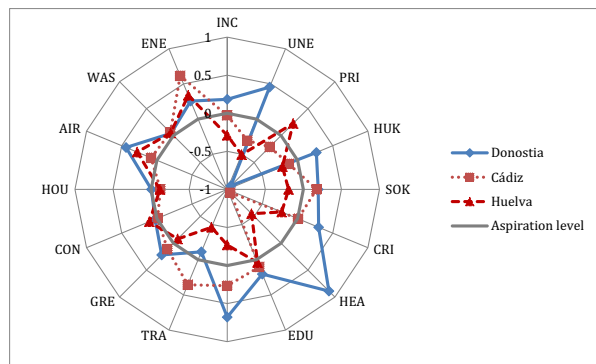
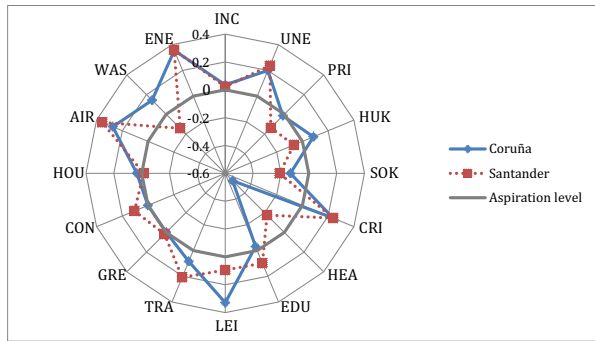


Table 7 Cities with a margin for improvement in sustainability and some reference cities

Cities with a margin for improvement in sustainability				Reference cities			
City	ESI	Population	FUA	City	ESI	Population	FUA
Guadalajara	-0.0238	84,404	Regional/local	León	0.3928	132,744	Regional/local
Girona	-0.0167	96,113	Regional/local	Lleida	0.2820	137,283	Regional/local
Santander	-0.0476	178,095	Transnat./national	A Coruña	0.2575	245,053	Transnat./national

Fig. 5 Comparative analysis of the relative deviations of the partial indicators for urban sustainability and liveability. A Coruña and Santander



As with Fig. 4, Fig. 5 analyses the relative deviations with respect to the aspiration level registered by each of the partial indicators for urban liveability and sustainability. A Coruña and Santander have very similar ULI scores and very similar profiles regarding strengths and weaknesses expressed through each of the 13 partial ULI indicators. In terms of environmental sustainability, Fig. 5 shows that Santander cannot be considered to be a sustainable city since it fails to fulfil the aspiration level for the “Waste” indicator, whereas for A Coruña this represents a significant strength. Therefore, were Santander to manage to reduce its levels of waste to those of A Coruña, it might become a sustainable city without significant detriment to urban liveability.

Overall, the bivariate and the consecutive benchmarking analyses performed could be very useful for urban planners of those cities which cannot achieve a minimum sustainability level, or which present a liveability level below the average, i.e., cities in groups II and IV. This usefulness is based on three reasons. Firstly, these analyses allow urban planners of cities with these limitations to identify a city which can serve as a point of reference since it presents similar demographical and socioeconomic characteristics, but which is able to obtain better results in at least one of the analysed attributes (liveability or sustainability). Secondly, in comparing with a reference city with similar characteristics, urban planners of these cities could obtain an estimation of the improvement margin in the attribute whose performance is worse, by comparing the result of the corresponding index with the value obtained by the reference city. Thirdly, an additional comparative analysis of the deviation variables

of both cities, i.e., the city which have a potential of improvement and the reference city, allows the urban planners of the former city to identify the specific dimensions of liveability or sustainability on which they should focus their improvement efforts.

Conclusions

This article attempts to contribute to the body of work that deals with the link between urban liveability and sustainability by taking an empirical look at Spain. More specifically, the work aims to analyse the relationship between urban liveability and sustainability that a set of Spanish cities offer their inhabitants by studying the respective levels of these concepts for each of the cities.

The relationship between urban liveability and sustainability is studied using bivariate analysis. These concepts are proxied by using two synthetic indices and aggregated by using a technique based on goal programming. This technique has numerous advantages from the point of view of urban planning. On the one hand, it allows the analysis to evaluate the current situation with respect to a specific objective or previously established aspiration level. On the other, it facilitates the interpretation and comparison of the results and provides a range of options for subsequent analysis.

