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Methodological and Ideological Options

An Operational Non-compensatory Composite Indicator: Measuring Sustainable Tourism in Andalusian Urban Destinations

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1. Introduction

The management of tourist destinations using criteria of sustainability is a question which currently no-one calls into question. The planning processes developed in the last decades at all institutional levels have had the aim of defining diverse quality tourist models sustainable in the medium and long term. The practical implementation of these models requires appropriate measures which enable evaluating the situation of the territories and graduating their evolution over time.

The use of indicators has been consolidated at an international level as one of the most suitable options to evaluate the achievements toward more sustainable situations in tourist destinations, facilitating the operationalization of the concept of sustainability (Bell and Morse, 2008; Mayer, 2008). Sustainable tourism indicators are analytical evaluation instruments whose absolute levels and the direction in which they change show if the zone evaluated has a more or less sustainable situation (European Commission, 1996), according to the tendency shown with respect to previous situations (Romero et al., 2003). So, the progress or regress of destinations in sustainability terms can be analyzed if these indicators are quantified in different periods.

Given its multidimensional character, the evaluation of a territory's degree of sustainability must be done simultaneously using a set of indicators relative to social, economic and environmental questions. The simultaneous analysis of the information contained in these indicator panels is not always easy, hindering the global valuation of the destination or territory analyzed. This problem is resolved in practice by defining a global measure that provides a view of the whole situation of each destination analyzed, aggregating the information of the initial system in a unique measurement known as a synthetic indicator (OECD, 2008).

This methodological situation is commonly used at an international level when carrying out studies of complex concepts such as sustainability or quality of life (Munda and Saisana, 2011; Floridi et al., 2011; Chaaban et al., 2016; Luzzati and Gucciardi, 2015), as well in the specific case of the tourist sector at different territorial levels, where we find numerous applications (Castellani and Sala, 2010; Lozano-Oyola et al., 2012; Blancas et al., 2015; Carrillo and Jorge, 2017; Blancas et al., 2018). Saltelli (2007) provides a very detailed discussion of the pros and cons of the construction of a composite indicator to analyze altogether the information of a system. Basically, the main advantage of a synthetic indicator is that it synthesizes the evaluation of a complex and multidimensional phenomenon and facilitates its interpretation by the public managers and makes benchmarking practices possible. Likewise, its view of the whole attracts the public interest by its capacity of making a comparison between analysis units easier via rankings and their evolution. This is particularly important given that it expedites the efficiency of the policies and the accountability of the public managers. However, if the synthetic indicator is not correctly constructed according to international guidelines (OECD, 2008), or not correctly interpreted, it can send erroneous policy messages.

There are numerous alternative methodologies for the construction of composite indicators and there is not an international consensus that determines which of them is the most appropriate (Domínguez et al., 2011). In this context, the methods based on the use of multicriteria decision-making techniques seem to be an adequate option for the evaluation of sustainability objectives, given their capacity to deal with multiple conflicting indicators (Díaz-Balteiro et al., 2017). Although they share the same underlying idea, multicriteria methodologies for the construction of composite indicators are very diverse. Hence, the methodologies vary from the simplest, consisting of a global measurement that defines via a weighted linear aggregation with specific weights through subjective methods (Pulido and Sánchez, 2009) to operationally more complex methodologies. Among the latter we find indicators that use multiplicative aggregation (Zhou and Ang, 2009; Blancas et al., 2013; Blancas et al., 2014; Sevigny and Saisana, 2016), Compromise Programming (Díaz-Balteiro and Romero, 2004; Gómez-Limón and Sanchez-Fernandez, 2010), Goal Programming (Blancas et al., 2010a; Lozano-Oyola et al., 2012; Blancas et al., 2015) and Data Envelopment Analysis Models (Hatefi and Torabi, 2010; Reig-Martínez et al., 2011).

When the previous aggregation methods are used with a system of quantitative indicators, the weights assigned do not represent the relative importance of each aspect evaluated (Munda and Nardo, 2003; OECD, 2008), this being the main limitation which they have. Specifically, the weightings show the substitution rates between the indicators which obliges taking into account the compensatory character

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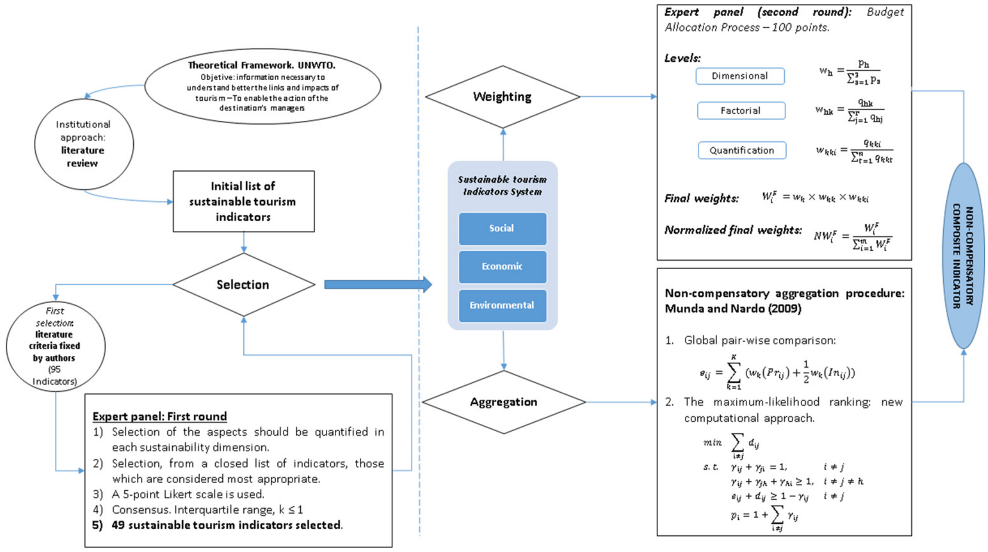


Fig. 1. Composite indicator: methodological process.

of the synthetic indicator obtained. This compensatory character refers to the possibility that in a specific case the weaknesses presented in a group of indicators can be compensated by the strengths registered in others. In this way, the composite indicator shows the net result which is obtained when bearing in mind the compensations that are produced between the indicators present in the system. In this context, a search for new procedures to obtain synthetic indicators which do not have a compensatory character has been proposed (Podinovskii, 1994). Note that this discussion about compensation only refers to the procedure based on linear aggregation. When geometric means or other rules are used, the substitution rates are not constant and they also depend on the values taken by the other indicators (see, Casadio-Tarabusi and Palazzi, 2004).

