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EVALUATION OF TWO MCDM TECHNIQUES FOR STAGING THE MULTICRITERION DESIGN OF LONG-TERM WATER SUPPLY IN SOUTHERN FRANCE [1]

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RÉSUMÉ

A l'occasion d'un plan régional (1989) de développement des ressources en eau supplémentaires pour le bassin Adour-Garonne (Sud-Ouest de la France), ce travail examine comment des méthodes d'aide multicritère à la décision permettent de porter un regard critique sur le processus multi-acteur de sélection d'un site où construire un grand barrage-réservoir. Ce papier décrit d'abord les éléments du problème décisionnel: 4 acteurs, 13 critères et 38 alternatives. Dans une première phase, on montre comment la méthode ELECTRE III permet d'analyser les alternatives et d'en réduire le nombre aux 8 plus "efficaces" qui sont étudiées plus en détail. Ensuite, deux techniques d'aide multicritère à la décision, l'une quantitative (extension d'ELECTRE III), l'autre non-numérique (ME-MCDM) sont utilisées pour simuler le processus de décision multi-acteur et multicritère. Les solutions obtenues sont comparées à celles issues du processus réel de décision. L'existence de points de convergence et de divergence entre ce processus et la formalisation proposée met en évidence la pertinence des méthodes employées et permet de les évaluer.

mots-clef: aide à la décision multi-acteur, aide multicritère à la décision, allocation de ressources en eau, environnement, irrigation, planification de ressources en eau, réservoirs.

ABSTRACT

A 1989 regional development plan for augmenting water resources in the Adour-Garonne Basin (Southwestern France) is reexamined from the point of view of aiding this multiple criteria decision-making (MCDM) process involving multiple actors. The specific problem of the choice of a site for building a large reservoir is investigated. The problem elements consist of 4 actors, 13 criteria and 38 alternatives. In first phase of the methodology, the ELECTRE III technique is used to screen alternatives and reduce the choice set to 8 "efficient" alternatives which are then examined in some detail. In the second phase, the multi-actor multicriterion decision process is modelled by means of two decision aiding techniques, namely: a quantitative one (an extension of ELECTRE III) and a non-numerical one (ME-MCDM). The solutions thus obtained are compared to the outcomes of the actual decision process. The similarities and differences between the two models and reality are used to assess the suitability of these approaches in this specific case.

keywords: environment, group decision maker, irrigation, multicriterion decision making, reservoirs, water resource planning, water supply.

INTRODUCTION

Multicriterion decision-making (MCDM) theories provide efficient tools to deal with operational research problems containing more than one objective. Theoretical advances (Roy, 1985; Zeleny, 1982) appear to provide a strong framework and foundation for a genuine decision-making aid science. Although application oriented papers, such as Heidel & Duckstein (1983), Guariso et al (1986), Parent & Lebdi (1992), Tecle & Duckstein (1992) have tried to bridge the gap between theory and practice, much is still left to be done in real engineering planning problems.

This study represents an attempt to put into practice MCDM concepts in a real case study from the very beginning of the decision process. Water resource planning is undoubtedly a typical area where MCDM techniques can be efficiently employed to help *decision-makers* (DM), as reviewed earlier in Cohon & Marks (1975). Most real world water resource planning problems are characterized by:
- various degrees of uncertainty;
- a complex objective space, generally with multidimensional goals,
- a difficult identification of the DM (single, group or none!),
- a sophisticated structure of the alternatives which often combine in sequence several elementary actions and various planning horizons (short, medium and long term).

The practical aim of our study is to stage the multicriterion design of long term water supply in Southwestern France for the next decade. We have simplified much of the problem by assuming:
- no interaction between actors;
- static overall evaluation of alternatives;
- no explicit uncertainty;
- discrete alternatives,

Yet the application of MCDM theories appears to be realistic and to provide deep insight into this case study.

The paper is organized in order to point out the major steps of the decision process. In Section 1, we introduce the general decision context and the relevant elements for decision modelling (decision-makers, criteria, alternatives). Section 2 presents the methodology that was used to model the various decision phases **a)** screen the alternatives, **b)** select a reduced number and **c)** possibly choose a "satisficing" one. Section 3 provides the details of each step both for the methodology and the case study validation. Two different techniques, one mostly quantitative - ELECTRE (Roy, 1985) and the other one more qualitative ME-MCDM (Yager, 1993), are then compared and their results and conditions of implementation are discussed and evaluated.

