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# Weighting social preferences in participatory multi-criteria evaluations: a case study on sustainable natural resource management.

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*The use of multi-criteria evaluation tools in combination with participatory approaches provides a promising framework for integrating multiple interests and perspectives in the effort to provide sustainability. However, the inclusion of diverse viewpoints requires the "compression" of complex issues, a process that is controversial. Ensuring the quality of the compression process is a major challenge, especially with regards to retaining the essential elements of the various perspectives. In this article, we suggest a process in which the explicit elicitation of weights (i.e., the prioritisation of criteria) within a participatory multi-criteria evaluation serves as a quality assurance mechanism to check the robustness of sustainability integrated assessment processes from a social perspective. We demonstrate this approach using a case study focused on the sustainable management of the Urdaibai Estuary in the Basque Country (Southern Europe). Drawing on the large body of literature on sophisticated mathematical models that help identify and prioritise criteria, this approach allows (1) an explicit "social sensitivity" analysis despite the incommensurability of values regarding individual or group priorities, and (2) participants to learn from and reflect upon diverse social preferences without forcing their consensus.*

Keywords: complex systems, social preferences, participatory multi-criteria evaluation, incommensurability of values, weights.

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# 1. Introduction

The demand for deliberative approaches to decision-making with respect to sustainability related issues has grown in recent years. Complex, evolving socio-ecological systems affect decision-making because of the associated high degrees of uncertainty, incommensurability of values, and non-equivalent descriptions of the same system (Funtowicz and Ravetz, 1990; Kasemir et al., 2003; Gimarães-Pereira et al., 2006). Traditional scientific approaches and the hegemony of science,which search for unique and objective truths have been questioned (Wynne, 1992; Harremoës et al., 2001). These are not sufficient for the social resolution of sustainability issues (Giampietro et al., 2006). Consequently, new decision support methods have emerged to engage the public in decision-making processes (Santos et al., 2006; Stagl, 2007; Antunes et al., 2009; Videira et al., 2009). These include the increased use of participatory and deliberative approaches in multi-criteria evaluation processes related to sustainability and natural resource management (Munda, 2004; Proctor, 2004; Gamboa, 2006; Stagl, 2006;; Gamboa and Munda, 2007; Hermans et al., 2007; Roca et al., 2008; Hajkowicz, 2008; Kowalski et al., 2009; Liu et al., 2010; Monterroso et al., 2010). Increased participation and/or deliberation allows complex issues to be structured systematically to consider the multidimensional, incommensurable, and uncertain effects of decisions (Banville et al., 1998; Munda, 2004; Stirling, 2006; Proctor and Drechsler, 2006; Munda, 2008). However, the inclusion of social preferences in these processes is still controversial.

Numerous transformations (and in some cases simplifications) are required to convert social preferences into (technical) problem structuring (i.e., the construction of alternatives and definition/evaluation of criteria) and the quality of the transformation process is critical to assure high quality outcomes and sound policy advice (Giampietro et al., 2006). Quality assurance, understood in this context to be a reflexive mechanism for ensuring that the relevant properties of a given system have been incorporated adequately in the assessment, should be based, at a minimum, on scientific, political, and practical criteria (MEA, 2005; Giampietro, 2010). This requires validating the robustness of the analysis from a technical perspective, including non-equivalent descriptions of the same system and the application of sensitivity analyses (Saltelli et al., 2000). At the same time, and more interestingly in the context of this paper, quality check mechanisms should allow for the validation of results from a social perspective, taking into account the diversity of social preferences.

The aim of this study was to explore the issue of criteria weighting from a new perspective, drawing on the extensive body of literature focused on sophisticated toolkits and mathematical algorithms for the elicitation of weights. In this paper, we briefly address the critical “compression” phases of participatory multi-criteria evaluation (MCE) processes and, using a case study as illustration, provide an approach to criteria weighting that enhances the social sensitivity aspects of group decision making, while facilitating critical reflection upon social preferences without forcing consensus.

# 2. Reducing complexity and determining weights in MCE

Public decision-making for sustainability must deal with multiple legitimate but often contrasting priorities. MCE was developed to aid this type of decision-making. Initially, multi-criteria decision making was used to elicit clear preferences from a (theoretical) decision maker and then to solve a well-structured problem by means of a mathematical algorithm. Progressively, ideas about *procedural rationality* (Simon, 1976) and the *constructive* or *creative approach* (Roy, 1985) led to the development of multi-criteria decision aid (MCDA), in which the quality of the decision-making process became central. Investigators began to emphasise the need to include public participation in MCE (Banville et al., 1998; de Marchi et al., 2000), thus fostering the emergence of participatory multi-criteria evaluation (PMCE) and social multi-criteria evaluation (SMCE), in which context appropriate deliberation is a prerequisite to assure a quality outcome.

In operational terms, the application of a participatory or social MCE usually entails the following steps:

1. Identification/classification of relevant social actors
2. Definition of problem
3. Creation of alternatives (policy options) and the definition of evaluation criteria
4. Valuation of criteria in a multi-criteria impact matrix
5. Assessment of social actors' preferences and values: preference and indifference thresholds, and prioritisation of criteria (i.e., weights)
6. Selection of the MCE method and application of the model through a mathematical aggregation procedure
7. Social analysis and validation of results, including a sensitivity analysis to check the robustness of the analysis

## 2.1. Reducing complexity in multi-criteria evaluations

Key compression processes allow the information about a complex reality to be simplified for use in a multi-criteria structure. First, a virtually infinite information space is reduced to a limited set of goals, narratives, attributes, and representations of social actors that describe the "problem." Next, based on the multi-criteria structure, further compression is accomplished through the selection of criteria, the analysis of possible scenarios, and the selection of the alternative (i.e., policy) to be implemented. The validity of the (multi-criteria) representation depends on how well the virtually infinite information about the external world is compressed into a finite representation specific to the task at hand (Giampietro, 2010). Because of its normative nature, this process cannot be addressed from a purely technical perspective; participation and collaboration among all relevant social actors is needed. Complex decisions must be made about who participates in defining and structuring the problem, the choice of the aggregation procedure, and the corresponding parameters for the MCE (i.e., preferences and indifference thresholds, weights, operators, degree of compensation).