The results of the bivariate analysis allow us to identify four groups of cities according to the levels of urban liveability and sustainability they attain. The utility of this analysis is twofold. First, it provides an overview of the Spanish cities in each of the groups based on aspects such as size, area of urban influence, and economic specializations. From the analysis, it can be seen that in the case of Spain at least, the cities that are considered to be both liveable and sustainable are normally fairly small, and are often characterized by an industrial specialization. In contrast, those cities with low levels of liveability and sustainability tend to be located in the south and east of the peninsula, and their mean size tends to be quite large when compared to the national average. Second, this analysis should be particularly useful for urban planners responsible for those cities in which one or both of the two indicators being analysed perform badly. Thus, by taking cities with a similar profile, which outperform their counterparts with whom they are compared, it becomes possible to obtain an estimation of the margin for improvement with respect to urban liveability and sustainability and to identify the specific dimensions upon which these cities would be advised to focus their efforts.

Despite the evident utility of this analysis, it does have certain limitations. Of these, the most important arises from the limited availability of urban data for certain indicators, particularly those that refer to environmental sustainability. This deficit dictated the sample size for the Spanish cities included in the analysis, which necessitated the exclusion of those cities for which data was unavailable. Hence, the limited number of cities makes it difficult to draw theoretical findings as to the relationship between urban liveability and sustainability. Related to this, the lack of data for those urban centres with more precise boundaries, i.e., functional urban areas, constitutes a further limitation to the study.

However, the analysis carried out provides an important basis from which to develop future research. Firstly, while it has been possible to isolate and observe different patterns of performance in Spanish cities in the sample and how they behave with respect to liveability and sustainability, broadening the analysis to include a greater number of cities would allow a deeper theoretical understanding of the relationships that underlie both concepts. Further, by using functional urban areas instead of municipalities it would be possible to carry out a more precise analysis of this connection. In any case, in the absence of this data, the replication of the analysis using the urban areas of other countries would help to a better knowledge of the relationship between liveability and sustainability in cities, complementing this case study for the Spanish urban context.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose. The authors have no conflicts of interest to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

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References

- Allen, T. F. H. (2010). Making livable sustainable systems unremarkable. *Systems Research and Behavioral Science*, 27, 469–479. <https://doi.org/10.1002/sres.1059>
- Berry, B. J. L. (1990). Urbanization. In B. L. Turner, W. C. Clark, R. W. Kates, J. F. Richards, J. T. Mathews, & W. B. Meyer (Eds.), *The Earth as transformed by human action: Global and regional changes in the biosphere over the past 300 years*. Cambridge: Cambridge University Press.
- Bettencourt, L., & West, G. (2010). A Unified theory of urban living. *Nature*, 467, 912–913. <https://doi.org/10.1038/467912a>
- Bithas, K. P., & Christofakis, M. (2006). Environmentally sustainable cities. Critical review and operational conditions. *Sustainable Development*, 14, 177–189. <https://doi.org/10.1002/sd.262>
- Blancas, F. J., Caballero, R., González, M., Lozano-Oyola, M., & Pérez, F. (2010). Goal programming synthetic indicators: An application for sustainable tourism in Andalusian coastal counties. *Ecological Economics*, 69, 2158–2172. <https://doi.org/10.1016/j.ecolecon.2010.06.016>
- Blancas, F. J., Lozano-Oyola, M., González, M., & Caballero, R. (2018). A dynamic sustainable tourism evaluation using multiple benchmarks. *Journal of Cleaner Production*, 174, 1190–1203. <https://doi.org/10.1016/j.jclepro.2017.10.295>
- Campbell, S. (1996). Green cities, growing cities, just cities? Urban planning and the contradictions of sustainable development. *Journal of the American Planning Association*, 62, 296–312. <https://doi.org/10.1080/01944369608975696>