1 CASE STUDY DESCRIPTION

The Garonne river basin (55,650 km^2) is a part of Southern France with traditional agricultural activities. Although the mean annual precipitation depth could be considered as sufficient for various types of agricultural development, constant high levels of productivity could not be regularly obtained because of the high variability of intra and inter-annual rainfall distribution.

In the last thirty years, with the implementation of the EEC (*European Economic Community*) Agricultural Policy, which improved the economical competitiveness of the agricultural goods within the EEC countries, the necessity of obtaining more regular production levels induced the adoption of irrigation techniques in this region. New irrigation areas were mainly exploited for cereals, especially corn, because of the high prices granted by EEC for this crop, the low investments level for the farmer and the quasi-guaranteed benefits (corn is one of the crops that responds well to most irrigation techniques). Between 1970 and 1988, the total irrigated area in Adour-Garonne River Basin (115,000 km^2) has increased from 133,000 ha to 500,000 ha. The annual average agricultural water consumption has risen from 200 to 750 hm^3. This consumption could reach 1,100 hm^3 in the driest year over a ten-year period.

On the other hand, taking advantage of the surrounding mountains (*Pyrénées, Massif Central and Montagne Noire*), the National Electrical Utility, *EDF*, started to build, in the 50s, hydropower reservoirs. Presently, the storage total capacity of these dams reaches 2,500 hm^3.

In the same period, industrial growth in the region caused an important increase in wastewater production, with negative effects on river pollution levels. Presently, the situation may be qualified as critical. Both evolution of social demand in terms of increased environmental quality of rivers and the 1988/1989/1990 exceptionally dry summers, with high levels of agricultural water consumption, contributed to conflicting situations between water users, with very negative effects on fluvial ecosystems (high level of pollution, fish mortality, etc.).

In response to this situation, the *Adour-Garonne Water Committee* , which consists of local politicians, government staff, water users and *non governmental organizations* (NGOs) and considered in France as a "regional water parliament", approved a ten-year Master Water Plan, which stated that a 400 hm^3 new water storage system should be developed. This quantity is approximately the sum of 170 hm^3 of actual water deficit and 230 hm^3 of forecasted water demand.

The water deficit was estimated taking into account natural water resources, existing water storage, satisfaction of priority uses of water (such as drinking water), satisfaction of agricultural water demand over a ten-year period for a defined irrigation perimeter and levels of "instream" flows (defined in order to yield "satisfying aquatic life conditions and residual pollution dilution").These new resources would be developed by water transfers, improvements of existing reservoir operation rules (mainly hydroelectric ones) and construction of dams of different capacities. In this paper, we focus on a particular decision of the Committee that stated that "at least 50 hm^3 of the total volume of 400 hm^3 should be provided by a large dam to recover the inflow levels of the Garonne river that flowed naturally in the past before agricultural and industrial development".

As a center dealing with applied research in the fields of hydrologic systems and project assessment, The *Teaching and Research Centre for Natural Resources and Environment Management* - CERGRENE - was asked by the French Ministry of the Environment to elaborate criteria so as to compare each large dam project on a rational basis. The results of the CERGRENE study, a technical comparison of projects and a simplified pay-off matrix, were presented in Cordeiro-Netto (1990, 1991).

From a decisional point of view, local and national authorities had decided to create an Expert Commission, whose task was to indicate the best dam project. That

Commission, formed by three engineers of two National Corps of Engineers, used the results of the CERGRENE study in its own project evaluation.

Although CERGRENE was not asked to elaborate a complete multicriterion analysis or to help to prepare decisions, it has been decided to apply some MCDM techniques to this case study within another research program. The results of such an investigation could be analyzed in conjunction with the actual decision-making process.

1.1 The Actors

In the French administrative structure, one can identify four main groups of actors taking part in the decision-making process:
- AGS - Agricultural Government Staff;
- EGS - Environmental Government Staff;
- WUO - Water User's Organizations;
- EPO - Environmental Protection Organizations.

The first one (AGS) is composed of official representatives of the Ministry of Agriculture and includes civil servants with both technical and administrative responsibilities. From a financial viewpoint, these individuals have the possibility to subsidize up to 50% of the project selected, if this project proves to result in favorable social consequences for agriculture.

The second group (EGS) belongs to another Ministry, the Ministry of the Environment, and can eventually partly fund the "best" project. Its main concern is head water quantity/quality and waste water regulation enforcement.