## 2.2. Use of weights in public policy decisions related to sustainability

The definition of weights in PMCE is a means of reflecting on social preferences/priorities in the assessment. Allowing social actors to express their priorities explicitly can also help identify areas of conflict critical to analysing plausible compromise solutions. The elicitation of weights can greatly influence the results of the MCE (Strager and Rosenberg, 2006; Triantaphyllou and Sanchez, 1997) and has been the focus of many studies (Stillwell et al., 1987; Roy and Mousseau, 1996; Vansnick, 1986, Choo et al., 1999; Hämaläneinen and Salo, 1997; Al-Kloub et al., 1997; Tzeng et al., 1998; Hajkowicz et al., 2000; Jacobi and Hobbs, 2007; Hämaläneinen and Alaja, 2008; Ananda and Herath, 2009). Nevertheless, how to define weights in the context of public policy for sustainability, where numerous social-actors with confronted interests interact and negotiate, is not an easy task.

### *2.2.1. Compensation among criteria*

Broadly speaking, we can distinguish two types of weights: importance coefficients and trade-offs. The main difference between them is the use of compensation among criteria — the possibility that the good performance of some criteria can offset the bad performances of others. Weights must be derived in a manner that is coherent with the multi-criteria model used (Choo et al., 1999); for sustainability issues, non-compensatory multi-criteria methods are the most suitable for ensuring that all dimensions considered important by one or more stakeholder groups are included in the process (Janssen and Munda, 1999; Munda, 2005). Outranking multi-criteria methods (e.g., ELECTRE, REGIME, PROMETHEE or NAIADE) are partially or non-compensatory, which makes them more suitable to assess sustainability from the 'strong' perspective (Garmendia et al., 2010b).

### *2.2.2. Determination of weights in a social setting*

Another critical question regarding the use of weights in sustainability decision-making regards their use in a social context. When an analysis involves only one decision-maker, the incorporation of preferences by means of weights into the MCE model is straightforward, although the method used and the way it is applied can yield different results (Schoemaker and Waid, 1982; Borcherding et al., 1991; Weber and Borcherding, 1993; Pöyhönen and Hämäläinen, 2001). However, in the public policy domain decision processes often include many social actors, and thus the elicitation of social preferences becomes more complex. Several approaches for defining weights in a social setting have been described in the literature; these are summarized in the following paragraphs.

The first group of approaches is extensively used in mainstream economics and borrows from decision theory and risk assessment work. Based on the principle that social preferences can be obtained by aggregating individual preferences, these approaches typically assume that preferences are fixed and independent of social conditions. Studies that fall within this category obtain social weights as the average of the individual weights. This perspective usually assumes that the satisfaction of individual preferences is good for both the individual and the society (Zografos and Howarth, 2008).

A criticism of this approach is that important trade-off information related to extreme priorities can be lost when several prioritisations are reduced to a single vector (by using a modal or even a median value). Moreover, "such a technocratic enforcement of consensus might increase the disagreement of those participants whose values are very different from the calculated average value and may not wish to participate in the process any more" (Proctor and Drechsler, 2006: 175).

A second group of approaches aimed at defining weights in a group setting is prone to the ideas of deliberative and discursive democracy (Habermas, 1996; Dryzek, 2000). According to this perspective, social groups and individuals involved in a decision should engage in a deliberative process wherein individuals can reframe their personal beliefs, value judgements, and underlying assumptions through the exchange of information, rational reflection, and social learning (Howarth and Wilson, 2006). This approach acknowledges that preferences are socially constructed and can evolve over time (Slovic, 1995; O´Hara, 1996; Norton et al., 1998). Studies that fall in this group usually obtain individual weights following some type of deliberative process and then aggregate them by means of a modal or mean value (Wei et al., 2000; Proctor and Drechsler; 2006; Hajkowicz and Collins, 2009); they also try to reach a consensus on the set of weights through a group discussion.

Deliberative approaches address some of the criticisms of the 'standard' aggregate/averaging approaches in that they allow that preferences can be changed and formed through deliberation.

However, forcing consensus and searching for a unique prioritisation scheme can erode the legitimacy and effectiveness of participation as a learning process to solve complex issues (van den Hove, 2006). Irreducible value conflict cannot be ignored or oversimplified; value disparities and conflicts must be recognised and managed.