- Cicerchia, A. (1999). Measures of optimal centrality: Indicators of city effect and urban overloading. *Social Indicators Research*, 46, 273–299. <https://doi.org/10.1023/A:1006808506878>
- Das, D. (2008). Urban quality of life: A case study of Guwahati. *Social Indicators Research*, 88, 297–310. <https://doi.org/10.1007/s11205-007-9191-6>
- de Chazal, J. (2010). A systems approach to livability and sustainability: Defining terms and mapping relationships to link desires with ecological opportunities and constraints. *Systems Research and Behavioral Science*, 27, 585–597. <https://doi.org/10.1002/sres.1058>
- de Haan, F. J., Ferguson, B. C., Adamowicz, R. C., Johnstone, P., Brown, R. R., & Wong, T. H. F. (2014). The needs of society: A new understanding of transitions, sustainability and liveability. *Technological Forecasting & Social Change*, 85, 121–132. <https://doi.org/10.1016/j.techfore.2013.09.005>
- Díaz-Balteiro, L., & Romero, C. (2004). Sustainability of forest management plans: A discrete goal programming approach. *Journal of Environmental Management*, 71, 351–359. <https://doi.org/10.1016/j.jenvman.2004.04.001>
- Dietz, S., & Neumayer, E. (2007). Weak and strong sustainability in the SEEA: Concepts and measurement. *Ecological Economics*, 61, 617–626. <https://doi.org/10.1016/j.ecolecon.2006.09.007>
- Ekins, P., Simon, S., Deutsch, L., Folke, C., & De Groot, R. (2003). A framework for the practical application of the concepts of critical natural capital and strong sustainability. *Ecological Economics*, 44, 165–185. [https://doi.org/10.1016/S0921-8009\(02\)00272-0](https://doi.org/10.1016/S0921-8009(02)00272-0)
- ESPON. (2003). The role, specific situation and potentials of urban areas as nodes in a polycentric development. Third interim report. Luxembourg: ESPON. https://www.espon.eu/sites/default/files/attachments/3.ir_1.1.1-full_0.pdf. Accessed 28 Sept 2021
- Estrela, T., Pérez-Martin, M. A., & Vargas, E. (2012). Impacts of climate change on water resources in Spain. *Hydrological Sciences Journal*, 57(6), 1154–1167. <https://doi.org/10.1080/02626667.2012.702213>
- European Commission. (2019). *Urban agenda for the EU. Multi-level governance in action*. Brussels: European Commission. https://ec.europa.eu/regional_policy/sources/docgener/brochure/urban_agenda_eu_en.pdf
- European Directive 2008/50/EC of the European Parliament and of the Council of 21st May 2008 on ambient air quality and cleaner air for Europe*. Brussels: European Parliament.
- Fu, B., Danlin, Y., & Yaojun, Z. (2019). The livable urban landscape: GIS and remote sensing extracted land use assessment for urban livability in Changchun Proper, China. *Land Use Policy*, 87, 104048. <https://doi.org/10.1016/j.landusepol.2019.104048>
- García, F. (2016). Compacidad y densidad de las ciudades españolas. *Revista EURE – Revista de Estudios Urbano Regionales*, 42(127), 5–27. <https://doi.org/10.4067/s0250-71612016000300001>
- Godschalk, D. R. (2004). Land use planning challenges: Coping with conflicts in visions of sustainable development and livable communities. *Journal of the American Planning Association*, 70, 5–13. <https://doi.org/10.1080/01944360408976334>
- González, E., Cárcaba, A., & Ventura, J. (2011). The Importance of the geographic level of analysis in the assessment of the Quality of Life: The case of Spain. *Social Indicators Research*, 102(2), 209–228. <https://doi.org/10.1007/s11205-010-9674-8>
- Gough, M. Z. (2015). Reconciling livability and sustainability: conceptual and practical implications for planning. *Journal of Planning Education and Research*, 35(2), 145–160. <https://doi.org/10.1177/0739456X15570320>
- Howley, P., Scott, M., & Redmond, D. (2009). Sustainability versus liveability: An investigation of neighbourhood satisfaction. *Journal of Environmental Planning and Management*, 52(6), 847–864. <https://doi.org/10.1080/096440560903083798>
- IDAE, Instituto para la Diversificación y Ahorro de la Energía (2006). *Guía Práctica para la elaboración e implementación de Planes de Movilidad Urbana Sostenible*, PMUS. https://www.idae.es/sites/default/files/documentos/publicaciones_idae/documentos_10251_guia_pmus_06_2735e0c1.pdf. Accessed 28 Sept 2021
- Kilkis, S. (2016). Sustainable development of energy, water and environment systems index for Southeast European cities. *Journal of Cleaner Production*, 130, 222–234. <https://doi.org/10.1016/j.jclepro.2015.07.121>
- Lozano-Oyola, M., Blancas, F. J., González, M., & Caballero, R. (2012). Sustainable tourism indicators as planning tools in cultural destinations. *Ecological Indicators*, 18, 659–675. <https://doi.org/10.1016/j.ecolind.2012.01.014>