The water user organization (WUO) is a loose interest group composed of agricultural unions and elected (and influential) local officials (or assemblies) from the rural world. WUO is mainly concerned with short term and individual effects of the alternatives. One cannot ignore its influence on the decision process because of the national and local political weight. This group cannot be ignored, specifically in the French context, since, among other activities, it has the ability to organise demonstrations, especially after a three-year sequence of drought and poor crops.

The last group (EPO) is formed by non-governmental organizations for nature conservation, and associations of anglers that are extremely powerful in the French context. They do want to participate in the decision process because one of the essential consequences of the project will be to compensate for the last thirty-year irrigation intakes and reestablish good ecological conditions in the Adour-Garonne rivers.

In fact, AGS and EGS are real decision-makers, i.e., they have the power of making decisions, at least by funding technical solutions. WUO and EPO would rather be considered as "stakeholders" because they do not formally take the decision, although they have an actual strong influence (by "lobbies", advice, etc.). In the following of this paper, we will not make this distinction: WUO and EPO will be also denoted under the generic term DM.

Usually, all groups are organized on three levels: local, regional and national. The present paper will only consider the regional level because projects are studied and compared at that level. The regional *Adour-Garonne Water Committee* includes members of each one of the four groups.

1.2 Criteria

1.2.1 *Criteria to be used*

Through discussions held with several members of each group, we came to an agreement concerning thirteen criteria to be adopted. These criteria can be divided into two main groups: external characteristics of an alternative (corresponding to the criteria that are independent of the effects of the alternative) and internal characteristics of an alternative. Table 1 lists these criteria, specifying for each criterion the unit and its direction of preference (increasing or decreasing preference).

I) *External characteristics of an alternative*

Financing - The financing is of major concern in this kind of project with social interest because it always involves strong financial support of public agencies. In this case, it is evaluated on a subjective scale rating from 1 to 10 according to the will of national and regional administrations to finance the project. This rating reflects the complexity of internal negotiations within each interest group.

Reservoir operation experience requirement - This criterion is connected to the company or organization that will take in charge the realization and/or the management of the alternative. Depending on its experience and its reputation, a subjective judgement shared by the four groups has been assessed between 1 and 10.

II) *Internal characteristics of an alternative*

These major criteria are based on the performance of the Garonne water resource system after implementation of the project. To model this performance, a simplified simulation model has been developed in Cordeiro-Netto (1991), using a spreadsheet format. Technical and environmental impact assessment studies have also been taken into account in CACG (1989), SAFEGE (1984), SAVINE (1987) and SOGREAH (1989). Roughly speaking, these criteria can be classified as measures of reliability, resiliency and vulnerability, as suggested by Hashimoto et al. (1982).

a) *Vulnerability*

The vulnerability types of criteria are the most important ones in this study. Some of them are evaluated on a qualitative scale, such as **environmental impact**, **social impact** and **macro-economic effects**. Monetary units are used for criteria such as **construction**, **operation**, **compensation** costs and **agricultural benefits** (expected values). These are derived from the simulation of the modified complete system. Other vulnerability criteria include **riparian length benefits** (length in km of rivers that will benefit from the project) and expected values of **annual irrigated area** in hectares.

b) *Reliability*

For each project we can compute by simulation the probability that at least 90% of the total annual water demand will be satisfied each year (**reliability** criterion).

c) *Resiliency*

In this case study, we use a subjective scale to estimate the extent of irreversible effects for each alternative. An alternative will receivea good evaluation if it can be easily shut down and/or transformed at low cost so as to return the system as nearly as possible to its original state (**flexibility** criterion).

1.2.2 *How do criteria relate to DM group preferences?*

Although all actors agreed on the existence of the previous 13 criteria, they would not consider each one of them as equally important. Table 2 shows the judgement of each criterion importance according to the four groups. After discussions were held to reach general agreement of members within each group, a four-level scale was adopted (none, low, medium and high). One should note that the value "none" was used by an actor to characterize a criterion which would not be taken into account in the final overall judgement.

1.3 The Alternatives

Previous studies identified three potential sites for building a large dam: Charlas, Laurélie and Vabre. Figure 1 shows the study area with the localization of those sites and their zone of influence. The zone of influence of Charlas consists of Cells 1a and 1b. Cells 2 and 3 correspond to the zone of influence of Laurélie and Vabre, respectively. Cell 4 is the region that would benefit from each one of the three dams. Table 3 displays the most important characteristics of each project.