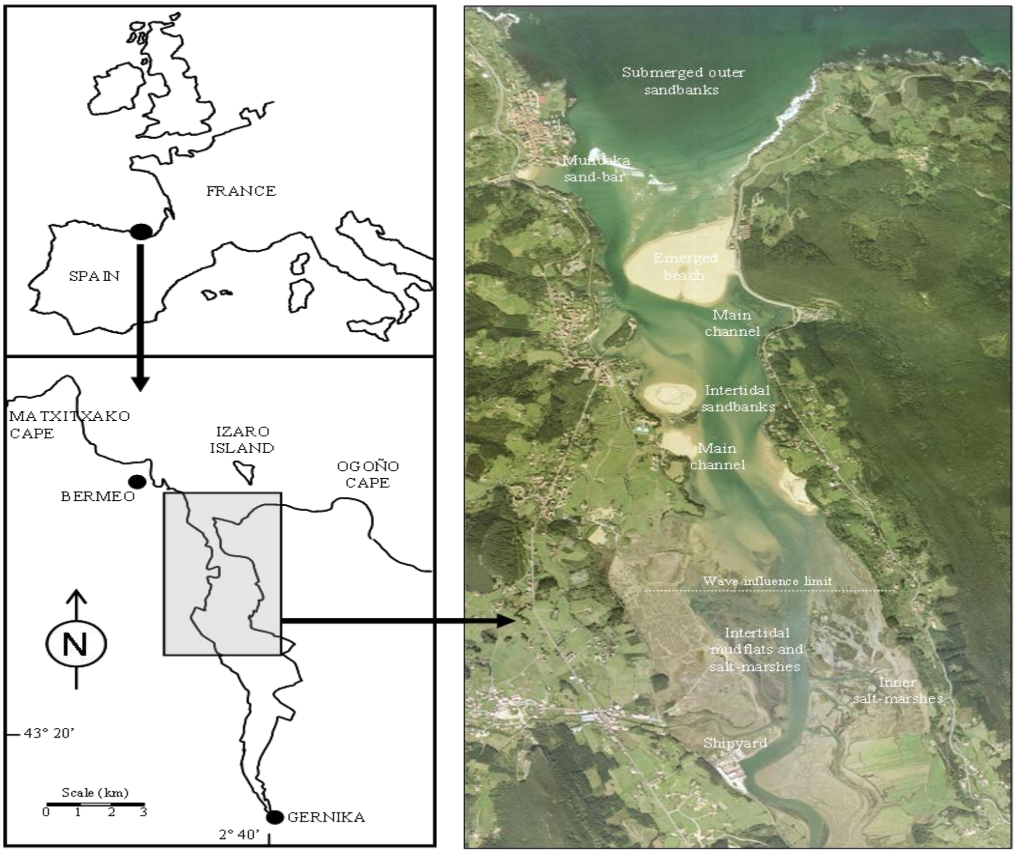
Finally in the context of social multi-criteria evaluation, Munda (2004, 2008) has argued against the elicitation of weights. His view is that criterion weights in the evaluation of public policies for sustainability should be derived only from a plurality of ethical principles (e.g., economic prosperity, ecological stability, or social equity).

In Section 3, we use a case study to present an alternative approach for the weighting of diverse viewpoints and criteria in participatory approaches. Drawing on the rationality of the deliberative approaches presented above, this approach centers on a quality assurance mechanism that serves to validate — or, if necessary, redefine — the inclusion of social preferences and expand the social learning process, without forcing consensus.

## 3. Case study

Our case study focuses on the sustainable management of the Urdaibai Estuary, located in the Basque Country of Southern Europe (Fig. 1). This small area embodies many of the challenges decision-makers are faced with when dealing with complex socio-ecological systems. The estuary is the heart of the Urdaibai Biosphere Reserve and has been subject to the human activities that modify it since prehistoric times. At present, a variety of interests (tourism, agriculture, fishing, industry, recreation and conservation) coexist in the area.

Fig. 1. Location of Urdaibai Estuary and the main habitats in the estuary




The Urdaibai Estuary is recognised for its natural and cultural value. In 1984, it was accepted as part of the World Network of Biosphere Reserves by UNESCO (Man and Biosphere Programme) and in 1989, the Basque Country Parliament adopted the Urdaibai Biosphere Reserve Protection and Planning Act (Law 5/1989). Later, in 1992 the estuary was included on the Ramsar Convention's List of Wetlands of International Importance; in 1994 it joined the network of Special Protection Areas (SPAs) for Birds; and finally, in 2006, the Urdaibai littoral zones and marshes were declared a Site of Community Importance (Natura 2000 Network).

Despite all these regulations, coexistence of the various interest groups in the area is not always easy, and many conflicts have risen in recent decades. In 2007 a diverse group of researchers (including a marine scientist, biologist, sociologist, economist, engineers, lawyers, and an ecologist) together with local, regional, and national social actors concerned with the current situation of the area started a collaborative research process. The aim was to evaluate different sustainable management options for the estuary from an integrated (with regard to different fields of knowledge) and inclusive (by considering all the involved actors) perspective. A participatory MCE was carried out from 2007 to 2008 (Garmendia et al., 2010a). The process used to elicit social preferences, with an emphasis on the prioritisation of criteria, is described in detail in Section 3.1, below.

## 3.1. Inclusion of social preferences in the participatory multi-criteria evaluation

To assure the inclusion of diverse social preferences in the evaluation process, the following activities were conducted:

- Over 30 in-depth, personal interviews during the identification phase and subsequent consultations with external experts and authorities (Jan-May, 2007)
- A preliminary open meeting to set the scope and methodological framework of the evaluation process (5 July 2007): 20–25 participants
- A participatory workshop to define criteria (11 July 2007): 25–30 participants
- A participatory workshop to establish weights and define different management options (alternatives) (13 December 2007) 25–30 participants
- Two final workshops to validate results (13 December 2007 and 3 July 2008): 40 participants

### *3.1.1. Social actors*

To identify relevant social actors, the so called snow-ball technique was adopted, beginning with a few key informants. To ensure a broad scope, the diversity of the group was assessed according to three attributes: power, legitimacy, and urgency (Mitchell et al., 1997). These classifications provided useful information for understanding the dynamics of the social conflict and deciding on the social group composition of the workshops (e.g., to avoid an excessive number of dominant actors in the same discussion group or to ensure a balance among actors with highest influence on a decision and those most affected by it). Table 1 summarises the list of the involved social actors, their profile and the interest they represent.