Among the multicriteria aggregation procedures, we highlight that developed by Munda and Nardo (Munda, 2005; Munda (2008); Munda and Nardo, 2009) which adapts the ideas from voting systems (the so-called *Kemeny's rule*, see Kemeny (1959) and Young and Levenglick (1978)) to the problem of aggregating indicators. This procedure has several advantages over traditional aggregation schemes. Among them, we underscore the following: 1) the evaluation of each individual indicator is computed separately by considering the relative position of the unit with respect to a particular variable. Hence, compensation between different indicators is not allowed; 2) problems derived from differences in scale and/or interval ratios are overcome; 3) quantitative and qualitative indicators can be considered simultaneously, without any previous transformation; 4) normalization is not required prior to the aggregation process; and finally, 5) the weights assigned can be interpreted as the relative importance of each indicator (for a detailed discussion of this point, see Munda and Nardo (2009)).

The main problem of this non-compensatory procedure is the computation of the optimal ranking. The number of permutations (feasible solutions) becomes rapidly unmanageable. For example, a problem with 10 alternatives implies to evaluate $10! = 3, 628, 800$ solutions. Note that here, the term alternative is utilized in a multicriteria decision-making procedure context; that is, as any of the units which must be evaluated, compared and ranked. This is a NP-hard problem (non-deterministic polynomial time problem), and hence the main algorithms proposed in the literature are heuristics based on artificial intelligence, branch and bound approaches, and multi-stage techniques (see, among others, Barthelemy et al., 1989; Davenport and Kalagnanam, 2004; Dwork et al., 2001). In order to overcome this limitation, in this paper we develop a new computational approach to the non-compensatory composite indicator problem proposed in Munda and Nardo (2009) which will conclude with the construction of a mixed-integer linear programming model (MILP). In order to illustrate how this new computational approach can be used, this paper presents a further attempt in the assessment of the regional tourism sustainability of Andalusia (Spain). Specifically, the sustainability of the main Andalusian urban destinations is compared.

The rest of the paper is structured as follows. After this introduction, the methodological issues related to the composite indicator construction are presented in Section 2 in order to evaluate sustainable tourism. Specifically, we present in this section sustainable tourism indicators defined utilizing UNWTO guidelines, using an expert panel for selecting and weighting indicators. Furthermore, the new computational procedure to define a non-compensatory composite indicator is also defined in this section. Section 3 puts forward the empirical results obtained in the case study focused on urban destinations of Andalusia, presenting some examples to illustrate how the composite indicator proposed can be used in practice. Section 4 is devoted to concluding remarks.

2. Methodology

For the elaboration of the composite indicator we follow the guidelines of the OECD (Nardo et al., 2008). Firstly, we introduce the theoretical framework. Then, we select the indicators that we include in the initial system of sustainable tourism indicators. Weighting and aggregation are the next steps (Fig. 1).

2.1. Theoretical Framework

The starting point for the construction of a composite indicator is always the setting of the theoretical framework that should clearly define the phenomenon to be measured and its dimensions, selecting individual indicators to evaluate each aspect which they are made of. As is demonstrated in the literature (Floridi et al., 2011), the definition of sustainable tourism and its operationalization in practical valuations and effective policies are highly subjective and debatable questions. To define a theoretically powerful composite indicator, our choice is to rely on a widely agreed framework developed by the UNWTO (World Tourism Organization). In this sense, we define a composite indicator that provides the information necessary to understand better the links and impacts of tourism with respect to the cultural and natural environment in which in the activity develops and upon which it is broadly dependent (UNWTO, 1996). It is a question of obtaining a global measurement that enables the action of the destination's managers to achieve a more or less sustainable situation, according to the tendency shown with respect to previous situations.

To achieve an operational measurement, we decompose the concept of tourist sustainability into three large dimensions: social, economic and environmental. To add substance to each one of them, we elaborate an initial list of aspects to be evaluated, taking into account the objective set for the synthetic indicator.

In order to adopt a standard and broadly accepted definition, we decompose the concept of tourist sustainability into three large dimensions: social, economic and environmental. To add substance to each one of them, we first reflected about the sustainability issues of each dimension to be included in the composite indicator and then we found out which of the available indicators best proxy those aspects. The preliminary list of sustainability issues and indicators was then validated by a panel of experts.

To work out the initial list of sustainable tourism indicators, we have set out from international studies in the matter of the UNWTO (1993, 1996, 2004), the United Nations (United Nations Commission on Sustainable Development, 2001; United Nations Environment Programme, 2007), the Organization for Economic Cooperation and Development (2002, 2005, 2008) and the European Union (European Commission, 2003, 2007, 2010). Likewise, we have reviewed other works in the area of tourist sustainability (Gallego and Moniche, 2005; Sancho and García, 2006; Mauerhofer, 2008; Paracchini et al., 2011; Tanguay et al., 2010, 2013; Rio and Nunes, 2012; Mikulic et al., 2015; Cucculelli and Goffi, 2016; Pérez et al., 2017). All of this ensures the scientific validity of the system of tourist sustainability indicators produced.

In the provision of content, it is not only important to consider theoretically valid aspects, we have to incorporate practical aspects. In this sense, the system must include questions which are easy to calculate by the tourist managers and to interpret by the users of the information. The provision of detailed content to each dimension allows obtaining an operative definition of sustainable tourism, which facilitates its measurement.

In the next section, we analyze the selection process of indicators followed.

2.2. Selection of Sustainability Issues and Indicators

The following step was to select the sustainability issues and the indicators that would give content to each dimension considered in the original system, setting out from the initial lists elaborated (see supplementary material). International experience and prior research done by experts in the matter was taken as a base by the authors in order to reduce the number of indicators considered initially, selecting the sustainable issues that we included in each dimension. In this choice process, theoretical and practical considerations were interplayed.

To select the indicators that allow quantifying each dimension, we had to bear in mind international and local previous studies in this field, thus covering the lack of guidelines in this regard (Ávila et al., 2002; Blackstock et al., 2006; Blancas et al., 2010a, 2010b; Dachary and Arnáiz, 2002; Fullana and Ayuso, 2002; Lozano et al., 2009; Lozano-Oyola et al., 2012; Mauerhofer, 2008; Paracchini et al., 2011; Tanguay et al., 2010).

Specifically, the criteria followed to select the indicators to include in the system that we propose were the information's usability, how frequently it is used, its relevance, conceptual core, temporality, representativeness and the availability of the statistical information. This last aspect is of great importance as on numerous occasions the lack of statistical information to be able to quantify the indicators is a major inconvenience. We find this especially in the regional and local areas, particularly in environmental matters (Floridi et al., 2011). Likewise, when making the selection we considered the possibility of quantifying the indicator over time to analyze the evolution of the destinations.