From an operational point of view, an alternative should answer to the following questions:

- which dams are to be built?
- which capacities are to be chosen?
- at which time would these dams begin contributing to the Adour-Garonne water resources?
- what are the complementary actions (other sites, improvement of existing reservoir operational rules,...) that could be implemented?

To summarize an alternative consists of a set of possible elementary actions taken in a given sequence aimed at improving the Adour-Garonne water resources. We have reduced the uncountable number of such alternatives to the 38 listed in Table 4, taking into account technical feasibility and the results of preliminary discussions with local decision-makers.

One should note that this set is composed of five main families of alternatives:

- a null alternative (which was considered in this study as the reference point);
- the reallocation of hydroelectric storage for irrigation uses, which has the merit of avoiding the construction of a new dam but implies a complete change in the *EDF*'s priorities: due to networking of national electricity production and distribution such a solution would imply consequences at a national level;
- alternatives 3 to 16 refer to a prior construction at the site of Charlas with a decision made either in 1992 or 2000, to take various complementary water resource actions;
- alternatives 17 to 30 are centered at the site of Vabre with different storage capacities, in addition to other water resource augmentation solutions schemes from Charlas or Laurélie river basins;
- alternatives numbered 31 to 38 consist of building the main dam at the Laurélie site with complementary supply from other valleys.

1.4 The Pay-Off Matrix

Table 5 presents, for a selected group of eight alternatives, the ratings or consequences on the 13 selected criteria: these ratings were estimated as explained in Section 1.2.1. Taking into account DMs arguments, we defined, for each criterion, three thresholds:

TABLE 1

SELECTED CRITERIA

CHARACTERISTICS OF ALTERNATIVE	TYPE OF CRITERION	CRITERION	UNIT	direction of preference
external		financing	1 to 10	>
		reservoir operation	1 to 10	>
		experience requirement		
internal	vulnerability	environmental impact	1 to 10	<
		social impact	1 to 10	<
		macro-economic effects	1 to 10	>
		construction costs	MF	<
		operation costs	MF	<
		compensation costs	MF	<
		agricultural benefits	MF	>
		riparian length benefits	km	>
		annual irrigated area	hectares	>
	reliability	90% reliability	% of sat.*	>
	resiliency	flexibility	1 to 10	>

* - probability of satisfying at least 90% of the total annual water demand
(MF - one million French francs)

TABLE 2

ASSESSMENT OF THE IMPORTANCE OF EACH CRITERION

Criterion	actor			
	GAS	GES	WUO	EPO
financing	high	medium	none	none
reservoir operation	medium	medium	medium	none
experience requirement				
environmental impact	medium	high	low	high
social impact	medium	high	low	high
macro-economic effects	low	medium	low	low
construction costs	high	medium	medium	medium
operation costs	high	medium	medium	medium
compensation costs	medium	high	low	high
agricultural benefits	medium	medium	high	medium
riparian length benefits	none	medium	none	high
annual irrigated area	medium	none	high	low
90% reliability	medium	medium	high	low
flexibility	medium	medium	medium	medium