Table 1. Stakeholders and their profiles

| Actor | Type | Scale | Summary of Position |
|---|---|---|---|
| Spanish Environmental Ministry (Head Coastal zones) | Dominant | National | Will finance restoration of estuary and other coastal zones. Against dredging activities. |
| Basque Environmental Ministry | Definitive | National | Want environmental criteria to prevail. |
| Director of Harbours and Maritime Affairs | Dominant | National | Consider that management of the estuary is not their business but believe continued operation of the shipyard in the estuary will be difficult. |
| Head of the Biosphere reserve | Definitive | Regional | Want to recover degraded habitats. Against dredging; want more restrictive measures to protect the estuary. |
| Fishers | Dependent | Local, | Against any human intervention that may alter the ecosystems (whether dredging or dune recovery). |
| Environmental guides | Dependent | Regional, international | Concerned about continuous deterioration of the estuary; against dredging. Want ecology of area improved. |
| Surfers | Definitive | Local | Threatened by dredging and suspicious of conservation measures that might alter the dynamics of the estuary. |
| Labour union | Dependent | Local, regional | Want to conciliate industrial activity with the environment. Priority is to keep local jobs. |
| Bird watchers | Dependent | Local, regional, international | Concerned with the decline in bird due to fishing, or uncontrolled navigation. Against dredging; want more restrictive measured to protect the area. |
| Recreational Boaters | Demanding | Local | Support human intervention that would recover the old shape and depth of the channel. Oppose dune recovery program. |
| Shipyard workers | Definitive | Local, regional, international | Claim the right to continue their activities and financial support to keep the channel depth. Would leave the estuary if compensated. |
| Ekologia Tailerra (volunteers) | Dependent | Regional | Want stricter law enforcement and socio-economic activities compatible with conservation. Want integrated plan for the area. |
| Zain Dezagun Udaibai (NGO) | Dependent | Local | Support natural value of area to foster local development avoiding major tourism. Habitat recovery is a priority. |
| Duna recovery group | Discretionary | Regional | Want to limit human activity to within ecological constraints (e.g., dredging should not undermine the natural evolution of the dunes). Want more research to monitor the evolution of the estuary. |
| Murueta Council | Demanding | Local | In favour of keeping shipyard and promoting agropecuary activities in the estuary. Claim economic compensation for those whose lands were converted to public use. |
| Sukarrieta Council | Discretionary | Local | Want sand for their beaches and to build a harbour in the estuary for recreational boats. In favour of dredging the channel for recreational purposes. |
| Mundaka Council. | Dependent | Local | Against major dredging that might affect shell-fishing and surfing. Want to conserve environment as a tourism attractor. |
| Busturia Council | Discretionary | Local | In favour of promoting local development and employment compatible with conservation. Against massive dredging. Involved in habitat recovery plans |
| Arteaga Council | Discretionary | Local | Against massive dredging; are developing conservation initiatives. Want more autonomy for local authorities. |

### *3.1.2. Criteria*

A diversity of perspectives coexists in the Basque society, many of which were represented in the participatory workshops. As expected, meetings were characterised by intense debates among the counterparts. Taking into account the contrasting views regarding the principles that should guide the future management of the estuary, the research team defined the set of criteria shown in Table 2 and validated these with the main social actors and external experts.

Table 2. Evaluation criteria

| Criteria | Needs and expectations |
|---|---|
| Employment | - Enhance local employment and avoid displacing residents<br>- Support local economic activities<br>- Improve the quality of life<br>- Guarantee job stability<br>- Coherence with local reality |
| Local incomes | - Increase municipality's income<br>- Avoid becoming a "bedroom community"<br>- Promote local business<br>- Support equitable development among municipalities |
| Compatibility between socio-ecological activities | - Avoid severe impacts to activities<br>- Minimize impact on fishing, surfing , industry, conservation, tourism, navigation<br>- Foster a balance between development, education, and conservation |
| Cost of implementation | - Maintain industrial competitiveness and warranty, economic viability<br>- Consider administrative budget constraints<br>- Take opportunity costs into account |
| Environmental disturbance | - Keep noise pollution to a minimum<br>- Avoid massive affluence and foster quality tourism<br>- Limit navigation<br>- Enhance non invasive cultural and economic activities<br>- Conserve the environmental quality of the area |
| Impact on habitat and fauna | - Reduce impact over ecosystems: marshes, reed beds, sandbanks, etc.<br>- Avoid impact on fauna: birds, shellfish, etc.<br>- Diminish the impact of toxic sediments.<br>- Avoid invasive species proliferation |
| Reversibility | - Maintain the potential of the area for the future<br>- Respect the dynamics of the river<br>- Encourage a long-term orientation for reaching an equilibrium |
| Uncertainty | - Reduce uncertainty of management options<br>- Acknowledge the uncertain and complex response of the system<br>- Adopt a precautionary approach |

### *3.1.3. Alternatives*

Following Massam's suggestion (1988), a set of alternatives was defined to include (a) the *status quo* or business as usual scenario, (b) an ideal best plan, (c) a hypothetical worst plan, and (d) a compromise solution or minimum satisfaction. These alternatives covered a wide range of options, enabling all social actors to identify with at least with one option. The external experts provide preliminary feedback and after calculating the criterion scores for all alternatives, those that resulted dominated were omitted. The remaining alternatives are summarised in Table 3.

Table 3. Summary of alternatives/ management options

| ALTERNATIVES | SUB-ALTERNATIVES |
|---|---|
| **A1 Do nothing:** leave the system on its own without any type of intervention. No active conservation measures, no dredging activities, no compensation measures. | |
| **A2 Compensation:** do not allow dredging and compensate the affected parties (mainly shipyard workers) for the constraints on their activities. | |
| **A3 Conservation:** do not allow dredging and direct all the public resources into conservation measures for the estuary. Eradication of invasive species, recovery plans for damaged areas, creation of guard and maintenance services in the estuary and removing the illegal boats… | |
| **B Satisfy demands from industry (shipyard)** with a maximum dredging along the channel (200,000-300,000 $m^3$) and disposal of dredged material in… | **B2**… inter tidal zone |
| | **B4** … submerged area |
| **C Compromise**: minimum dredging according to the "systems limit" (20,000-30,000 $m^3$ to guarantee navigability for small boats) and conservation measures.[a] Disposal of dredged material in… | **C2**… inter tidal zone |
| | **C4**…submerged area |

[a] In this case the conservation measures will be less than in scenario A3 considering that part of the public budget would be assigned for a minimum dredging.

