Negotiation Aid System to Define Priority Maps for Wind Farm Development

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***Abstract*—This paper presents the structure of a negotiation aid system (NAS) to select the best locations for new DG facilities, using sophisticated spatial techniques [based on geographical information systems (GISs)] and decision aid methodologies for negotiation, based on consensus among groups that may have conflicting interests. This system helps to overcome the problems posed by initially opposing positions stemming from diverse technological, economic, environmental and/or social interests. The NAS use is illustrated with results from a negotiation process between two groups to select locations for new wind farms in the region of La Rioja, Spain.**

***Index Terms*—Decision-making, decision support systems, distributed generation and storage, power generation planning.**

I. Introduction

NEW nonpolluting and environmentally friendly power plants based on renewable resources are increasing their presence in the electric power systems. Nevertheless, their development frequently poses problems. A first difficulty is the selection of locations where these facilities can be built. The agreement on the best locations (planning solutions) is often subject to the interests of groups involved in the planning process. In fact, these interests can be conflicting. For example, private investors and power utilities will logically look for locations for wind farms more attractive in economic terms. But for other agents, such as environmentalist groups, the installation of generators at a given place might have an unacceptable impact. This conflict of interests can delay, and even block, the construction of new generation facilities.

Power system planning in general is subject to multiagent (multigroup) decision-making processes under uncertainty where different and/or conflicting technological, economic, environmental and social aspects are involved. Public opinion plays an important role, particularly in the promotion of environmental restrictions that can affect the expansion of the system under economic criteria. In this context, most power system planning processes should introduce new useful ways to present/display feasible planning proposals to the agents involved and emphasize the negotiation and consensus among groups with conflicting interests [1].

In the early power system planning models, the solution selection was guided mainly by minimum economic cost, although later models were developed to manage uncertainty and conflicting objectives [2]. Other authors have proposed planning models that include planning preferences of social groups as a part of the process to select the best planning strategy under uncertainty [3] or have studied the effect of different methods to quantify values and use them to rank alternatives when they are presented to such groups [4]. Most of these models integrate a multiple criteria model in an attempt to consider jointly all the economic, technical, environmental and social implications of the planning problem, where the selection of the weights given to each criterion is one of the most contentious tasks in the planning process [5].

Although several strategies to identify the best acceptable solutions for all groups involved have been published, it seems that there is a lack of works published on the development of original and useful tools to reach a prior consensus and support advanced negotiation processes among such groups. The achievement of consensual alternatives for the location of new wind farms is a multiagent decision-making process with significant geographical characteristics [6] that can be studied by geographical information sciences [7]–[10]. The development of novel computer tools to support advanced negotiation processes and select locations for wind parks with initially conflicting positions would help to make these processes more agile and effective and reach good or acceptable solutions for all.

Geographical information systems (GISs) are suitable computational platforms to implement new tools for this kind of negotiations. Furthermore, GISs present/display the results as maps, in a global and visual way, and constitute a platform adapted to immediate and interactive analyzes in negotiation processes. In this context, GISs have been applied to other decision-making processes in power systems planning thanks to their geographical data manipulation ability [11].

This paper presents the structure of a GIS-based negotiation aid system (NAS) for the selection of the best locations for new wind farms. This NAS can also be applied to other types of power generation plants, whenever conflicting groups are present and a distinct geographical characteristic is inherent to the problem.

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This NAS is significantly distinct from a former proposal [12]. Now this paper presents holistic comparisons of maps to extract from users (agents) the hidden knowledge about relative criteria weights (pair-wise comparison of criteria on maps), as well as suitable standardization of criteria and criteria aggregation, leading to more complex and structured support to advanced negotiations, starting from an initial ranking of geographical locations based on a consensus among agents.

Several detailed advanced modules make up the structure of the new NAS. We pay special attention to the explanation of the GIS-based sophisticated spatial techniques used to implement decision aid methodologies suitable for negotiation processes. Moreover, these techniques also help to overcome problems caused by the initially conflicting interests of distinct groups. Intensive testing of the new NAS has been carried out to simulate the selection of the best locations for new wind farms in the region of La Rioja, Spain, in negotiation processes between two groups—some of the results of such testing are presented also in the paper.

II. Problem, Objectives, and Nomenclature

The problem basically consists in the identification of the collective preferences (in terms of consensus/compromises between decision-makers) to rank (by priority clusters) feasible geographical locations (feasible alternatives) for wind farms. A Group n is a group of decision-makers with the same interests. Different groups may have conflicting interests. The number of groups will be denoted by M.

The first objective of the NAS is to help groups in the definition of maps of preference/tolerance to be presented during the negotiation process. The second objective is to provide a first ranking of feasible alternatives (geographical locations) based on a consensus among groups.

The definition of priority geographical locations for wind farms is a multiattribute problem in which the alternatives are well defined. An alternative H is one of the geographical locations proposed to install wind generation. In the spatial structure of a GIS, each alternative is an elementary cell (with a known area in km^2) on the map of the studied region. In order to accelerate computations, cells with similar characteristics are grouped in geographical clusters and D will stand for a cluster of cells.