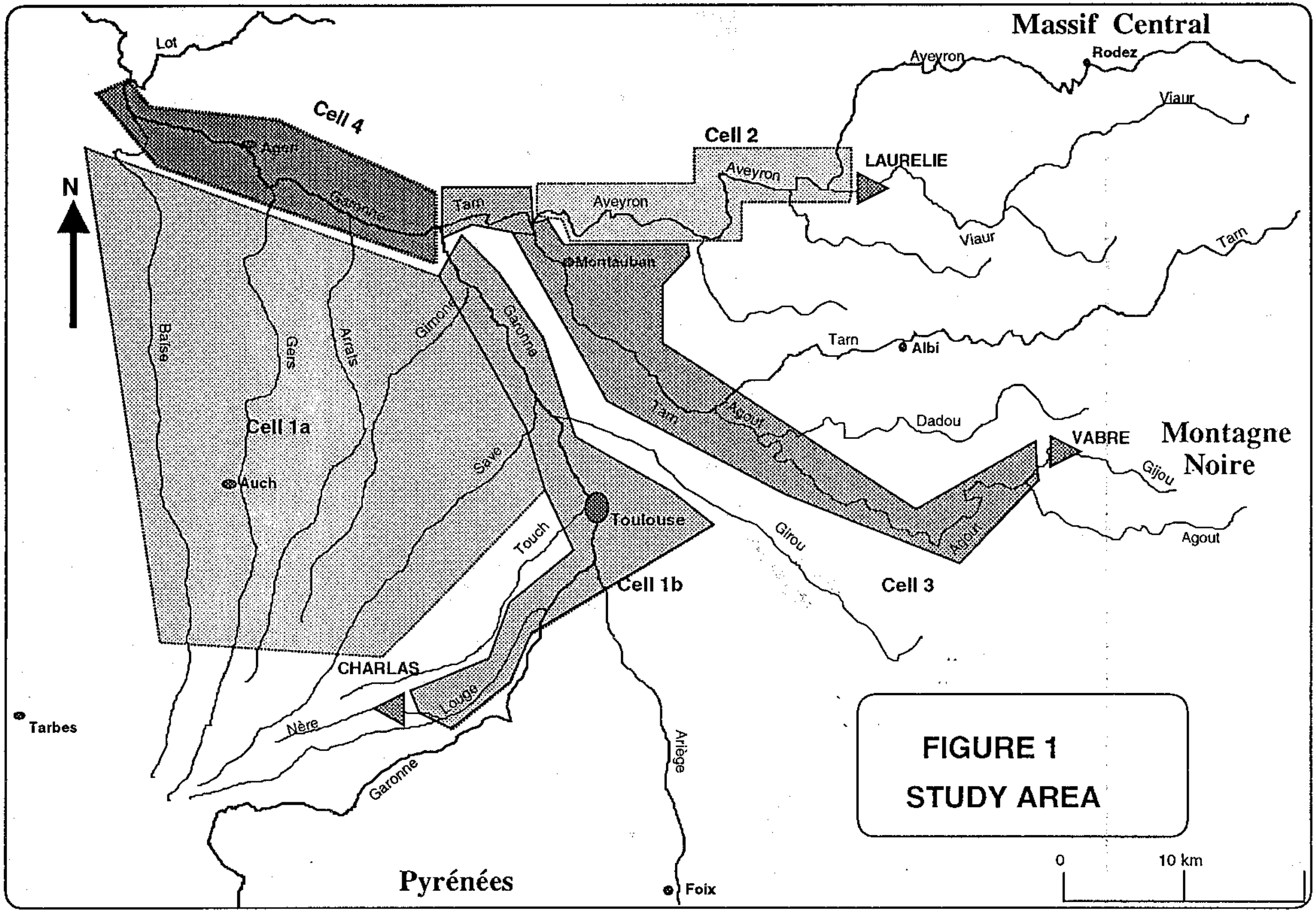

FIGURE 1
STUDY AREA

TABLE 3
CHARACTERISTICS OF EACH DAM PROJECT

	PROJECTED DAM	CHARLAS	LAURELIE	VABRE
	location	70 km south of Toulouse	25 km north of Albi	40 km southeast of Albi
	number of potential sites	2 (two)	3 (three)	2 (two)
	type of dam	earth and rockfill dam	rockfill dam	rockfill or arch-gravity dam
C	height above ground level	49,5 m	67,0 m	70,0 m
H	reservoir level	380 NGF	242 NGF	449 NGF
A	reservoir surface	556 ha	375 ha	281 ha
R	storage capacity	110 hm3	75 hm3	72 hm3
A	catchment area	13 km2	1,425 km2	151 km2
C	interbasin diversion	YES	NO	NO
T	upstream controled area	2,150 km2	1,425 km2	151 km2
E	hydroelectric production	NO	POSSIBLE	NO
R	ancillary works	39.5 km of headrace	hydroelectric plant	NO
I		and diversion canals		
S	dam cost (1)	509 MF	382 MF	255 MF
T	canals cost (1)	411 MF	----	----
I	submersion costs (1)	76 MF	57 MF	102 MF
C	total cost	996 MF	439 MF	357 MF
S	investment cost per m3 improved (1)	9.05 F/m3	5.85 F/m3	4.95 F/m3
	social impacts	medium	medium	high
	environmental impacts	low	high	medium
	number of flooded buildings	1 (one)	31 (thirty-one)	66 (sixty-six)
	other flooded structures	roads, energy transmission line	roads	roads, pisciculture, church and cemeteries
	flooded woods/agric. lands/others	69.5 / 555.5 / ----	271.0 / 117.0 / ----	192 ha / 87 ha / 27 ha
	upstream hydrolectric storage capacity	283 hm3	168 hm3	121 hm3

Notes:
1) All costs are expressed in French francs (reference January 1988). Presently, 1 US$ = 5.50 FF.