After selecting the indicators, it was necessary to assign them to one of the three conceptual dimensions considered: social, economic and environmental. To do so, we had to bear in mind other previous studies, thus covering the lack of guidelines in this regard (Ávila et al., 2002; Blackstock et al., 2006; Blancas et al., 2010a, 2010b; Dachary and Arnáiz, 2002; Fullana and Ayuso, 2002; Lozano et al., 2009; Lozano-Oyola et al., 2012; Mauerhofer, 2008; Paracchini et al., 2011, Tanguay et al., 2010). We also assigned the indicators chosen a positive or negative character based on their relations with the achievement of sustainability objects. We considered that an objective is positive when a value that is greater is an improvement in sustainability and that it is negative for the opposite situation.

To complete the final composition of the initial system, we used the information obtained from a panel of 31 experts using a Delphi procedure adapted according to the international practices in this field (Nardo et al., 2005a; Nardo et al., 2005b; OECD, 2008; Coll-Serrano et al., 2013). Within this panel, those people who carry out work or research activity in public and private institutions in areas related with the tourist sector are considered as experts. Our proposal is specifically to regard as potential panellists those scientific researchers (Choi and Sirakaya, 2006) who have published at least one peer-reviewed paper concerning sustainable tourism development or sustainability indicators in journals which are included in the Journal Citation Reports. In this way, we ensure the consistency and reliability of the experts' assessments. To obtain the information we employed a closed questionnaire via email between May and December 2017, making it possible that each expert member, when stating his/her opinion, did not influence the assignations of others (Hermans et al., 2008).

We requested the experts' collaboration in selecting the baseline aspects and the indicators (in a first round), as well as in establishing the importance which they conceded to the dimensions, baseline aspects and indicators (second round).

Regarding the first round, we asked each member of the expert panel to select the aspects which he/she considered should be quantified in each sustainability dimension (Carrillo and Jorge, 2017). We also asked them to select, from a closed list of indicators, those which they considered most appropriate to evaluate each baseline aspect. In this first selection in the first round we used a 5-point Likert scale, aiming to obtain a greater number of complete questionnaires (Pulido and Pérez, 2003).

To quantify the consensus within the expert panel in this first phase, it is considered that the median is the measurement that best represents the group opinion, as it expresses the central tendency of the answer (Landeta, 1999). From the 2 semi-series situated on both sides of the median, we obtain what is known as the interquartile range [that we denote by k]. The interquartile range is a measure of variability that is based on dividing a data set into quartiles. The quartiles divide a rank-ordered data set into four equal parts. The values which divide each part are called the first, second, and third quartiles; and they are designated by q_1, q_2, and q_3, respectively. Specifically, k is defined from the difference between the third quartile and the first quartile $[q_3 - q_1]$, and the aim is to k measure the dispersion of the sample. In this case, data are expressed in a Likert scale so the possible values of k go from 1 to 5. It is considered that the value of k is inversely proportional to the group consensus; that is to say, the greater the range, the less the consensus (Landeta et al., 2008). Unanimity is achieved when $k = 0$. We consider a degree of acceptable convergence (consensus) among the experts when $k \leq 1$ (Mateos-Ronco and Server, 2011; Campos et al., 2014). In our case, 39 indicators present an acceptable consensus among the experts with an interquartile range < 1.

Nevertheless, no selection process of indicators is exempt of a certain arbitrariness in the decisions adopted (Tanguay et al., 2013). In any case, the indicators must be selected according to their capacity to describe the objective of sustainability and their relevance to appropriately characterize the dimensions considered. To do so, due to their importance we have added some indicators whose interquartile range were above the unit in order to study the destination's tourist

Table 1
Social sustainable tourism indicators selected: sign, weighting and consensus.
Source: Own elaboration.

Indicator	I_j	Sign	Final weight	Median	k
Provision of health facilities to the population	I_{S1}	Positive	0.03063	4	1
Relative number of passenger transport vehicles	I_{S2}	Positive	0.02978	4	1.5
Establishments for the service sector activities	I_{S3}	Positive	0.02406	3	1.5
Security in the destination: evaluation of visitors	I_{S4}	Positive	0.02876	4	1
Accidents with victims on urban roads: number per person	I_{S5}	Negative	0.02584	4	1
Cultural heritage: number of protected sites	I_{S6}	Positive	0.03913	4	1
Pressure on cultural heritage	I_{S7}	Negative	0.03913	4	1
Festivities and customs preserved with tourist interest	I_{S8}	Positive	0.03576	4	1
Percentage of resident foreign population	I_{S9}	Negative	0.02984	4	1
Destination social carrying capacity: tourist per inhabitant	I_{S10}	Negative	0.03456	5	1
Inter-annual variation of disposable income	I_{S11}	Positive	0.01647	4	1
Population enrolled in non-compulsory levels: percentage	I_{S12}	Positive	0.01703	3	1
Demographic dependency: general index	I_{S13}	Negative	0.01732	4	1
Cadastral value of real estate per inhabitant	I_{S14}	Negative	0.01731	3	1

Table 2
Economic sustainable tourism indicators selected: sign, weighting and consensus.
Source: Own elaboration.

Indicator	I_j	Sign	Final weight	Median	k
Tourist demand: number of visitors	I_{E1}	Positive	0.01771	4	2
Average stay per tourist	I_{E2}	Positive	0.01894	4	1
Revenue from tourism	I_{E3}	Positive	0.02063	5	1
Employment in the service sector: proportion of employees	I_{E4}	Positive	0.01942	4	1
Total unemployment rate	I_{E5}	Negative	0.01580	3	1
Level of satisfaction of tourism demand: global evaluation	I_{E6}	Positive	0.02668	5	1
Perception of the quality-price ratio by the visitor	I_{E7}	Positive	0.02284	4	1
Territorial planning plan that includes tourism: existence	I_{E8}	Positive	0.01837	2	2
Official tourism accommodation places offered	I_{E9}	Positive	0.00490	4	1
Vacancies offered in high quality tourism accommodation establishment: percentage	I_{E10}	Positive	0.00527	4	2
Establishment of restaurant services: per capita number	I_{E11}	Positive	0.00499	4	1
Tourist information offices: relative endowment	I_{E12}	Positive	0.00549	4	1
Existence of a website for the destination	I_{E13}	Positive	0.00549	4	1
Experiences offered: number of tourist attractions	I_{E14}	Positive	0.00549	4	1
Seasonality of the tourist offer: accommodation establishments with activity throughout the year	I_{E15}	Positive	0.01181	4	2
Seasonality of the tourist demand: ratio of low-season tourists to peak-season tourists	I_{E16}	Positive	0.01333	4	1
Seasonality of tourism employment: ratio of low-season to peak-season	I_{E17}	Positive	0.01387	5	1
Tourism employment: number of employees	I_{E18}	Positive	0.03124	4	1
Percentage of employees in the tourism sector relative to total employment	I_{E19}	Positive	0.03023	4	1
Occupancy rate for official tourism accommodation establishments: average level	I_{E20}	Positive	0.01706	3	1

Table 3
Environmental sustainable tourism indicators selected: sign, weighting and consensus.
Source: Own elaboration.