The space of feasible alternatives V is the extent of the geographical map used for the region under study, "impossible locations" excluded. These result from unquestionable constraints and are pruned from the space of alternatives at the beginning of the process.

The criterion C is a global definition of a preference guideline. In our problem, the evaluation of criteria is represented as geographical coverages in a GIS. These criteria can be quantitative (e.g., minimum distance to urban centers, mean wind speed) or qualitative (e.g., high, medium or low environmentally protected area). Moreover, these criteria can be spatially continuous (e.g., distance to urban centers) or discontinuous (e.g., municipality area). Each Group n independently adopts X_n criteria.

An attribute T is a measure on how an alternative H satisfies a given criterion. In our approach, attributes are defined by internal value functions established by each group. In this paper we use attribute scales between 0, for very bad locations, and 1, for excellent locations. The attributes T are transformed into scaled values T', as explained later.

The relative importance of a criterion is associated to a weight z. Later on, we will comment how the new NAS adjusts the weights z to new z' values and corrects inconsistencies induced by the groups.

A utility value is given by a function F_n, for each alternative (location) H from the standpoint of each Group n. It results from criteria aggregation and represents the preferences (tolerance) of a group toward installing wind farms. D^+ represents a set of locations or map cells "consensually" better than a specified preference level. $ND^+ = \#D^+$ (# means the set cardinal) is the number of locations or corresponding area in km^2, associated to D^+. Similarly, D^- and ND^- are used for the map of worst locations and its cardinal. D_O^+ represents a ranking of order O, i.e., the location set (or corresponding geographical area, ND_O^+) ranked in the order O. $D_O'^+$ represents the NAS-adjusted priority ranking and $D_{O'}'^+$ represents the new priority ranking after each successive stage of the negotiation process, and $ND_O'^+$ and $ND_{O'}'^+$ are the cardinals.

III. Methodology

Our methodology requires three main sequential stages. In the first stage, criteria maps are defined, together with attribute sets and the criteria standardization process. These definitions are created by each Group n for each criterion C. Criteria standardization is an automatic process aimed at reducing the biased impact on the negotiation process of the behavior of altruistic or malevolent groups.

In the second stage, the preference order within each group is established. This stage includes the definition of criteria weights and the aggregation of criteria in an order of group preferences. Spatial techniques based on pair-wise comparison of criteria are used to help in the definition of weights.

The third stage uses the preference order of each individual group to try to generate a consensus ranking for the groups. Spatial techniques are used to set this ranking without the intervention of the groups. The negotiation process basically involves an agreement among the groups to alter rankings, with NAS rebuilding the maps of priorities according to the new negotiated ranking.

Fig. 1 shows the procedure for an example with two groups. Obviously, this methodology can be applied to more than two groups.

A. Criteria Maps

Each Group n chooses a set of significant criteria for the definition of its location preferences. For instance, an environmentalist group can use maps with actual legal environment restrictions, distances to inhabited areas, distances to avian protected corridors, etc. On the other hand, an investor group may use map indicators for the expected energy production cost, municipality influences, economic risk of the investment, terrain slopes, etc. These criteria should avoid knowledge overlapping because this would affect the subsequently defined criteria aggregation process. For instance, maps of leveled electricity cost (LEC) [8] (Euro/kWh) for wind farms include knowledge of the mean wind speed (the

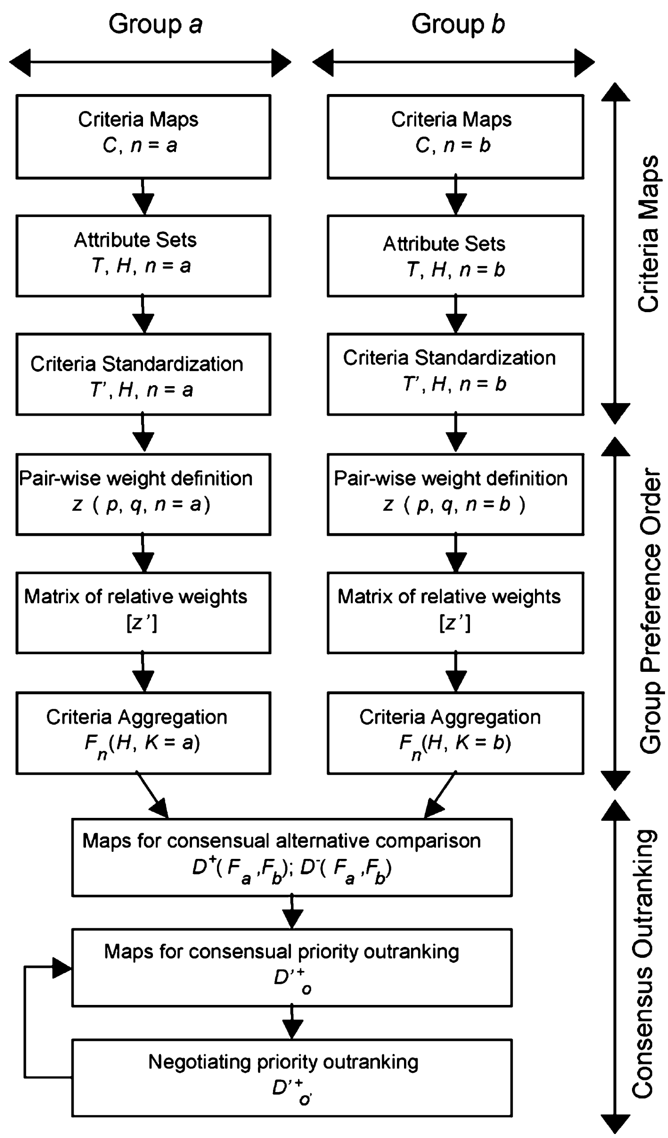

Fig. 1. Procedure for the spatial negotiation aid system.