- Lozano-Oyola, M., Blancas, F. J., González, M., & Caballero, R. (2019). Sustainable tourism tags to reward destination management. *Journal of Environmental Management*, 250, 109458. <https://doi.org/10.1016/j.jenvman.2019.109458>
- McPherson, A. J., Principe, P. P., & Mehaffey, M. (2013). Using Malmquist Indices to evaluate environmental impacts of alternative land development scenarios. *Ecological Indicators*, 34, 296–303. <https://doi.org/10.1016/j.ecolind.2013.05.009>
- Molinos-Senante, M., Marques, R. C., Pérez, F., Gómez, T., Sala-Garrido, R., & Caballero, R. (2016). Assessing the sustainability of water companies: A synthetic indicator approach. *Ecological Indicators*, 61, 577–587. <https://doi.org/10.1016/j.ecolind.2015.10.009>
- Morais, P., Miguéis, V. L., & Camanho, A. S. (2013). Quality of life of experienced by human capital: An assessment of European cities. *Social Indicators Research*, 110, 187–206. <https://doi.org/10.1007/s11205-011-9923-5>
- Mori, K., Fujii, T., Yamashita, T., Mimura, Y., Uchiyama, Y., & Hayashi, K. (2015). Visualization of a City Sustainability Index (CSI): Towards transdisciplinary approaches involving multiple stakeholders. *Sustainability*, 7, 12402–12424. <https://doi.org/10.3390/su70912402>
- Murias, P., Valcárcel-Aguiar, B., & Regueiro-Ferreira, R. M. (2020). A territorial estimate for household energy vulnerability: An application for Spain. *Sustainability*, 12(15), 5904. <https://doi.org/10.3390/su12155904>
- Newman, P. W. G. (1999). Sustainability and cities: Extending the metabolism model. *Landscape and Urban Planning*, 44, 219–226. [https://doi.org/10.1016/S0169-2046\(99\)00009-2](https://doi.org/10.1016/S0169-2046(99)00009-2)
- Newton, P. W. (2012). Liveable and sustainable? Socio-technical challenges for twenty-first-century cities. *Journal of Urban Technology*, 19(1), 81–102. <https://doi.org/10.1080/10630732.2012.626703>
- Nissi, E., & Sarra, A. (2016). A measure of well-being across the Italian urban areas: An integrated DEA-entropy approach. *Social Indicators Research*, 136, 1183–1209. <https://doi.org/10.1007/s11205-016-1535-7>
- Pérez, V., Hernández, A., Guerrero, F., León, M. A., da Silva, C. L., & Caballero, R. (2016). Sustainability ranking for Cuban tourist destinations based on composite indexes. *Social Indicators Research*, 129, 425–444. <https://doi.org/10.1007/s11205-015-1110-7>
- Rama, M., González-García, S., Andrade, E., Moreira, M. T., & Feijoo, G. (2020). Assessing the sustainability dimensión at local scale: Case study of Spanish cities. *Ecological Indicators*, 117, 106687. <https://doi.org/10.1016/j.ecolind.2020.106687>
- Reig-Martínez, E. (2016). Ciudades y calidad de vida en el área metropolitana de Valencia. *Revista de Estudios Regionales*, 106, 79–104.
- Royuela, V., & Suriñach, J. (2005). Constituents of quality of life and urban size. *Social Indicators Research*, 74, 549–572. <https://doi.org/10.1007/s11205-004-8210-0>
- Royuela, V., Suriñach, J., & Reyes, M. (2003). Measuring quality of life in small areas over different periods of time. *Social Indicators Research*, 64(1), 51–74. <https://doi.org/10.1023/A:1024789306734>
- Rueda, S. (2012). *Libro verde de sostenibilidad urbana y local en la era de la información*. Madrid: Ministerio de Agricultura, Alimentación y Medio Ambiente. https://www.mitma.gob.es/recursos_mfom/pdf/9982755F-02CF-47D9-9571-0723387D66F7/130252/Libro_Verde_Final_15012013_tcm7247905.pdf. Accessed 28 Sept 2021
- Ruth, M., & Franklin, R. S. (2014). Livability for all? Conceptual limits and practical implications. *Applied Geography*, 49, 18–23. <https://doi.org/10.1016/j.apgeog.2013.09.018>
- Saitluanga, B. L. (2014). Spatial pattern of urban liveability in himalayan region: A case of Aizawl City, India. *Social Indicators Research*, 117, 541–559. <https://doi.org/10.1007/s11205-013-0362-3>
- Santos, L. D., & Martins, I. (2007). Monitoring urban quality of life: The Porto experience. *Social Indicators Research*, 80, 411–425. <https://doi.org/10.1007/s11205-006-0002-2>
- Shafer, C. S., Lee, B. K., & Turner, S. (2000). A tale of three greenway trails: User perceptions related to quality of life. *Landscape and Urban Planning*, 49(3), 163–178. [https://doi.org/10.1016/S0169-2046\(00\)00057-8](https://doi.org/10.1016/S0169-2046(00)00057-8)
- Spanish Ministry of Development. (2019). *Agenda Urbana Española 2019*. Madrid: Ministry of Development. <https://apps.fomento.gob.es/CVP/handlers/pdfhandler.ashx?idpub=BAW061>. Accessed 28 Sept 2021
- Spanish Ministry of the Environment and Rural and Marine Affairs. (2010). *Sistema Municipal de Indicadores Urbanos*. IV Reunion del Grupo de Trabajo de Sostenibilidad de la Red de Redes de Desarrollo Local Sostenible.
- Spanish Ministry of the Environment, and Rural and Marine Environment and the Ministry of Development. (2011). *Estrategia española de sostenibilidad urbana y local (EESUL)*. Madrid: Ministry of