Indicator	I_j	Sign	Final weight	Median	k
Protected natural surface in the destination	I_{EN1}	Positive	0.05013	2	1
Biodiversity: number of species	I_{EN2}	Positive	0.04769	3	1
Final energy consumption attributable to tourism	I_{EN3}	Negative	0.02508	4	1.5
Percentage of renewable energy consumption attributable to tourism	I_{EN4}	Positive	0.02671	4	1
Water consumption attributed to tourism	I_{EN5}	Negative	0.02395	2	0
Volume of reused water	I_{EN6}	Positive	0.02471	4	1.5
Volume of wastewater receiving treatment	I_{EN7}	Positive	0.02611	4	1
Volume of waste generated	I_{EN8}	Negative	0.00910	4	1.5
Volume of recycled waste compared to total volume of waste	I_{EN9}	Positive	0.00989	5	1
Provision of containers for paper-cardboard collection	I_{EN10}	Positive	0.00989	5	1
Paper and cardboard collected: volume	I_{EN11}	Positive	0.00989	5	1
Provision of containers for glass collection	I_{EN12}	Positive	0.00989	5	1
Construction density per unit area	I_{EN13}	Positive	0.01019	4	2
Total area of natural landscape	I_{EN14}	Positive	0.01141	5	1
Unoccupied buildings	I_{EN15}	Negative	0.01019	5	1

sustainability (as we can see in Tables 1, 2 and 3). Specifically, we included indicators such as the number of tourists, passenger transport vehicles, establishments for the service sector activities, the existence of territorial planning plans that include tourism, the percentage of vacancies offered in high quality tourism accommodation establishments, the seasonality of the tourist offer, construction density, water reused and waste generation. The significance of these issues for the management of urban destinations using sustainability criteria justifies their inclusion in the system.

With this procedure we manage to reduce the number of sustainability indicators that make up the initial system, elaborated, as we have commented, taking into account a review of the literature in the matter as well as the availability of statistic information to be able to quantify the indicators. Specifically, we have gone from an initial system of 95 tourist sustainability indicators (25 social, 43 economic and 27 environmental) to one of 49 indicators (14 social, 20 economic and 15 environmental). The system of indicators obtained is shown in Tables 1, 2 and 3.

Before the construction of the composite indicator proposed, the underlying nature of the data needs to be carefully analyzed. Given the limited number of destinations analyzed in relation to the number of indicators considered, it is not appropriate to use a multivariate analysis technique to study the statistical validity of the system and its relationship with the system's theoretical structure. Therefore, we use an exploratory analysis based on the study of the level of correlation of the indicators. Specifically, we determine for the indicators of each dimension the Cronbach Alpha coefficient standardized from the correlations between the indicators of the system (Cronbach, 1951). This coefficient measures the degree of internal consistency, attaining in this case acceptable values > 0.6 in all the dimensions, with the economic dimension having the highest coefficient: 0.893. We also determined the correlation matrix between the indicators of the system, presenting an average value of 0.145, without problems of double counting of information, since no more than one indicator was used to evaluate the same aspect of sustainability.

2.3. Weighting

In a second round, the expert panel was asked to quantify the weightings which would represent the relative importance of each element of the system. To facilitate the valuation carried out by each expert three levels were considered: dimensional, factorial and quantification. In each level we used the Budget Allocation Process, and 100 points were assigned among the elements considered, giving a larger score to that element which was considered to have a greater relative importance. In the first level, the importance of each dimension in relative terms was evaluated. In the second, the different aspects considered within each dimension were compared. Finally, in the third level, the respondent valued the relative importance of each indicator considered to quantify each of the aspects of the upper level.

Having counted on the opinion of all the experts, a valuation of consensus for each indicator is obtained (Zhou et al., 2012). Specifically, we calculate the weight of the indicator as a quotient between the score attained by the indicator and the total sum of the scores of all the indicators which we have included in the same group. This allows us to easily value a system of indicators, although it is made up of a high number of indicators.

Having obtained the dimensional weightings of the baseline aspects and of the indicators, the value of the final weight assigned to each indicator was calculated as the product of the weightings obtained at each level. After this, we calculate the normalized value dividing the value of the final weight by the summation of the weightings of the total number of indicators which make up the system and this normalized value is the one that we use to calculate the composite indicator.

2.4. Non-compensatory Aggregation Procedure: A New Computational Approach

Having set the system and quantified the weightings, in this section we present the aggregation method used to construct the synthetic indicator. In this case, we have opted for using the method proposed by Munda and Nardo (2009) based on a non-compensatory aggregation.

The main idea here, the development of a computational procedure for an existing non-compensatory procedure, is based on multicriteria decision-making ideas. The proposal concludes with the computation of a linear programming in which, in our case, the requirement of binary variables implies the computation of an MILP.

2.4.1. The Non-compensatory Approach

The mathematical aggregation procedure proposed in Munda and Nardo (2009) contains two main steps. Firstly, the so called "outranking matrix" is constructed by carrying out the pairwise comparisons of alternatives according to the whole set of indicators. Then, in a second stage, a complete pre-order of alternatives is constructed, induced by the values of the pair-wise comparisons. The outranking matrix denoted E is built as follows.

Consider a problem with N alternatives which have been evaluated with respect to K individual indicators. The value assigned to alternative i ($i = 1, \dots, N$) in the individual indicator k ($k = 1, \dots, K$) is denoted by I_{ik}. Note that here, we refer to an alternative to designing each decision-making unit.

An $N \times N$ matrix can be constructed by comparing the elements I_{ik} with I_{jk} for i ≠ j. Each element of the matrix $e_{ij} (i \neq j)$ is the result of the pair-wise comparisons according to the K individual indicators between alternative i and j. This global pair-wise comparison is obtained by computing the following expression,

$$e_{ij} = \sum_{k=1}^{K} \left(w_k (Pr_{ij}) + \frac{1}{2} w_k (In_{ij}) \right) \tag{1}$$

where $w_k(Pr_{ij})$ and $w_k(In_{ij})$ are the weights of individual indicators presenting, respectively, a preference and indifference relation between alternatives i and j. The equality $e_{ij} + e_{ji} = 1$ clearly holds.