concept of LEC translates into an equivalent energy cost an aggregation of investments and operation costs over a period of years). Then, the use of both geographical coverages (wind speed coverage and leveled costs coverage) as criteria would duplicate the influence of wind speed on the preference map.

The geographical area studied can cover several thousands of km^2, depending on the resolution used, i.e., the size of the elementary square cell. For wind farm permitting, acceptable resolutions (areas) in the cells usually range from 400 to 10 000 m^2. Technical and legislative geographical constraints must be evaluated at the beginning of the process to exclude locations unquestionably unacceptable to install wind farms. This geographical filtering is performed in a supervision process agreed by all the groups involved.

B. Attribute Setting

An attribute T is a map with a measure of the performance of each alternative from the standpoint of Group n. The setting of the attribute is the mapping of preference/tolerance into a

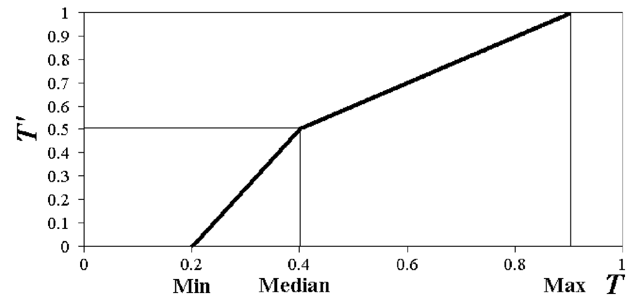

Fig. 2. Criteria standardization function, mapping attribute T into T'.

numerical range by an internal value function. The user (representing the group) defines the value function by assigning lookup values (from 0 to 1) in a legend table. The NAS uses this lookup table to reclassify the criteria map.

C. Criteria Standardization

A criterion standardization is required to make comparable the various criteria maps and avoid as much as possible the manipulation of value functions in order to influence the negotiation process. This process is accomplished via an adjusting function f, leading to a modified attribute map T' by the composition $T' = f \circ T$.

Fig. 2 shows an example of a function that may be used to standardize criteria. The function adjusts the minimum (*min*), maximum (*max*) and median values of the attribute T to the values 0, 1 and 0.5 of the attribute T'. Therefore, $T' = 0.5$ separates the map points in two sets of equal dimension, one for the points with higher evaluation and the other for the points with lower evaluation.

The basic adjusting function is linear between *min* and *max* and introduces no distortion in the classification values allocated by a group. Distortion is not needed if a group is not suspected of biasing its classification to gain improper advantage in the negotiation process.

D. Pair-Wise Weight Definition

In spatial problems, weights for a given set of criteria are particularly difficult to set. For example, if we study an electricity production cost criterion and an investment risk criterion, we should explore the relevance of the cost versus risk, which is not obvious. Thus, one of the basic functions of the NAS is to help a group to define "relative weights" and avoid inconsistencies. For a realistic comparison of the relevance of each criterion, the Group needs to examine maps that directly compare the relative relevance of each criterion for the different spatial patterns on the map.

In our approach, we use spatial methodologies to define pairwise comparisons of criteria and find "relative weights." For each pair of criteria p and q, the NAS proposes pairs of weights, z_p and z_q, that add up to 1, and uses these weights to build a linear aggregation function $S_{p,q}$

$$S_{p,q} = (z_p \times T_p) + (z_q \times T_q) \tag{1}$$

for a series of weights

$$(z_p; z_q = 1 - z_p), \quad \forall\, z_p \in \{0.1; 0.2; 0.3; \cdots; 0.9\}. \tag{2}$$

For each pair of weights, a map corresponding to the aggregate value $S_{p,q}$ is created. Then, with the resulting values associated to the cells of this map, isolines for any $S_{p,q}$ value can be generated on the map. These isolines represent the boundary between positively and negatively appreciated areas at different levels.

Fig. 3 shows an example of three maps of the aggregation function $S_{p,q}$ corresponding to three pairs of weights for two criteria, namely, the leveled cost of electricity (LEC) and RIX [8] (representing an investment risk index due to uncertainties). The maps are built from data referring to the region of La Rioja, Spain. Darker zones in the maps receive higher $S_{p,q}$ values and isolines for $S_{p,q} = 0.5$ are also drawn as black lines. Each pair of weights (each map) generates different boundaries between good and bad locations. Notice, in Fig. 3, how the separation (black line) between more acceptable (darker areas) and less acceptable regions (lighter areas) changes from map to map.