TABLE 4
ALTERNATIVES

ALTERNATIVES		ALTERNATIVES	
N°	DESCRIPTION	N°	DESCRIPTION
1	do nothing	20	Vabre 92/72
2	reallocation of hydroelectric storage	21	Vabre 92/72 + Charlas 00/110
3	Charlas 92/110 + partial Laurélie + partial Vabre	22	Vabre 92/72 + Charlas 05/110
4	Charlas 92/110 + partial Vabre	23	Vabre 92/72 + Laurélie 00/75
5	Charlas 92/110 + partial Laurélie	24	Vabre 92/24 + partial Charlas + partial Laurélie
6	Charlas 92/110	25	Vabre 92/24 + partial Charlas
7	Charlas 92/110 + Laurélie 00/75	26	Vabre 92/24 + partial Laurélie
8	Charlas 92/110 + Vabre 00/72	27	Vabre 92/24
9	Charlas 92/110 + Vabre 00/24	28	Vabre 92/24 + Charlas 00/110
10	Charlas 00/110 + partial Laurélie + partial Vabre	29	Vabre 92/24 + Charlas 05/110
11	Charlas 00/110 + partial Vabre	30	Vabre 92/24 + Laurélie 00/75
12	Charlas 00/110 + partial Laurélie	31	Laurélie 92/75 + partial Charlas + partial Vabre
13	Charlas 00/110	32	Laurélie 92/75 + partial Charlas
14	Charlas 00/110 + Laurélie 05/75	33	Laurélie 92/75 + partial Vabre
15	Charlas 00/110 + Vabre 05/72	34	Laurélie 92/75
16	Charlas 00/110 + Vabre 05/24	35	Laurélie 92/75 + Charlas 00/11(
17	Vabre 92/72 + partial Charlas + partial Laurélie	36	Laurélie 92/75 + Charlas 05/11(
18	Vabre 92/72 + partial Charlas	37	Laurélie 92/75 + Vabre 00/72
19	Vabre 92/72 + partial Laurélie	38	Laurélie 92/75 + Vabre 00/24

Name of the dam XX/YY where XX - year of decision and YY - dam capacity in hm3
partial "Name of the dam" - partial (and immediate) reallocation of the hydroelectric storage behind that "dam".

"q" (indifference threshold), "p" (strict preference threshold) and "v"(veto threshold), that are also shown on Table 5. Between "q" and "p" the preference situation is "hesitation", meaning that only after "p" one is confident on the data to state that one action is "surely" preferred to another (Roy, 1985).

2 METHODOLOGY

Here a two step procedure has been adopted for studying the above long term water resource planning program in Southwestern France within its multiple actor multiple criterion framework. Although this two step procedure has only been designed for research purposes, it appears to be quite realistic and could have been conveniently implemented in the real time decision process. Indeed the first step corresponds to a preliminary overview of all possible alternatives. This relative comparison between actions is not really very far from a "ß" type of problem, described in Roy (1985), in which one wants to assign each action into a category. In our case, this affectation is based in the relative comparison with no reference to norms distinguishing the categories of real problem of class "ß". Our aim is to select a subset of alternatives for negotiation between the four DM groups. Although screening the 38 alternatives could have been made with ELECTRE I, II or IV, PROMETHEE techniques (Vincke, 1992), we use ELECTRE III technique for convenience (Skalka et al., 1992). Only a small number of alternatives has been kept for a thorough examination on the basis of a combination of the four DMs' ELECTRE III results.

In the second phase , we will focus on how each DM group can bargain and express its preferences. We model this negotiation phase by analyzing the reduced number of alternatives obtained after step 1 using two different group decision making techniques to test if a "satisficing" compromise solution can be elucidated (termed as an "α" problem in Roy's classification). Namely, as in Zeleny (1982), we extend the ELECTRE III technique by assuming that the global group concordance matrix is the minimum intersection of the set of individual concordance matrices.

This first approach based on ELECTRE concordance and discordance concepts, which is mostly quantitative, has been compared to a non numerical multiple expert MCDM technique as given in Yager (1993) and briefly described in Section 3.2.2. Table 6 sums up the avenue of thought to our case study in the following sections.