The assignation of the values to preferences and indifferences must be obtained as the result of a weighting procedure as we consider weights for representing the relative importance of the partial indicators. Considering a given weighting vector w, obtained by an external process, the alternatives are pair-wise compared. Note that the value of each indicator is considered separately. For indicator k, if alternative i is preferred to j, then the corresponding value w_k is assigned to i and nothing is assigned to j. If both alternatives are indifferent, then i and j are each assigned half of the value of w_k. The value of e_{ij} is computed as the sum of all the comparisons of alternative i with respect to the remaining $n - 1$ alternatives.

Note that it is possible to modulate the concepts of preference and indifference in pair-wise comparisons. The simplest way to define this concept is to consider that alternative i is preferred to j with respect to variable k if $I_{ik} > I_{jk}$, and that indifference between the two alternatives appears when the values of the individual indicators coincide. Other definitions of preference and indifference could be considered, including, for instance, a minimum difference between values I_{ik} and I_{jk} to consider that the two alternatives are not of equal value.

To determine the best ranking of alternatives, Munda and Nardo (2009) propose an adaptation of the maximum-likelihood principle to the ranking problem (Munda, 2005). The maximum-likelihood ranking is the ranking supported by the maximum number of individual indicators for each pair-wise comparison, summed over all the pairs of alternatives.

More formally, consider all the $N(N - 1)$ pair-wise comparisons that constitute the outranking matrix. Let R denote the set of the complete rankings of the N alternatives, $R = \{r_s\}$, $s = 1, \dots, N!$. For each r_s compute the corresponding score ϕ_s as the summation of e_{ij} over all the $\binom{N}{2}$ pairs ij of alternatives, such that:

$$\phi_s = \sum e_{ij}, \quad \text{where} \quad i \neq j,\ e_{ij} \in r_s. \tag{2}$$

The final ranking r^* is the one which maximizes (3):

$$r^* \Leftrightarrow \phi_s^* = \max_s \sum e_{ij}, \ \text{with}\ e_{ij} \in r_s. \tag{3}$$

This proposed procedure verifies several desirable properties in the social choice context, such as neutrality, unanimity, monotonicity and reinforcement (for a detailed explanation, see Munda and Nardo (2009)). Also, the procedure described has several advantages over traditional aggregation schemes, as we have previously commented.

The main problem of the procedure described above is the computation of the optimal ranking. The number of permutations (feasible solutions) becomes rapidly unmanageable. Hence the main algorithms proposed in the literature are heuristics based on artificial intelligence, branch and bound approaches, and multi-stage techniques.

To overcome this limitation, in the following sub-section we propose a new computational approach to the problem described, based on the construction of a mixed-integer linear programming model.

2.4.2. Computational Approach

In this sub-section, a mixed-integer linear programming model is proposed for determine the optimum ranking described in the previous section. Suppose that the outranking matrix E has been constructed following the procedure described above.

In order to determine the maximum-likelihood ranking r^*, two tasks are required: firstly, the construction of the set of feasible rankings from the values of matrix E; secondly, the selection of the best ranking. For the construction of a ranking of alternatives, the procedure proposed in Contreras (2010) is considered and adapted for the particular context of interest. Consider the binary variables γ_{ij}, such that $\gamma_{ij} = 1$ if alternative j is preferred over alternative i. Note that with this variable, not only is it possible to compute how many alternatives are preferred to alternative i, but also to determine which these alternatives are. The rank position of i, denoted by p_i, can be computed as:

$$p_i = 1 + \sum_{i \neq j} \gamma_{ij}. \tag{4}$$

To guarantee that the assignation of values of binary variables is carried out adequately, two conditions must be met. First, it is necessary to ensure that the preference between two alternatives is in only one direction; that is to say, either i is preferred to j or j is preferred to i. It is not possible to select both directions simultaneously and only one of them can be assigned. It is important to bear in mind that a complete pre-order is being constructed.

In addition to this, the ranking has to verify the transitivity property. That is, it is unacceptable for alternative i to be preferred to j, alternative j preferred to h and alternative h preferred to i.

Consider a set of N alternatives. A complete pre-order of alternatives, in which each alternative is represented by its rank position $p_i = 1 + \sum_{i \neq j} \gamma_{ij} (i = 1, \ldots, N)$, is constructed if the following conditions are imposed on the binary variables γ_{ij}:

$$\gamma_{ij} + \gamma_{ji} = 1, \; i \neq j \tag{5}$$

$$\gamma_{ij} + \gamma_{jh} + \gamma_{hi} \geq 1, \; i \neq j \neq h. \tag{6}$$

$$\gamma_{ij} + \gamma_{jh} + \gamma_{hi} \leq 2, \; i \neq j \neq h. \tag{7}$$

It easy to see that constraints (5) guarantee that, in each pair-wise comparison, one alternative is preferred to the other. Since $\gamma_{ij} \in \{0, 1\}$, then necessarily the unity is assigned to one of the alternatives in each comparison. The conditions included in Eqs. (6) and (7) guarantee the verification of the property. Suppose three alternatives i, j, h such that i is preferred to j, j to h and h to i. This implies that $\gamma_{ij} = 0 (\gamma_{ji} = 1)$, $\gamma_{jh} = 0 (\gamma_{hj} = 1)$ and $\gamma_{hi} = 0$ $(\gamma_{ih} = 1)$, which is not possible since $\gamma_{ij} + \gamma_{jh} + \gamma_{hi} = 0 < 1$.

It can be seen constraints (6) and (7) guarantee that the preference relations over sets of three alternatives can be extended to larger subsets of alternatives. Therefore, with binary variables γ_{ij} and the sets of constraints (5), (6) and (7), a complete pre-order of N alternatives is constructed. Note that the representation of this ranking is through the rank positions of the alternatives (p_i) and that for alternative i, not only has the number of preferred alternatives been located but also which alternatives these are (those j such that $\gamma_{ij} = 1$).

The second step is to determine the maximum likelihood ranking. At this point it is interesting to clarify this concept in terms of the computational process. Suppose a group of four alternatives $\{A, B, C, D\}$ and the complete pre-order $ABCD$. The representation of this order with variables p_i is such that $p_A = 1$, $p_B = 2$, $p_C = 3$ and $p_D = 4$. The value of the score ϕ_{ABCD} computes the pair-wise values (matrix E) over the selected alternatives of the order, which implies the following:

$$\phi_{ABCD} = e_{AB} + e_{AC} + e_{AD} + e_{BC} + e_{BD} + e_{CD}. \tag{8}$$

Note that only the preference relations are computed. Only when A is ranked over B is the value e_{AB} computed and, consequently, if e_{AB} is included in the computation of ϕ, then e_{BA} is not included. This feature should be considered in the construction of the set constraints for the computation of the value of the score ϕ to determine the optimum ranking r^*.