Examining such maps, a group is invited to select the one where the set of isolines most faithfully separates good and bad locations according to its experience and professional point of view, taking in account the criteria involved in creating the map. This map selection automatically selects the corresponding weight values that were used to generate it.

This experimentation with maps is an innovative way of discovering the implicit weights in a decision-maker, because it relies on a holistic appreciation instead of pair-wise comparisons of individual solutions.

E. Relative Weights for the Global Criteria Set

Based on the relative weights between pairs of criteria, it is possible to identify "global relative weights" for all X criteria and correct inconsistencies. This correction assumes that the decision maker preferences are transitive; it may be argued that human reasoning may encompass inconsistencies, but some of these may also arise from the holistic process of appreciation and should be filtered.

Let us define the classical Saaty matrix [13] for each group with elements a_{pq} such that

$$a_{pq} = \frac{z_p}{z_q} \tag{3}$$

with z_p and z_q being the weights selected in the map comparison phase. The "global relative weights" z' implicit in a Group decision may then be obtained by a number of methods, such as the Saaty method of eigenvalues. For simplicity, in this paper we adopted the method of Chu [14], which gives results not far from the ones of Saaty's method, by simply solving

$$\begin{aligned} \text{Min} \quad & y = \sum_{p=1}^{X} \sum_{q=1}^{X} \left(a_{pq} z'_q - z'_p\right)^2 \\ \text{s.t.} \quad & \sum_{p=1}^{X} z'_p = 1; \quad 0 \le z'_p \le 1. \end{aligned} \tag{4}$$

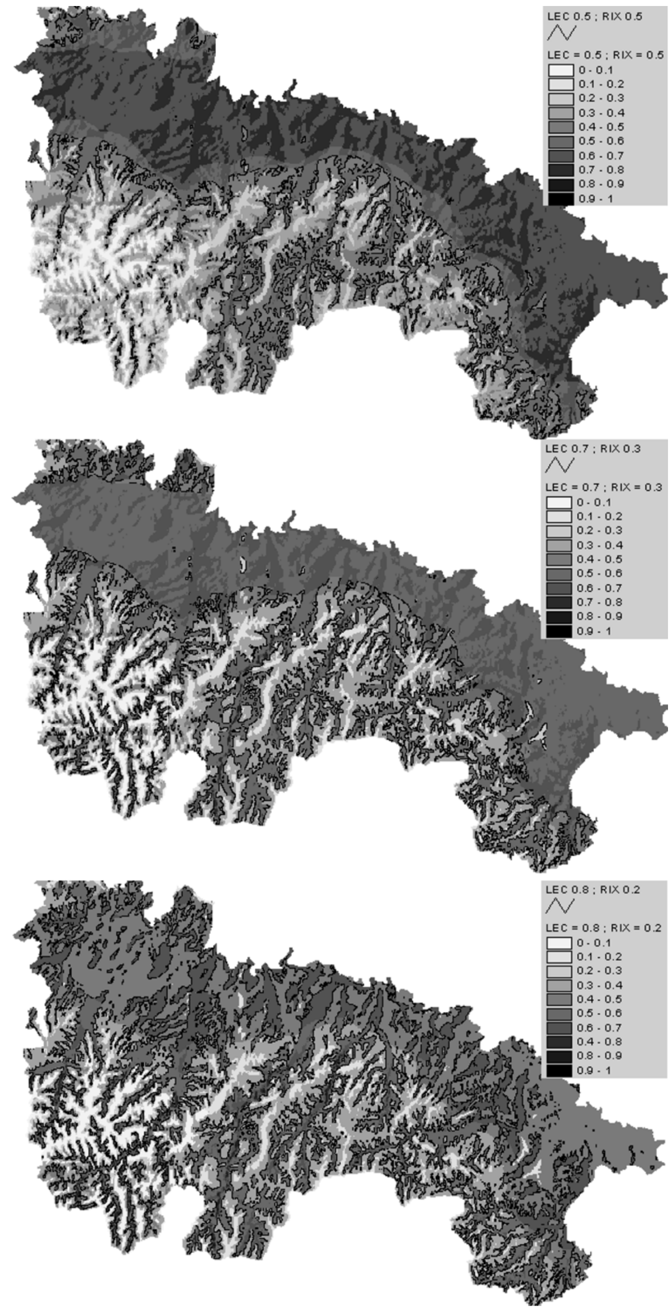

Fig. 3. Maps of the sets of isolines for three weight combinations.

F. Criterion Aggregation

Once a coherent global set of weights is reached, we are ready for calculating an aggregated index F from the attributes T' based on a linear combination of these attributes:

$$F = \sum_{p=1}^{X} \left(z'_p \times T'_p\right). \tag{5}$$

The result is a map of preference/tolerance with values F between 0 and 1 associated to each map cell for each group. These spatial maps are associated with tables of records, where each record represents an elementary cell or location (alternative, H). The ordering of these tables of records with respect to the function F_n, provides the individual ranking of Group n.