- the Environment, and Rural and Marine Environment and the Ministry of Development. <http://www.fomento.gob.es/NR/rdonlyres/1668CD1E-0B11-4C9E-84E2-E664DD3464C1/111503/EESULWEB2011.pdf>. Accessed 28 Sept 2021
- United Nations (2017). *New Urban Agenda*. Quito: UN-Habitat.
- Valcárcel-Aguiar, B., & Murias, P. (2019). Evaluation and management of urban liveability: A goal programming based composite indicator. *Social Indicators Research*, *142*, 689–712. <https://doi.org/10.1007/s11205-018-1861-z>
- Valcárcel-Aguiar, B., Murias, P., & Rodríguez-González, D. (2019). Sustainable urban liveability: A practical proposal based on a composite indicator. *Sustainability*, *11*, 86. <https://doi.org/10.3390/su11010086>
- Van Assche, J., Block, T., & Reynaert, H. (2010). Can community indicators live up to their expectations? The case of the Flemish city monitor for livable and sustainable urban development. *Applied Research in Quality of Life*, *5*, 341–352. <https://doi.org/10.1007/s11482-010-9121-7>
- Van Kamp, I., Leidelmeijer, K., Marsman, G., & de Hollander, A. (2003). Urban environmental quality and human well-being: Towards a conceptual framework and demarcation of concepts; a literature study. *Landscape and Urban Planning*, *65*, 5–18. [https://doi.org/10.1016/S0169-2046\(02\)00232-3](https://doi.org/10.1016/S0169-2046(02)00232-3)
- Veenhoven, R. (2000). The four qualities of life. Ordering concepts and measures of the good life. *Journal of Happiness Studies*, *1*, 1–39.
- Wang, J., Su, M., Chen, B., Chen, S., & Liang, C. (2011). A comparative study of Beijing and three global cities: A perspective on urban livability. *Frontiers of Earth Science*, *5*, 323–329. <https://doi.org/10.1007/s11707-011-0182-1>
- Way, H. (2016). Beyond the big city: The question of size in planning for urban sustainability. *Procedia Environmental Sciences*, *36*, 138–145. <https://doi.org/10.1016/j.proenv.2016.09.024>
- Zanella, A., Camanho, A. S., & Dias, T. G. (2015). The assessment of cities' livability integrating human wellbeing and environmental impact. *Annals of Operations Research*, *226*, 695–726. <https://doi.org/10.1007/s10479-014-1666-7>
- Zhang, L. P., & Zhou, P. (2018). A non-compensatory composite indicator approach to assessing low-carbon performance. *European Journal of Operational Research*, *270*, 352–361. <https://doi.org/10.1016/j.ejor.2018.02.058>

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