### *3.1.4. Prioritisation of criteria*

The fourth step in the evaluation process involved the prioritisation of criteria. The fact that a group of diverse social actors can agree on a set of criteria do not mean that they attach the same relevance to each of them. When deciding about our surrounding socio-ecological system there is a need of some form of deliberative institutions within which the relevance of different reasons can be considered (Holland et al., 1996).

#### 3.1.4.1 Individual weighting

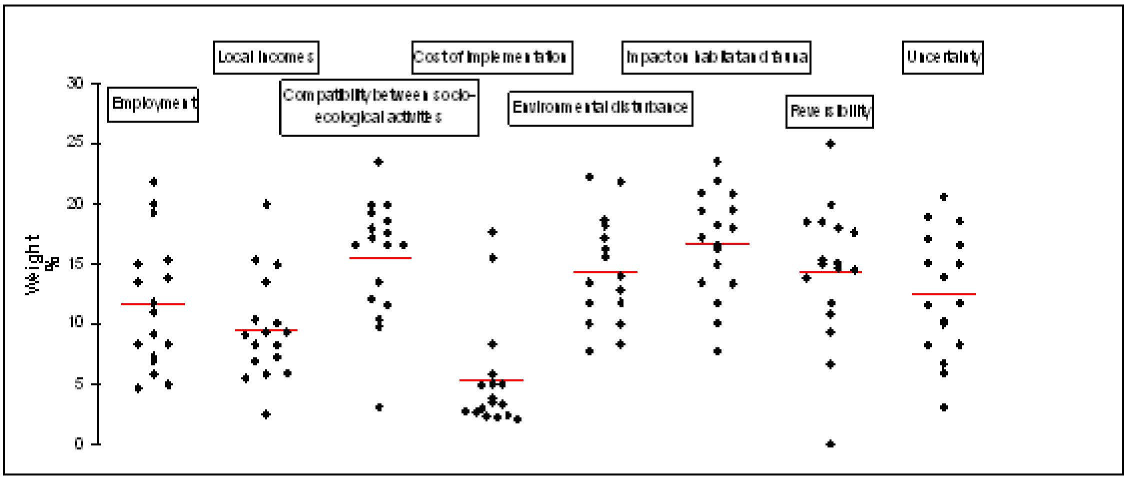
At the individual level, the social actors were first requested to rank criteria with regard to their own interest. This was done using Simos' revised method, which provides individual quantitative and ordinal weights (Maystre et al., 1994; Figueira and Roy, 2002). The result of this prioritisation exercise is illustrated in Table 4, which shows the different priorities assigned to the various criteria by the social actors. The weights obtained by this method should be applied as importance coefficients.

Table 4: Ranking of criteria according to social actors' weights

| Social Actor | Compatibility | Reversibility | Cost | Env. disturbance | Employment | Habitat | Local income | Uncertainty | SCALE |
|---|---|---|---|---|---|---|---|---|---|
| Spanish Env. Ministry | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | x 3 |
| Basque Env. Ministry | 6 | 4 | 10 | 2 | 7 | 1 | 7 | 3 | x 10 |
| Head Marine Affairs | 1 | 1 | 4 | 3 | 4 | 2 | 3 | 2 | x 3 |
| Fishers | 1 | 1 | 6 | 3 | 2 | 1 | 7 | 4 | x 4 |
| Env. Guides | 6 | 4 | 9 | 1 | 7 | 2 | 7 | 3 | x 10 |
| Surfers | 1 | 1 | 8 | 3 | 7 | 2 | 6 | 1 | x 3 |
| Labor Union | 7 | 5 | 3 | 3 | 1 | 1 | 5 | 6 | x 4 |
| Bird Watchers | 5 | 2 | 9 | 3 | 7 | 1 | 6 | 4 | x 5 |
| Busturia Council | 3 | 4 | 8 | 1 | 5 | 2 | 7 | 6 | x 5 |
| Arteaga Council | 1 | 3 | 4 | 3 | 4 | 1 | 4 | 3 | x 2 |
| Shipyard workers | 2 | 5 | 6 | 3 | 1 | 3 | 1 | 5 | x 3 |
| Env. Volunteers | 2 | 2 | 6 | 2 | 3 | 2 | 4 | 1 | x 10 |
| Dune Recovery | 3 | 4 | 7 | 3 | 3 | 3 | 3 | 1 | x 3 |
| Zain Dezagun (NGO) | 3 | 2 | 6 | 1 | 4 | 1 | 4 | 2 | x 4 |
| Murueta Council | 1 | 2 | 4 | 3 | 2 | 3 | 2 | 3 | x 2 |
| Mundaka Council | 1 | 2 | 5 | 4 | 1 | 4 | 2 | 3 | x 2 |
| Recreational Boats | 2 | 1 | 3 | 3 | 3 | 2 | 3 | 3 | x 3 |

The dispersion of individual weights is illustrated in Fig. 2, with each point representing the weight given to a criterion by one social actor.

Fig. 2. Diagram of dispersion of individual weights




Descriptive statistics of the weights attached to each criterion are provided in Table 5. The standard deviation shown in this table reflects the degree of conflict regarding the prioritisation of a given criterion. The greatest differences in opinion regarding weighting were associated with the employment and reversibility criteria.

Table 5: Descriptive statistic according to individual weight with 95% coefficient interval.

| Criterion | Mean | Standard Deviation | Min | Max |
|---|---|---|---|---|
| Employment | 11,6 | 5,2 | 4,7 | 21,9 |
| Local Income | 9,6 | 4,2 | 2,6 | 20,0 |
| Compatibility | 15,6 | 4,8 | 3,1 | 23,5 |
| Cost | 5,3 | 4,4 | 2,1 | 17,6 |
| Environmental Disturbance | 14,3 | 4,2 | 7,7 | 22,2 |
| Impact on Habit and Fauna | 16,7 | 4,2 | 7,7 | 23,5 |
| Reversibility | 14,4 | 5,5 | 0 | 25 |
| Uncertainty | 12,5 | 4,9 | 3,1 | 5,1 |

### 3.1.4.2 Social or group weighting

To determine group priorities, an ad hoc approach based on a deliberative process was developed with the support of a cluster analysis. The quantitative criteria weights of each social actor were grouped by means of a hierarchical clustering approach. First, each observation (in this case, each social-actor) is considered as an individual cluster, and then close pairs of clusters are merged using Ward's method for the clustering and the squared Euclidean distance (the sum of the squared differences in values for each variable) to measure the interval between observations. The dendrogram in Fig. 3 shows the sequence by which the observations and clusters were merged.