G. Comparison Maps of Consensual Alternatives

Based on the maps of the function F the NAS generates automatically a ranking of alternatives (ranking of locations to install wind farms). First, a set L of a given number of levels is generated. For instance, a set of 9 levels may be

$$L = \{0.1;\ 0.2; \cdots;\ 0.8;\ 0.9\}. \tag{6}$$

Each combination of the levels in L_n, $n = 1, 2 \ldots$ to M, allows the NAS to generate sets D of all the map cells being simultaneously labeled with different F values, and sets D^+ with all the map locations H which have simultaneously achieved function F values better than given values for each group. If we have only two groups, *a* and *b*, we have

$$D_{i,j} = \{H \in V | \lfloor F_a(H) = i \rfloor \wedge \lfloor F_b(H) = j \rfloor\} \tag{7}$$

$$D^+_{i,j} = \{H \in V | \lfloor F_a(H) > i \rfloor \wedge \lfloor F_b(H) > j \rfloor\}. \tag{8}$$

The cardinal of this set is $ND^+_{i,j}$, which is an index representing the number of alternatives (feasible locations) H, in the space of the feasible alternatives V, that are simultaneously better than level i for Group a and better than level j for Group b. Each set $D^+_{i,j}$ is stored in the GIS as a map. In a way, the number ND^+ measures the "distance" to the best consensual alternative.

We also define a number ND^- that measures the "distance" to the worst alternative, representing a counting of the map locations of alternatives $D^-_{i,j}$ that are consensually worse

$$D^-_{i,j} = \{H \in V | \lfloor F_a(H) < i \rfloor \wedge \lfloor F_b(H) < j \rfloor\}. \tag{9}$$

The ranking of consensual alternatives is defined by ordering the set of records of alternatives, i.e., by ordering the numbers ND^+ in increasing order. For alternatives with the same number ND^+, their ordering is established by the decreasing order of the numbers ND^-.

H. Consensual Priority Ranking Maps

The aim of priority ranking is to provide an order D_O of geographical locations to install wind farms, where O is the order in the ranking. Order $O = 0$ corresponds to the locations where consensus reaches its highest degree and $O + 1$ represents a worse set of alternatives than O. This requires the ranking to satisfy the following two conditions.

- *Condition A:* The location set (alternatives) D^+_O must be contained in the location set D^+_{O+1}. If a location is "consensually better" for the order index O, then it must continue to be "consensually better" for lower ranked sets $O + \alpha$ (where α is a positive integer).
- *Condition B:* The location set (alternatives) D^-_{O+1} cannot be part of the location set D^+_O. If a location is "consensually worse" for the index order $O + \alpha$, then it cannot be "consensually better" for higher ranked sets O.

In many cases, $D^+_O \subseteq D^+_{O+1}$. However there are cases where this is not true and Condition A is not met. Fig. 4 shows a map where the sets $S_1 = D_{i=0.9;j=0.5}$ and $S_2 = D_{i=0.5;j=0.9}$ are compared. The set $D^+_{i=0.9;j=0.5}$ is labeled "better than S_1", the set $D^+_{i=0.5;j=0.9}$ is labeled "better than S_2," the set $D^-_{i=0.9;j=0.5}$ is labeled "worse than S_1," and the set $D^-_{i=0.5;j=0.9}$ is labeled "worse than S_2."

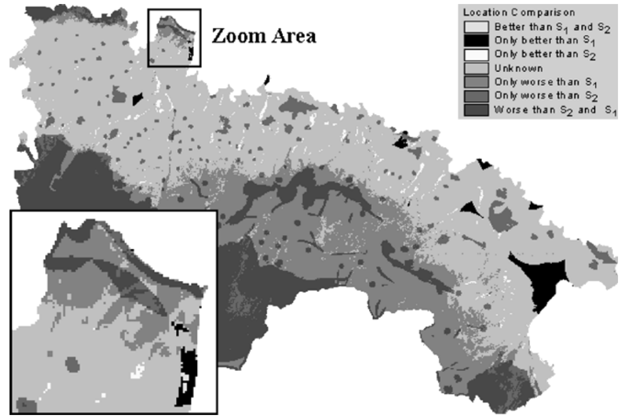

Fig. 4. Map with two overlapped classification sets: S_1 and S_2.

By overlapping these classification maps, we obtain a series of consensual classifications, as shown in the legend of Fig. 4. When we try to rank S_1 and S_2 some inconsistencies arise. On one hand some locations are better than S_1 and not better than S_2 (black spots labeled "only better than S_1"); on the other hand, other locations are better than S_2 and not better than S_1 (white spots labeled "only better than S_2"). For a perfect dominance of S_2 over S_1, the white spots should not appear in the map. In turn, for a perfect dominance of the set S_1 over the set S_2 the black spots should not appear.

To overcome this problem, maps D^+_O and D^-_O are recalculated to enforce conditions A and B. The sequence of spatial computations follows the increasing sequence of the ranking order index O

For order O_a, from $O_a = 1$

$$D'^+_{O_a} = D^+_{O_{a-1}} \cup D^+_{O_a} \qquad (Condition\ \ A)$$

For order O_i, from $O_i = 0$ to O_{a-1}

$$D'^+_{O_i} = D^+_{O_i} \setminus D^-_{O_a} \qquad (Condition\ \ B)$$

Next O_i

Next O_a until the last ranking record.