To obtain the optimal ranking, a well-known quantitative technique is considered to solve the multicriteria decision-making problem: compromise programming. The main idea is to achieve the solution by minimizing the distance to a reference or ideal point. Since the weighting vector w is normalized in order to add up to the unity, and the attainable values are assigned in the pair-wise comparison, the ideal value for the e_{ij} values are equal to the unity. This value is obtained if alternative i were preferred to j with respect to a complete set of individual indicators.

The deviation variable d_{ij} is introduced to compute the maximum-likelihood ranking as the result of a minimization problem. Only the values corresponding to preference relations reflected by the ranking must be included in the computation of the objective function. Hence, the variable d must reflect this double role: to measure the difference of the values e_{ij} from their ideal (the unity) and to compute these values only if i is preferred to j in the ranking proposed as an optimal solution. That is, $d_{ij} = 1 - e_{ij}$ if i is preferred to j in the ranking and $d_{ij} = 0$ otherwise.

This target is achieved with the following set of equations (within the minimization context proposed).

$$e_{ij} + d_{ij} \geq 1 - \gamma_{ij}, \; i \neq j. \tag{9}$$

Suppose that alternative i is preferred to j or, equivalently, alternative i is ranked over j in the selected order. In that case, $\gamma_{ij} = 0$ and the deviation variable d_{ij} should measure the difference between the unity and the value e_{ij}. In that case, we have $e_{ij} + d_{ij} \geq 1$, equivalently $d_{ij} \geq 1 - e_{ij}$. Note that when the objective is the minimization of variable d, the equation turns into equality.

In the opposite case, if j is preferred to i, binary variable $\gamma_{ij} = 1$. Note that the value e_{ij} (or the corresponding d_{ij}) should not be included in the objective function. In this case, the corresponding constraint in (9) becomes redundant since we have $e_{ij} + d_{ij} \geq 0$ and all the values are non-negative. The minimization objective supposes that a null value will be assigned to d_{ij} in that case. This implies that only the deviation variables correspond to the adequate pairs, those ij such that i is preferred to j, are included in an objective function such that $\Sigma_{i \neq j} d_{ij}$.

In this case, the inclusion of binary variables implies the construction of a MILP model. The complete model to compute the optimum ranking is described as follows:

$$\begin{aligned} \min \; & \sum_{i \neq j} d_{ij} \\ s.\,t. \; & \gamma_{ij} + \gamma_{ji} = 1, && i \neq j \\ & \gamma_{ij} + \gamma_{jh} + \gamma_{hi} \geq 1, && i \neq j \neq h \\ & \gamma_{ij} + \gamma_{jh} + \gamma_{hi} \leq 2 && i \neq j \neq h \\ & e_{ij} + d_{ij} \geq 1 - \gamma_{ij} && i \neq j \\ & p_i = 1 + \sum_{i \neq j} \gamma_{ij} \end{aligned} \tag{10}$$

Model (10) permits the maximum-likelihood ranking to be determined by solving a MILP. Although this is not a trivial problem, software packages, such as GAMS, can obtain the solution for sets of up to 100 alternatives within a matter of seconds. For larger problems, metaheuristic procedures based on this formulation would be necessary for their solution.

3. A Comparative Analysis of Tourism Sustainability in Andalusian Urban Destinations: Results and Discussion

In this section, we present the results obtained when applying the proposed methodology to a study case: the municipalities of Andalusian urban tourism. This analysis is a new attempt at a comparative assessment of the situation of the Andalusian local destinations as regards their tourism sustainability performance. Andalusia is a region located in the south of Spain traditionally characterized by sun and beach tourism. However, the strategic plans designed in the last decades have enabled the diversification of the tourist model, clearly backing an expansion and consolidation of tourist activity in urban centers and, to a lesser extent, in rural zones. In this study, we compare the sustainability of the tourist activity of the urban destinations which have been fostered in the regional plans. Specifically, we consider as urban destinations those municipalities not located in coastal zones, which have at least three cultural interest goods and a population of > 20,000 inhabitants, *as well as provincial capitals. Starting from the set of 478 municipalities with a significant tourism demand according to the data from the Andalusian Statistical Institute*, *we have selected 36 urban municipalities using the above criteria.*

In order to evaluate the sustainability performance in each urban destination, we create a database which enables quantifying the 49 indicators which make up the initial system. To do so, we have fundamentally used the official statistical information provided by the Multiterritorial Information System of Andalusia. The information available in this source is not complete, given that part of the information is used internally by the Statistical Institute of Andalusia to safeguard statistical secrecy, especially in those municipalities with a smaller population. Therefore, in order to quantify the system, it was necessary to request local information under statistical secrecy to quantify indicators (especially those related to tourism demand, such as to the average stay, the number of travelers in accommodation, the tourist establishments open all year round, the staff employed, the overnight stays of the travelers…). In the rest of the cases, it was necessary to transform the statistical information mathematically to quantify the indicators (especially those constructed using ratios), using various sources in some cases. When the information provided has not allowed us to quantify the indicators, especially in the environmental matter, we have carried out field work which enables the quantification.

Having quantified the system and used the weightings extracted from the expert panel (see Tables 1, 2 and 3), the information gathered for the 36 urban destinations is used to build a sustainable tourism composite indicator employing the new computational approach. The ranking obtained according to the values of our non-compensatory sustainability index for each destination is presented in Fig. 2. In this map the destinations appear in the order obtained in the optimal ranking determined by the proposed methodology.

We can note that the county capitals are in the first positions of the ranking, the cases of Cádiz, Granada and Seville being highlighted. Likewise, we see that other municipalities with relevant tourist activity are in the first places, such as Jerez de la Frontera, Los Barrios and Ronda.

One of the main operational limitations of the methodology proposed (Munda and Nardo, 2009) is the disaggregated study of the planning obtained to explain the position attained by a specific unit and carry out practical proposals for the improvement of the situation of a territory within the ranking. The new computational approach proposed tries to resolve this situation as the analysis of the binary variables γ_{ij} enables the computing of how many alternatives are preferred to the alternative considered, but also the determining of which these alternatives are. With the use of these variables and accounting for the number of territories to which each destination considered shows a situation of preference, the position achieved in the final ranking can be explained and the strengths and weaknesses shown by each destination determined. This process of identification and disaggregation of the synthetic indicator remains independent of the unit of measure of the individual indicators.