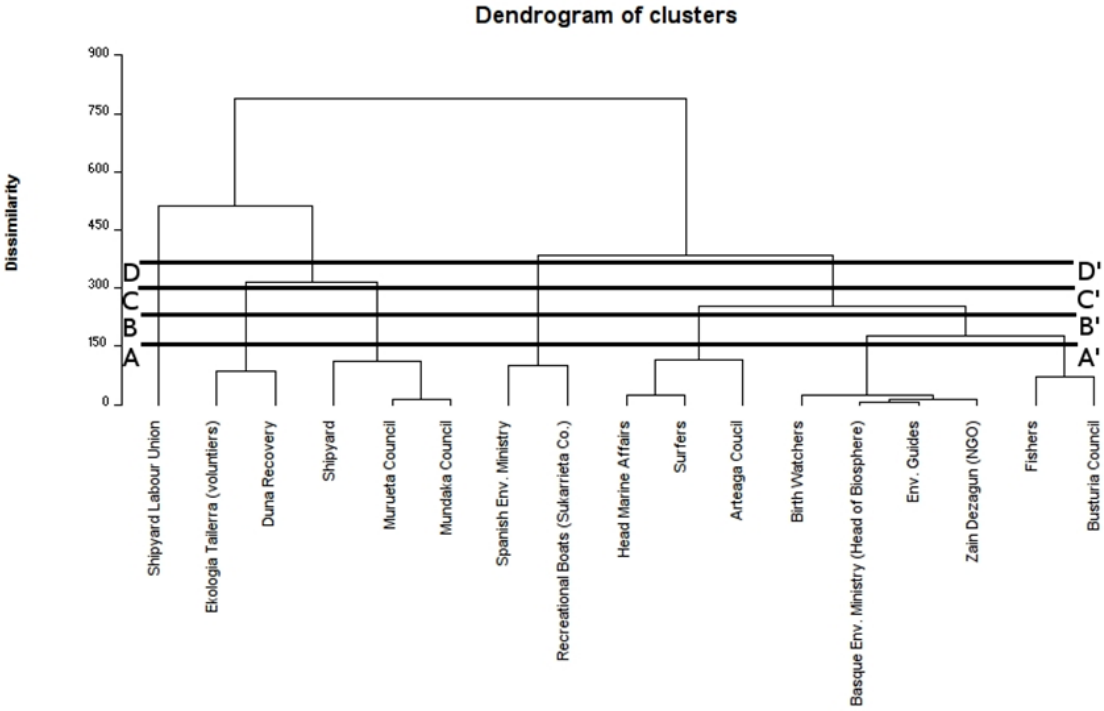



Fig. 3. Dendogram of clusters according to group weights. The cutting lines A–A' and B–B' yielded more groups that were operating in reality. For instance, the Head of Maritime Affairs and the Basque Environmental Ministry would fall in different groups according to this clustering, while they actually expressed similar priorities during the evaluation process. On the other hand, the cutting line D–D' yields too few clusters and combines some of the group social actors who actually had quite different views, e.g., volunteers of an environmental NGO and representatives of the shipyard.

Social-actors were first grouped according to the similarities of their priorities. Next, the relevant numbers of clusters for the analysis were determined. Several statistical tests and methods can be used to determine the "optimal" or adequate number of clusters. However, the grouping should be checked to make sure they are conceptually valid and not imposed by the classification method (Aldenderfer and Blashfield, 1984, quoted in Köbrich et al., 2003). The most meaningful way of testing the conceptual validity of the classifications is determining if they serve the purpose of the analysis (Köbrich et al., 2003).

Therefore, the decision about the number of relevant clusters for the analysis should be based on the researcher's experience and the knowledge acquired through empirical observations (e.g., in interviews and workshops in which it is possible to contrast the perception of "credible groups" with the results of the cluster analysis, and through subsequent feedback with a reduced group of relevant social-actors). For this case study, after we discussed the potential similarities and discrepancies of the individual priorities, we clustered the individual weights into five groups; these are represented by the "cutting line" C–C' in Fig. 3.

Table 6 provides descriptive statistics regarding the weights of each criteria derived by cluster groups.

Table 6. Descriptive statistic according to group weights with 95% coefficient interval.