Symbol \ stands for the subtraction of sets (subtraction of location maps) where $A \setminus B = \{x | x \in A \text{ and } x \notin B\}$.

This spatial recalculation (correction) algorithm creates a sequence of new maps (D'^+_O) that will be used as the priority order of locations (alternatives) to install wind farms.

I. Negotiating Priority Ranking

As in the negotiation process we do not have intergroup comparisons of preferences, all groups are on equal terms in the negotiation process and none has dictatorial power. From Arrow's impossibility theorem [15], we know that there is no procedure to combine an individual ranking into a group ranking that does not explicitly address preference interrelations. Even based on consensus approaches, our ranking is not absolute. But there are chances to negotiate and possibly change the preferences of the groups involved. Thus, ranking D'^{+}_{O} may be considered as a good starting point.

In the interactive negotiation process, the groups are given an incentive to negotiate pair-wise order exchanges of sets D'^{+}_{O}. The NAS verifies the validity of each exchange and recomputes the priority ranking map, generating new ranking sets $D'^{+}_{O'}$. A proposal by a Group could be invalidated by the NAS if the user proposes exchanging well-ordered sets (e.g., it is not possible to exchange the well-ordered $D^{+}_{i=0.5;j=0.5}$ and $D^{+}_{i=0.4;j=0.4}$ sets because the set $D^{+}_{i=0.5;j=0.5}$ must always be better ranked than set $D^{+}_{i=0.4;j=0.4}$).

IV. Case Study

In the following paragraphs, we will describe an example of ranking maps as a practical application of the NAS and simulate an example of a negotiation process.

A. Example of Ranking Maps

In order to illustrate the ranking process, we will discuss a problem related to wind farms permitting in the region of La Rioja (Spain). Consider two groups: the environmentalist group (EnvG) and the development group (DvpG). The EnvG group represents environmental agencies, organizations, activists and community groups worried about the negative impact of wind farms. The DvpG group represents wind project developers, financial institutions and economic development agencies interested in installing wind farms in sites with a high economic potential.

The environmentalist group chooses the following set of criteria: environmental protected areas according to the regional environment protection plan (2 different GIS coverages), bird protected areas, vegetation GIS coverage, and proximity to inhabited areas.

The development group chooses the following set of criteria: electricity production cost, LEC (including energy resources, costs of roads and electric network connections, land property value), terrain slope, altitude, and investment risk.

The process is guided by a negotiation supervisor. The first step is to obtain the maps of individual preference/tolerance as shown in Fig. 5 for EnvG and in Fig. 6 for DvpG. F_EnvG and F_DvpG in Fig. 5 and Fig. 6 are the values of F_n for each group. In Fig. 5, the lighter areas represent locations with a lower tolerance—less tolerable areas are near urban centers and in some environmentally protected areas. In Fig. 6, the lighter areas represent locations with a higher tolerance—more interesting areas are locations with high potential wind resources and technically acceptable sites.

Following the procedure described in Sections III-G and III-H, the set of alternatives presented on Table I and Fig. 7 are ranked. Table I gives the best 20 location sets. The ranking O is the ranking order. L_EnvG and L_DvpG are the levels L_n for the environmentalist group and the development group. ND^{+} is a number of alternatives, represented as a geographical area in km^2, and measures a "distance" to the best consensus set. ND^{-} represents the same relative to the worst consensus set. ND'^{+}_{O} is the area after adjusting the priority ranking map.

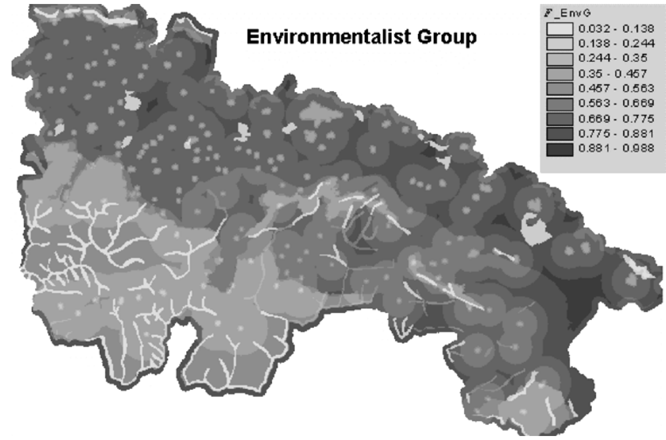

Fig. 5. Tolerance index maps for the environmentalist group.

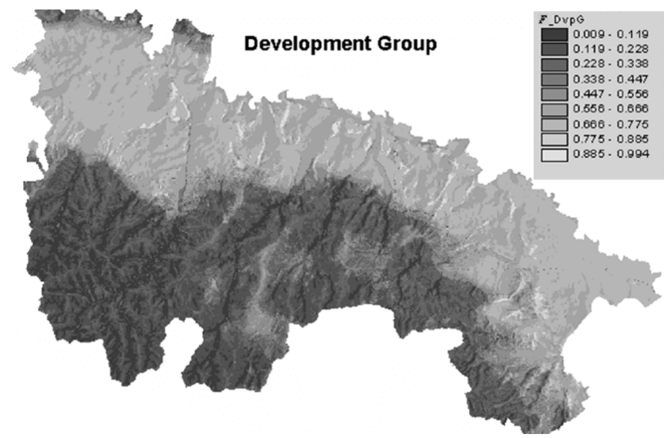

Fig. 6. Tolerance index maps for the development group.