3 APPLICATION

3.1 Using an extension of ELECTRE III to reduce the number of alternatives

3.1.1 *Methodological basis of ELECTRE III.*

ELECTRE III is an MCDM technique which is used to describe the behavior rationale of a single DM (Roy, 1985; Vincke, 1992). It represents the characteristics of the DM's preferences by pairwise concordance and discordance tables calculated for each criterion. The concordance index $\mathbf{c_i(a,b)}$ expresses the fuzzy membership value of the statement *Alternative **a** is at least as good as alternative **b*** as far as criterion **i** is concerned, while the discordance index evaluates the "comparability" of action **a** and action **b**, i-e, tests whether or

TABLE 5
PAY-OFF MATRIX FOR THE ALTERNATIVES SELECTED

CRITERION	UNIT	sens of pref.	thresholds q	p	v	ALTERNATIVES 2	10	11	17	18	19	26	31
financing	1 to 10	>	1	2	7	7	4	4	5	5	5	6	5
reservoir operation experience requirement	1 to 10	>	1	2	7	9	8	8	5	5	5	5	2
environmental impact	1 to 10	<	1	2	7	2	3	4	5	6	5	4	8
social impact	1 to 10	<	1	2	7	2	4	4	9	9	9	8	4
macro-economic effects	1 to 10	>	1	2	7	5	6	6	6	6	6	5	6
construction costs	MF	<	100	200	600	938	1387	1275	814	702	583	266	1015
operation costs	MF	<	2	5	20	15	16	11	16	11	11	8	16
compensation costs	MF	<	5	20	180	0	87	87	168	168	168	84	92
agricultural benefits	MF	>	3	5	50	38,7	27,7	24,7	33,7	30,7	24,7	12,8	35,5
annual irrigated area	km2	>	20	40	30	1160	1050	1020	1110	1080	1020	900	1130
riparian length benefits	km	>	40	100	600	758	653	426	710	483	468	468	720
90% reliability	% *	>	0.05	0.20	0.70	0.35	0.80	0.70	0.90	0.80	0.70	0.50	0.90
flexibility	1 to 10	>	1	2	7	10	7	6	8	7	6	5	8

* - satisfaction of at least 90% of the total annual water demand each year

TABLE 6
TECHNIQUES USED IN THE CASE STUDY

ANALYSIS	PURPOSE	MAIN CHARACTERISTICS	SOLUTION PROCEDURE USED
1st phase Reproduce DMs' selective overview of solutions	to reduce the number of alternatives and prepare a thorough examination	Aggregation of preorders obtained for each DM by an ELECTRE III analysis	Extension of ELECTRE III
2 nd Phase Negotiation between DM's on a limited number of solutions	to select a subset of compromise solutions by weighting quantitative indices	Search for a compromise solution on a minimum concordance technique	Extension of ELECTRE III
	to approximate the qualitative behavior of DMs' in the negotiation process	A project should be discarded if it gets a poor rating on an important criterion	ME-MCDM

not their range is beyond a veto threshold for the i^{th} criterion scale. Using a set of criterion weights, it is then possible to aggregate these concordance and discordance tables into an overall credibility matrix which contains in row **A** and column **B** the general valuation for the assertion *action **a** outranks action **b***, i-e, the relative positive global weight in favor of **a** (whenever **a** can be compared to **b**). As this fuzzy outranking relation is usually too refined for any practical use, a distillation procedure is implemented to approximate this complex pairwise comparison by two complete preorders obtained by "cutting" the fuzzy outranking relations with "slicing" thresholds first in a decreasing and then in an increasing order. Figure 2 shows a schematic view of ELECTRE procedure.

3.1.2 *Specific extension of ELECTRE III.*

Using the 38 alternatives and 13 criteria in the case study, we performed four ELECTRE III analyses, one for each DM group and its particular set of weights. It is worth noting that, due to our strong modelling assumptions, the preference of a DM group is represented by this set of weights.

For a sensitivity analysis, we considered two sets of weights. The four-level linguistic scale, shown in Table 2 (none, low, medium and high) has been transformed into numeric ones using the two sets of weights {1, 2, 3, 4} and {1, 3, 5, 7}. We thus assume that the linear value function was used with two different slopes. Note that different considerations could have been applied for this transformation process.