| **Criteria** | | **Weights** | | | | |
|---|---|---|---|---|---|---|
| | | ***Group 1*** | ***Group 2*** | ***Group3*** | ***Group 4*** | ***Group 5*** |
| Employment | Max | | 13,8 | 20,0 | 11,8 | 15,4 |
| | Mean ± S.D. | 21,9 ± 0 | 13,7 ± 0,1 | 18,1 ± 2,2 | 10,0 ± 1,7 | 8,2 ± 3,2 |
| | Min | | 13,5 | 15,0 | 8,3 | 4,7 |
| Local incomes | Max | | 13,5 | 20,0 | 8,3 | 10,0 |
| | Mean ± S.D. | 9,4 ± 0 | 11,9 ± 1,6 | 16,8 ± 2,3 | 7,1 ± 1,2 | 7,2 ± 2,2 |
| | Min | | 10,3 | 15,0 | 5,9 | 2,6 |
| Compatibility between socio-ecological activities | Max | | 17,2 | 20,0 | 17,6 | 23,5 |
| | Mean ± S.D. | 3,1 ± 0 | 15,4 ± 1,9 | 18,6 ± 1,4 | 17,2 ± 0,5 | 15,6 ± 4,6 |
| | Min | | 13,5 | 16,7 | 16,7 | 9,8 |
| Cost of implementation | Max | | 3,4 | 5,0 | 17,6 | 5,9 |
| | Mean ± S.D. | 15,6 ± 0 | 3,1 ± 0,4 | 4,1 ± 0,7 | 13,0 ± 4,7 | 3,4 ± 1,4 |
| | Min | | 2,7 | 3,3 | 8,3 | 2,1 |
| Environmental disturbance | Max | | 17,2 | 13,3 | 11,8 | 22,2 |
| | Mean ± S.D. | 15,6 ± 0 | 15,4 ± 1,9 | 10,3 ± 2,3 | 10,0 ± 1,7 | 16,2 ± 4,1 |
| | Min | | 13,5 | 7,7 | 8,3 | 10,0 |
| Impact on habitat and fauna | Max | | 17,2 | 13,3 | 16,7 | 23,5 |
| | Mean ± S.D. | 21,9 ± 0 | 15,4 ± 1,9 | 10,3 ± 2,3 | 14,2 ± 2,5 | 19,1 ± 2,4 |
| | Min | | 13,5 | 7,7 | 11,8 | 15,0 |
| Reversibility | Max | | 10,8 | 15,4 | 25,0 | 20,0 |
| | Mean ± S.D. | 9,4 ± 0 | 5,4 ± 5,4 | 12,4 ± 4,0 | 21,3 ± 3,7 | 16,1 ± 2,6 |
| | Min | | 0,0 | 6,7 | 17,6 | 11,8 |
| Uncertainty | Max | | 20,7 | 11,5 | 8,3 | 18,6 |
| | Mean ± S.D. | 3,1 ± 0 | 19,8 ± 0,9 | 9,4 ± 2,0 | 7,1 ± 1,2 | 14,1 ± 3,2 |
| | Min | | 18,9 | 6,7 | 5,9 | 8,3 |

Group composition: **Group 1**: shipyard workers; **Group 2**: Ekologia Tailerra (volunteers) and dune recovery; **Group 3**: shipyard, Murueta council, Mundaka council, **Group 4**: Spanish Environmental Ministry, recreational boaters; **Group 5**: head of marine affairs, surfers, Arteaga council, bird watchers, Basque Environmental Ministry, environmental guides, Zain Dezagun (NGO), fishers, Busturia council

The standard deviations shown in this table indicate the polarisation of opinions within each group; these are smaller than the standard deviations associated with the whole array of social actors (see Table 5)

Once validated, the results of the clustering process with the social-actors enabled us to assess the influence of weights in the multi-criteria aggregation process in an explicit manner. This complements the standard sensitivity analysis used in MCEs, reinforcing the robustness of the analysis from a social perspective. After the impact of each alternative is obtained in accordance with the selected set of criteria (see Garmendia et al., 2010a), and group weights are identified, a multi-criteria aggregation procedure must be run to account for these diverse priorities, as discussed below in Section 3.2.

It is important to note that social preferences expressed as part of a group may be different from those held by the individual group members (Sagoff, 1988). Therefore, discussion among social actors on the results of the cluster analysis is critical for encouraging the emergence of different opinions.

## 3.2. Multi-criteria aggregation procedure under diverse social preferences

Numerous mathematical algorithms have been devised to solve multi-criteria problems (Figueira et al., 2005; Ananda and Heralth, 2009), each with its own advantages and disadvantages, depending on the application context (Montis et al., 2004).

In accordance with our earlier statement that partially or non-compensatory multi-criteria models are the most suitable for use with sustainability related issues, we adopted the C-K-Y-L ranking procedure presented in Munda (2005) for this study. According to this procedure, the maximum likelihood ranking of alternatives is that which is supported by the maximum number of criteria for each pair-wise comparison, summed over all pairs of alternatives considered. More formally, all the $N(N-1)$ pair-wise comparisons compose the outranking matrix $E$, where $e_{jk} + e_{kj} = 1$, with $j \neq k$. If $R$ is the set of all $N!$ possible complete rankings of alternatives, $R=\{r_s\}$, $s=1,2,..., N!$. For each $r_s$, we compute the corresponding score, $\varphi_s$, as the summation of $e_{jk}$ over all the $\binom{N}{2}$ pairs $j,k$ of alternatives. Thus,

$$\varphi_s = \sum e_{jk} \quad (1)$$

[illegible].

The final ranking ( $r*$ ) is the one which maximises equation 1:

[illegible].

## 3.3. Results:

Table 7 presents the rankings of alternatives with best $\varphi_s$ scores according to the priorities of each social-group. As shown, Groups 2, 3, 4 and 5, would prefer to constrain dredging activities and develop conservation measures through habitat recovery plans or invasive species eradication that enhance local development, while improving the quality of the environment (alternative A3). For these groups, minimum dredging activity accompanied by some conservation measures (alternative C4), or no dredging activities with compensation paid to affected parties (A2) are the second best options. Only Group 1, which represents the shipyard labour union, would prefer that alternatives A2 and C2 would prevail over A3.