In Table I high-ranking location sets correspond to high L_n levels for both groups (columns L_EnvG and L_DvpG). For lower ranked locations, we observe that the levels decrease, in some cases with very different levels of preference for the groups (see the location sets with a ranking of 8 and 12).

The best area for well-ranked and highly consensual locations is very limited (0.26 km^2 with excellent locations in a total study area of 5030 km^2). However, there are approximately 80 km^2 with quite acceptable locations for both groups. In many cases, an increase in the ND^{+} number leads to a decrease in the ND^{-} number.

Column ND'^{+}_{O} represents the area of consensual better locations after the adjustment of the priority ranking map described in Section III-H. We can observe larger areas when comparing ND'^{+}_{O} with ND^{+}, due to the union of zones corresponding to nonoverlapping sets.

Fig. 7 shows the initial priority ranking for each location in the studied region. This global ranking is the basis of the negotiation process. The progressive selection of locations according to the ranking enlarges the selected area (of consensual better locations), and the individual ranking (levels in columns L_EnvG and L_DvpG) decreases from the standpoint of each group until the lowest limit tolerable for each group is reached.

TABLE I
PRIORITY RANKING

Ranking O	L_EnvG	L_DvpG	ND^{+} (km^2)	ND^{-} (km^2)	$ND_O'^{+}$ (km^2)
0	0.9	0.9	0.26	4912.16	0.26
1	0.9	0.8	0.45	4867.77	0.45
2	0.8	0.9	10.39	4433.73	10.58
3	0.8	0.8	22.49	4401.25	22.49
4	0.7	0.9	35.43	2731.10	47.43
5	0.9	0.7	35.74	3939.28	82.72
6	0.6	0.9	36.48	2005.33	83.87
7	0.5	0.9	37.37	1791.66	84.76
8	0.4	0.9	37.87	915.14	85.26
9	0.9	0.6	71.74	2904.73	121.26
10	0.7	0.8	73.52	2724.71	147.35
11	0.9	0.5	73.80	2569.82	149.41
12	0.9	0.4	74.59	2329.59	150.20
13	0.6	0.8	77.58	2001.85	153.11
14	0.5	0.8	79.37	1789.08	154.01
15	0.4	0.8	80.45	913.14	154.59
16	0.8	0.7	270.19	3685.71	367.00
17	0.8	0.6	478.74	2823.17	539.55
18	0.8	0.5	513.08	2520.54	571.83
19	0.8	0.4	525.01	2291.45	582.97
20	0.7	0.7	910.03	2597.44	1171.78

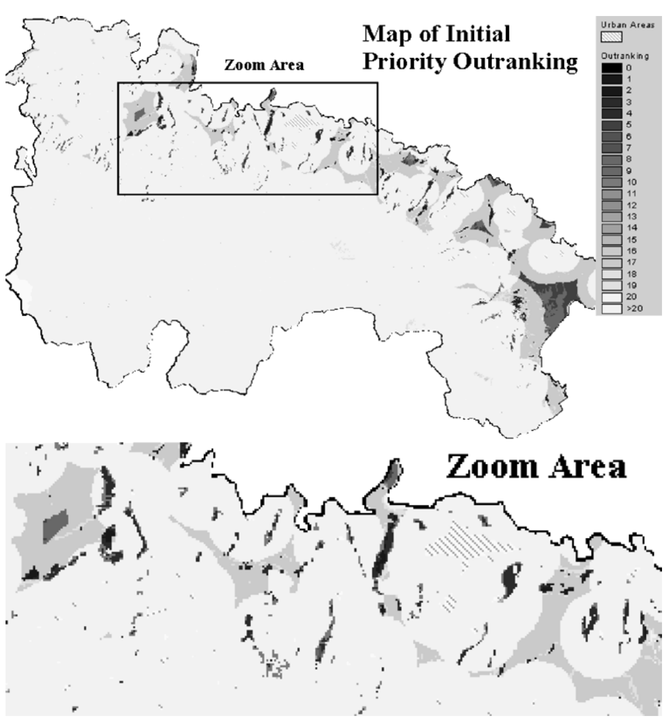

Fig. 7. Map of initial priority outranking.