The calculation of the number of territories for which each destination shows a situation of preference can be studied the values used to construct matrix *E*. These values permit an easy explanation of the situation attained in the optimal ranking as well as identifying those zones which have a better situation than the rest and that, therefore, could act as benchmarks within a benchmarking process between destinations. In this sense, the benchmark in a specific indicator will be that zone which shows a situation of preference with respect to all the other destinations considered, presenting the best value of the indicator in the sample. As we can note in Table 4, Cádiz is the benchmark on seven occasions with an average preference of 23.125. The high positions of the ranking are completed by those zones which manage to attain the benchmark position a greater number of times, having a preference number above the average.

Likewise, the number of times that each destination is preferred to the rest enables an easy identification of the strengths and weaknesses which the territory shows in relative terms, as we can observe in Fig. 3. Hence, in the case of Seville, broad strengths are noted in a great majority of the indicators considered in the system, having a preference number which far exceeds 20. The main weaknesses shown by this territory correspond to the indicators in which the destination surpasses a very low number of territories. Its main weaknesses are to be found in questions such as: the providing of restaurant services and tourist information, the perception of price-quality ratio and the destination's safety, the capacity of social burden and the pressure of the demand on heritage resources, and the management of solid urban waste.

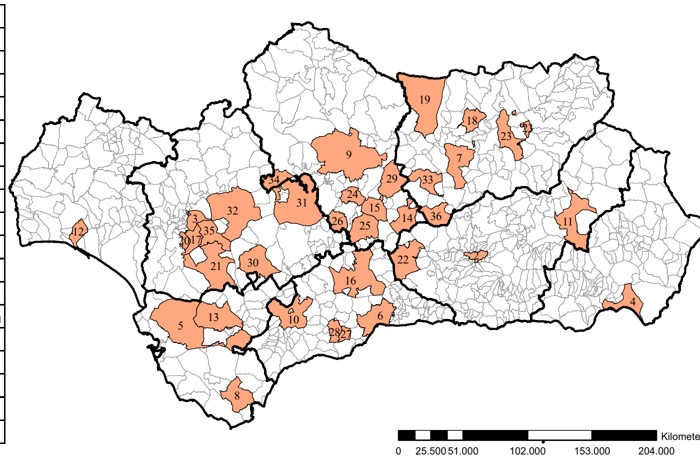
On the other hand, the possibility of solving the mixed-integer linear programming problem proposed to determine the maximum-likelihood ranking using software packages allows carrying out practical improvement proposals adapted to each destination. Specifically, an analysis of post-optimization can be carried out which enables the determining of the quantity in which must be modified the value of a specific indicator (remaining constant the rest) for the destination to improve its position in the ranking obtained. Thus, we can provide the destination with specific action strategies which have objective goals to achieve in order to solve the weaknesses it has shown. To do so, a model is developed in which the individual variation of the indicators selected is minimized subject to two conditions: the improvement of the position in the ranking and the maintaining or improving of the solution's level of plausibility. The minimum variation to carry out in the initial indicators to achieve improving the position in the ranking is thus determined.

By way of example, we carry out the analysis of Seville for various indicators. Table 5 summarizes the results obtained for it to pass from position 3 to 2, measured as a variation rate (that is, for positive indicators would happen I_{ik} $(1 + a_{ik})$, being a_{ik} the increase of indicator *k*). To achieve this objective, various alternative strategies are proposed in order for the managers of the destination to be the ones who choose the most feasible option to achieve rising one position in the ranking. It is interesting to note that for those indicators in which there exists a high number of draws, the variations which we would obtain would be infinitesimal, that established to discriminate the numerical values.

4. Conclusions

For decades tourism has been considered a fundamental economic sector for its direct and indirect effects in terms of generating

Rank	Destinations
1	Cádiz
2	Granada
3	Sevilla
4	Almería
5	Jerez de la Frontera
6	Málaga
7	Jaén
8	Barrios, Los
9	Córdoba
10	Ronda
11	Baza
12	Huelva
13	Arcos de la Frontera
14	Priego de Córdoba
15	Cabra
16	Antequera
17	Dos Hermanas
18	Linares



Rank	Destinations
19	Andújar
20	Coria del Río
21	Utrera
22	Loja
23	Úbeda
24	Montilla
25	Lucena
26	Puente Genil
27	Alhaurín el Grande
28	Coín
29	Baena
30	Morón de la Frontera
31	Écija
32	Carmona
33	Martos
34	Palma del Río
35	Alcalá de Guadaíra
36	Alcalá la Real

Fig. 2. Andalusian urban destinations: non-compensatory sustainability index ranking.

Table 4
Destinations identified as benchmarks: number of times and average preferences.
Source: Own elaboration.

Destination	Benchmark: times	Number of preferences: average
Cádiz	7	23.125
Granada	6	22.65957
Sevilla	6	21.17021
Huelva	5	20.80952
Almería	4	21.13043
Barrios, Los	4	18.20408
Ronda	4	18.408163
Morón de la Frontera	3	14.04255
Arcos de la Frontera	2	17.17391
Baena	2	14.70833
Baza	2	17.69388
Coín	2	14.44898
Dos Hermanas	2	16.95918
Linares	2	17.18367
Loja	2	15.48980
Alcalá la Real	1	12.39583
Alhaurín el Grande	1	14.84783
Andújar	1	16.58696
Coria del Río	1	14.15217
Jaén	1	19.08163
Málaga	1	20.91667
Palma del Río	1	14.52083
Puente Genil	1	13.77551

employment, the creation of firms to satisfy the new demands, the improvement of infrastructures, etc. Nevertheless, for this activity to be sustainable over time the planning of the sector must take into account fundamental aspects such as the carrying capacity of the environment in which it is developed and the quality of life of the residents, at the same time as improving the competitiveness of the tourist destinations.

To achieve this, it is essential for the policy makers to have tools which allow graduating the situation of the tourist destinations according to their sustainability, from a social, economic and environmental point of view. In the last years one of the tools most used to evaluate the progress toward tourist sustainability has been composite indicators. These enable the simple evaluation of a multidimensional phenomenon, setting out from the information provided by a system of sustainable tourism indicators.

Although an internationally accepted methodology does not exist, the methods based on the use of multicriteria decision-making techniques are considered the most appropriate. Among these, compensatory methods present a problem when they are used on a system of quantitative indicators, as the strengths in some indicators can offset the weaknesses in others and therefore the value of the composite indicator does not reflect the reality.