Table 7: Raking of alternatives according to group weights

| | **Rank** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ***First*** | ***Second*** | ***Third*** | ***Fourth*** | ***Fifth*** | ***Sixth*** | ***Seventh*** | $\varphi_s$ ***score*** |
| Group 1 | A2 | C2 | C4 | A3 | A1 | B4 | B2 | 13,03 |
| | C2 | C4 | A3 | A2 | A1 | B4 | B2 | 12,97 |
| | C4 | A3 | A2 | A1 | C2 | B4 | B2 | 12,94 |
| | C4 | A3 | A2 | C2 | A1 | B4 | B2 | 12,94 |
| | A2 | C4 | C2 | A3 | A1 | B4 | B2 | 12,94 |
| Group 2 | A3 | A2 | C4 | C2 | A1 | B4 | B2 | 15,09 |
| | A3 | A2 | C2 | C4 | A1 | B4 | B2 | 15,04 |
| | A3 | C4 | A2 | C2 | A1 | B4 | B2 | 15,02 |
| | A4 | A2 | C4 | A1 | C2 | B4 | B2 | 14,97 |
| Group 3 | A3 | C4 | C2 | A2 | A1 | B4 | B2 | 14,75 |
| | C4 | A3 | C2 | A2 | A1 | B4 | B2 | 14,74 |
| | C4 | C2 | A3 | A2 | A1 | B4 | B2 | 14,72 |
| | A3 | C4 | A2 | C2 | A1 | B4 | B2 | 14,68 |
| | C4 | A3 | A2 | C2 | A1 | B4 | B2 | 14,67 |
| Group 4 | A3 | C4 | A2 | A1 | C2 | B4 | B2 | 15,17 |
| | A3 | A2 | C4 | A1 | C2 | B4 | B2 | 15,06 |
| | A3 | C4 | A2 | C2 | A1 | B4 | B2 | 15,06 |
| | C4 | A3 | A2 | A1 | C2 | B4 | B2 | 14,98 |
| | A3 | A2 | C4 | C2 | A1 | B4 | B2 | 14,95 |
| Group 5 | A3 | A2 | C4 | A1 | C2 | B4 | B2 | 16,07 |
| | A3 | A2 | C4 | C2 | A1 | B4 | B2 | 16,02 |
| | A3 | C4 | A2 | A1 | C2 | B4 | B2 | 16,02 |
| | A3 | C4 | A2 | C2 | A1 | B4 | B2 | 15,96 |

In addition to revealing that alternatives A3, A2, and C4 were favoured by the majority of the identified social-actors, the weighting analysis showed that alternatives B4 and B2 (i.e., maximum dredging in order to satisfy the demand from industry) are ranked lowest according to the preferences of all social-actors. Note that beyond the search for optimal solutions, in defining public policies it is also desirable to discard alternatives that are unsupported by the majority of the stakeholders. Interestingly, the evaluation process for this case study revealed a paradox: massive dredging, which has been the prevailing policy in the Urdaibai Estuary during the last decades, is the one option that all involved social-actors agreed should be abandoned. These results are in coherence with the preliminary results obtained by means of NAIADE: a non-compensatory outranking model that does not incorporate the explicit definition of weights (for further details of this analysis see Garmendia et al., 2010a).

The prioritisation process also yielded relevant information with regard to confronted social preferences and extreme positions (see Table 4). In this context, defining the relevance of each criterion explicitly provided a quality assurance mechanism to guaranty that the relevant properties of the issues at hand, which emerge during the participatory evaluation process, were incorporated adequately in the analysis. In other cases, this mechanism also could serve to identify and reconsider the incorporation of irrelevant criteria that could disturb the quality of the analysis.

As discussed bellow, time for reflection on individual and group preferences also provided in this case study an opportunity for a social learning process and the increase of participants' mutual understanding.

## 4. Discussion and conclusion

In a public policy debate, the number of diverse priorities can become so great that both the MCE process and the analysis of the results are intractable. On the other hand, compressing a complex situation into a single point-value solution (e.g., weights) can result in deadlock for the decision-making process because the conditions have become too rigid for compromise (Munda et al., 1995).

The novel approach proposed in this paper seeks a balance between these two extreme situations. It shows how diverse perspectives can be included in decisions related to sustainability issues without forcing consensus or searching a single aggregated parameter (e.g., mean value). Moreover, by explicitly defining weights in a deliberative manner, the present case study shows how to enhance the robustness of the analysis from a 'social' perspective. That is, taking in to account explicitly the confronted values of a given socio-ecological problem, this study shows that reflecting explicitly over social actors priorities can serve to assess the degree of acceptance/conflict of a given decision while reflecting over its legitimacy.

In this sense, the cluster dendogram (Fig. 3) provided a useful interface to facilitate the dialogue among all the counterparts by mapping the diversity of priorities and addressing potential coalitions without the need of oversimplifying a more complex reality. As several participants have pointed out, this analysis allowed structuring in a systematic way a considerable amount of information, which other wise would be difficult to communicate, while addressing the most controversial areas in clear way.

Notwithstanding, the whole participatory process described above is not safe from difficulties. Coping with the influence of powerful social-actors and respecting the diversity of perspectives is central to the framework of our approach; the adoption of a decision based upon specific social priorities must be as transparent and inclusive as possible. Transparency requires continuous feedback loops among all the counterparts (social-actors and external experts) and the ability to reframe the issue at hand with the best available knowledge that emerges during the process. Inclusivity requires the help of professional facilitators, a combination of public sessions and confidential interviews, and the use of participatory dynamics that allow flexible group discussions that support the rights of all participants to express their positions in a non-coercive (free) situation.

In this particular case study, the dialogue for the elicitation of weights allowed social-actors to be explicit with regard to their priorities, to address common and conflicting areas, and to participate in a social learning process. An ex-post analysis of the project showed that the entire participatory MCE contributed to the acquisition of more factual knowledge and created more opportunities for joint action after the project. Allowing time to reflect on social preferences and providing a wide opportunity for interaction among participants also fostered greater mutual understanding of the preferences of others (for further details regarding the ex-post analysis see Garmendia and Stagl, 2010).

To conclude, based in the lessons learned during this participatory process, we would like to underline that in the search for a sound decision we should not oversimplify complex social realities nor impose an artificial consensus. Individual values and preferences should be aggregated by mutual consent and agreement and not necessarily merged into a single, all-encompassing identity. This is crucial to ensure that the subsequent decision-making process is legitimised and socially accepted. Moreover, compression of the option space through open dialogue, with the help of decision support tools like the one presented in this study, can provide a robust basis for reaching agreement in the formulation of public policies for sustainability.

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