B. Example of a Negotiation Process

Guided by a supervisor, groups negotiate pair-wise changes of location sets in the priority ranking. We will illustrate this with an example. The environmentalist group (EnvG) proposes a exchange between the set ranked 10 and the set ranked 8 (in Table I) in an attempt to lower the ranking of this set (ranked 8), that is, obtain a lower ranking value for the preference level 0.4 (column L_EnvG). The development group (DvpG) accepts

TABLE II
NEW RANKING BASED ON NEGOTIATION PROPOSALS

Old Ranking	New Ranking	L_EnvG	L_DvpG	$ND_O'^{+}$ (km^2)	$ND_{O'}'^{+}$ (km^2)
0	0	0.9	0.9	0.26	0.26
1	1	0.9	0.8	0.45	0.45
2	2	0.8	0.9	10.58	10.58
3	3	0.8	0.8	22.49	22.49
4	4	0.7	0.9	47.43	47.43
10	5	0.7	0.8	147.35	73.52
6	6	0.6	0.9	83.87	74.67
7	7	0.5	0.9	84.76	75.56
5	8	0.9	0.7	82.72	110.85
9	9	0.9	0.6	121.26	146.85
8	10	0.4	0.9	85.26	147.35

Fig. 8. Ranking modifications.

the proposal of the environmentalist group (EnvG) if it includes an exchange between the set ranked 5 and the set ranked 10, which corresponds to an increase in the ranking of the location set with the preference level 0.8 (column L_DvpG) and a decrease in the ranking of the location set with the preference level 0.7 (of column L_DvpG). Note that in the proposals of each group there is an attempt to increase its preference level, but this implies a decrease in the preference level of the other group.

The NAS checks the validity of the exchanges by reordering and verifying whether outranked sets are ranked lower than outranking sets. This is done by checking the preference "levels" in columns L_EnvG and L_DvpG. In our example, the new order is presented in Table II. Column $ND_O'^{+}$ presents the values before, and column $ND_{O'}'^{+}$ shows the value after the new ranking. After the validation, the NAS recomputes the priority ranking maps with the algorithm presented in Section III-H and obtains a new map.

Fig. 8 shows the modifications obtained for the location ranking (of the zoom area) with respect to the previous ranking map presented in Fig. 7. Fig. 8 shows that simple negotiations can cause complex ranking modifications. Some locations go down the ranking (they obtain a ranking lower than before the exchange) whereas others go up (they obtain a higher ranking). Furthermore, the spatial NAS negotiation provides additional indicators to summarize the modifications and analyze the benefits and losses derived from the negotiation. Table III shows some of these indicators. It shows that there are more locations (km^2) where the ranking "drops" (decreases) than locations

TABLE III
SPATIAL STATISTICS FROM THE RANKING MODIFICATIONS

Ranking modifications	km^2	F_DvpG	F_EnvG
Decreases	47.890	0.766	0.914
Increases	26.090	0.844	0.758

where it "rises" (increases). This means that the negotiation process reduces the area with "consensual better locations". The mean values of preference level in columns F_EnvG and F_DvpG of Table III (for the two groups) show that for the development Group DvpG, locations where the ranking has gone up have a higher preference level than locations where it has gone down, which denotes a favorable negotiation agreement for the development group. However, for the environmentalist group EnvG, locations where the ranking has gone up have a lower preference level than locations where it has gone down, which suggests an unfavorable negotiation agreement.

V. CONCLUSION

This paper has presented a new NAS implemented in a GIS devoted to the selection of consensual better locations among groups, in a negotiation process to build new Distributed Generation (DG) power plants, basically from renewable energy sources. Potential users of this NAS are groups such as investors, project developers, financial institutions and economic development agencies (interested in the development of DG facilities) as well as public organizations, environmental agencies, activists and community groups (interested in limiting or smoothing the effects of new power plants in the interest of the environment or society) and even governmental agencies (with legislative and/or normative interests).

The NAS is based on an original methodology composed of sophisticated map operations and procedures (technologically based on GIS) focused on the definition of preference/tolerance maps used in the negotiation process among different groups, as well as the provision of an initial ranking of feasible geographic locations. The NAS implements some original characteristics such as standardization and pair-wise comparison of criteria, criterion weighting and criteria aggregation thanks to the powerful calculation and visual representation abilities of GIS.

The power of GIS technology allows the application of an unusual method of discovering the relative set of weights that a decision-maker implicitly applies in the presence of multiple criteria. This discovery is based on holistic evaluations of proposals, which are made possible by inducing decision makers to examine maps describing the possible consequences of choices.

The NAS builds an initial ranking of feasible geographic locations, which is the starting point of the actual negotiation process, where successive exchanges of ranking positions are performed among the groups according to their negotiation proposals. Then, with the resulting (GIS-based) maps, the groups can easily and interactively analyze and negotiate the most adequate locations to build generation plants based on the consensus reached by these groups and can also overcome the problems caused by initially conflicting interests stemming from their different and/or opposed technological, economic, environmental and social standpoints. Thus, this NAS contributes to achieve valuable agreements and avoid delays or cancellations in generation plants projects due to conflicting initial opinions/wishes.

The NAS has been intensively tested to select appropriate locations to build new wind farms in the region of La Rioja, Spain, during the negotiation process between two groups. Furthermore, this NAS can be easily exported and used in any region, with any number of groups and for any type of DG facility. In summary, this original GIS-based NAS is an innovative tool suitable for advanced negotiation processes among groups. It can help to foster and integrate new DG power plants into power systems, particularly renewable energy plants, increasingly promoted all over the world, by reducing the impact of opposition to their construction and working toward consensus.

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