To avoid this, non-compensatory multicriteria aggregation procedures are used. In this paper we start from the procedure developed by Munda and Nardo (2009). We have defined a new computational approach to the non-compensatory composite indicator problem, based on the construction of a mixed-integer linear programming model. The main advantage of the composite indicator proposed is that it allows obtaining a complete pre-order of alternatives.

The main limitation of the proposed procedure computational cost required for determining the ranking. Even if the solution is obtained from an MILP, in those applications with a large number of units the computation of the optimal solution could require a metaheuristic procedure. The comparisons between units is carried out in a strict sense. That is, for each indicator, a minimum difference supposes assigning all the value to the winner in the construction of the outranking matrix. In this sense, alternative criteria to compare can be considered, including, for instance, a greater difference for considering that the observed value is better (considering that both units are tied if the differences between them are lower).

Likewise, to compute the final ranking as the optimal solution of an MILP permits investigating strategies or improvement for each unit to achieve a better position. That is, analyzing the binary variables used permits an easy disaggregation of the value of the non-compensatory composite indicator to explain the position attained by each destination in the ranking, an identification of the benchmarks and a formulating of action strategies and drawing up of objective goals.

To illustrate the use of this new computational approach to build the composite indicator, we have analyzed the tourism sustainability of the urban tourist destinations of Andalusia (Spain), establishing a ranking of them. Previously, for the selection of the baseline aspects and indicators included in the system, as well as the weighting system, in addition to reviewing the literature on the subject, we had the collaboration of a panel of experts in areas related to the tourism sector.

We consider that the methodology proposed in this paper can be applied to analyze other tourist segments, as well as tourist destinations on another spatial scale, to be able to compare the sustainability of tourist destinations located in different regions or countries. Furthermore, future lines also include the consideration of uncertainty in the procedure. We can consider that the preferences of the experts are not elicited partially, in this case we can regard models inspired in the benefit of the doubt principle. Also, uncertainty about the values of the individual indicators can be contemplated. In this case, the solution will require the use of interval evaluations or fuzzy concepts.

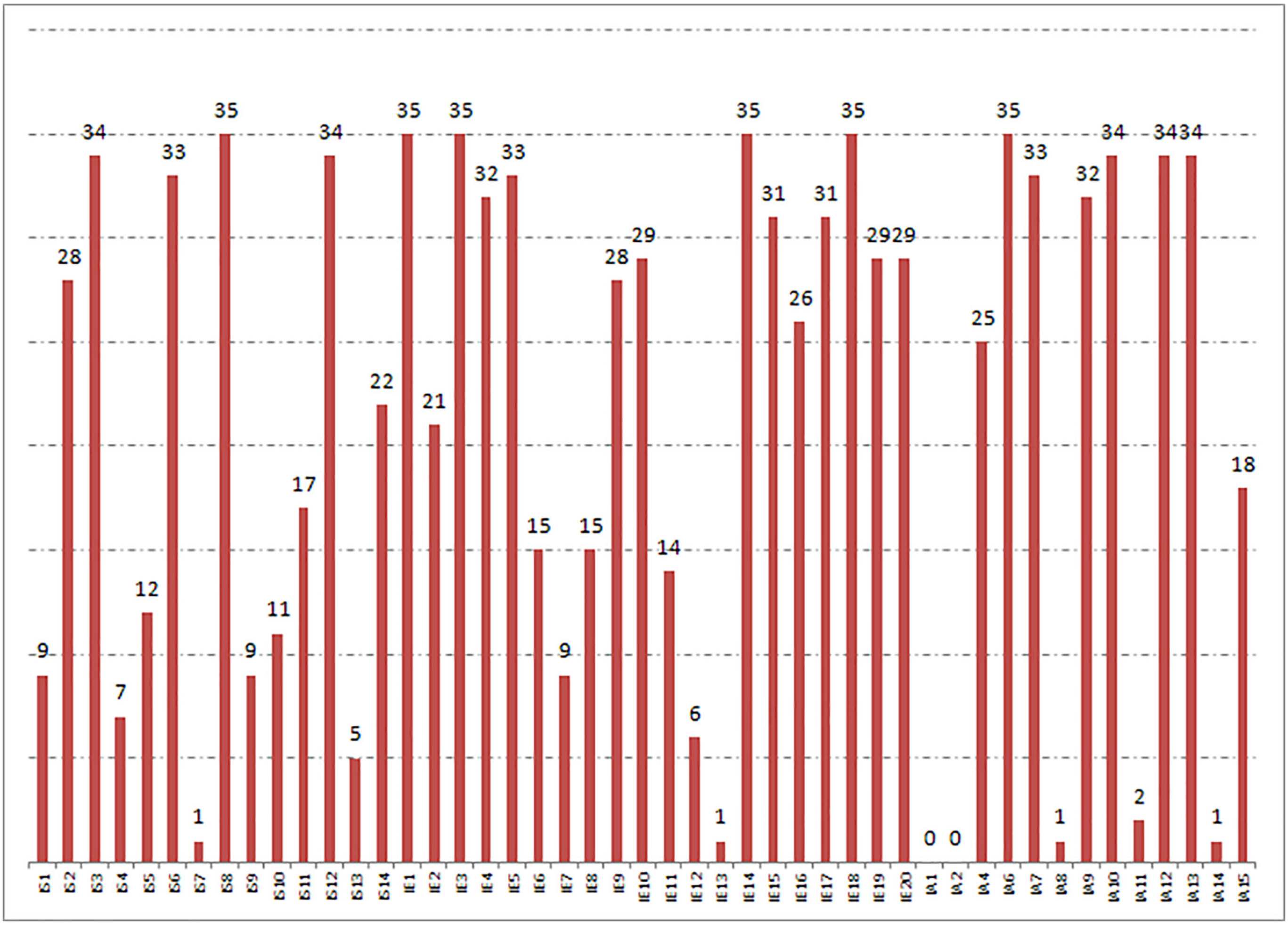


Fig. 3. Strengths and weaknesses for destination of Seville: number of preferences.

Table 5
Variations necessary to improve the position of Seville.
Source: Own elaboration.

Indicators selected	Variation necessary	Objective value (goals)
I_{S5}	0.420	−0.336
(I_{S7}, I_{S10}, I_{S13})	(0, 0, 0.073)	(−42.829, −2.832, −73.293)
(I_{S7}, I_{S8}, I_{S10}, I_{S14})	(0, 0, 0.209, 0,034)	(−42.829, 5, −2.240, −27.605)
(I_{S1}, I_{S2}, I_{S3}, I_{S5}, I_{S7}, I_{S9})	(0, 0.099, 0, 0.033, 0, 0)	(0.052, 1.599, 0.072,-0.560,-42.829, −5.132)

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