Table 7 displays part of the 38x38 concordance for the sixth criterion. For a single DM, let us exemplify how to calculate the contribution $c_6(2,17)$ of the sixth criterion (construction cost in French Francs) to the concordance index between Alternative 2 (938×10^6 FF) and Alternative 17 whose cost is only a little "better" (814×10^6 FF). On that criterion, we note that the difference 124×10^6 FF(938×10^6 - 814×10^6) is such that it stands in between the indifference threshold of 113×10^6 FF and the strict preference threshold of 227×10^6 FF. Therefore Alternative 17 is weakly preferred to 2 and only a percentage of the weight of the criterion "construction cost" will count for the concordance index between Alternatives 2 and 17. This percentage is computed as follows:

$$c_6(2,17) = 0.91 = \frac{(227 - 124)}{(227 - 113)};$$

so that it varies between 1 (bellow the indifference zone) and 0 (beyond the strict preference threshold). Note that the concordance is a non symmetric concepts and this criterion would count with all its weight for the concordance index $c_6(2,17)$ for Alternative 17 is weakly preferred to Alternative 2.

In the same way, in Table 8, one can check that the discordance index $d_6(2,19)$ is **1** because Alternative 19 does not belong to the same category of construction costs as Alternative 2: the criterion values are farther apart than the admissible veto threshold range of the sixth criterion (470×10^6 FF).

These indices are then aggregated using the criterion weights to obtain, **for each DM,** a fuzzy outranking relationship (credibility table). Each one yields two complete preorders by means of the distillation procedure (Roy, 1985). For each set of weights, the 4x2 preorders can be combined to obtain a single partial preorder "p" as follows:

p(**a**,**b**) = **1** if all local preorders agree on **a** ≥ **b** with at least once **a** > **b**;
p(**a**,**b**) = **-1** if all local preorders agree on **b** ≥ **a** with at least once **b**> **a**;

p(**a**,**b**) = **0** if all local preorders agree on **a** = **b** ;
p(**a**,**b**) = * if we have contradictions, i-e, some preorders for which **a** $\geq$ **b** and some others for which **b** > **a** .

Table 9 shows, as an example, the partial preorder p(**a**,**b**) for a set "a" and "b", selected as a = (10, 11, 17) and b = 38 alternatives.

We will keep for further group negotiation analysis the projects belonging to a maximal set **M** of the partial preorder relationship p. Notice that using this aggregation technique does not resolve in any way *Condorcet's paradox*: we tolerate "non-comparability" between projects but keep only a subset **M** of alternatives (called "kernel") such that:

$$\forall\, \mathbf{y} \in \mathbf{J\text{-}M}, \exists\, \mathbf{x} \in \mathbf{M}, \mathbf{x} \underset{\mathbf{p}}{>>} \mathbf{y}$$

$$\forall\, \mathbf{x}, \mathbf{y} \in \mathbf{M}, \mathbf{Not}\ (\mathbf{x} \underset{\mathbf{p}}{>>} \mathbf{y})\ \mathbf{AND}\ \mathbf{Not}\ (\mathbf{y} \underset{\mathbf{p}}{>>} \mathbf{x})$$

"Non-comparability" between action **a** and **b** does not imply their systematic belonging to a set **M** , but for each of the partial family **A** and **B**, where the restriction of >> is a complete order, we shall only keep the maximum element $\mathbf{a}^*$ and $\mathbf{b}^*$ such that:

$$\forall\, \mathbf{a} \in \mathbf{A}, \mathbf{a}^* \underset{\mathbf{p}}{>>} \mathbf{a}$$

$$\forall\, \mathbf{b} \in \mathbf{B}, \mathbf{b}^* \underset{\mathbf{p}}{>>} \mathbf{b}$$

Of course a subset **M** is composed of equivalent or non comparable alternatives.

3.1.3 *Case study results*

After performing ELECTRE III. analysis four times (one for each DM) , we aggregate the 8 (2x4) complete preorders into a single partial preorder from which we extract the maximum subset M. To incorporate a sensitivity analysis into the various encoding of DMs' qualitative preferences among criteria, the procedure is applied using the two sets of weight parameters chosen in Section 3.1.2; finally the union of the maximum subsets is retained.

Table 10 shows the subset M in this case study by indicating the difference between the number of positive and negative outranking for each couple of alternatives. For instance we have Alternative 10 preferred to Alternative 2 three times and one equivalence out of 4 local preorders

As it can be expected, the 8 projects finally selected still reflect the high variability of possible alternatives that can be classified into **four families** according to their engineering characteristics:
- Alternative 2 is not to build any dam but to buy all water needed from large existing hydropower reservoirs;
- Alternative 10 prones the building of a large dam at the Charlas site with partial reallocation of hydroelectric storage upstream of Laurélie and Vabre sites, and Alternative 11 is a variation of Alternative 10, without reallocation of hydroelectric storage upstream of the site of Laurélie;

- Alternative 17 consists in creating a large volume of water resources at Vabre with minor complements from other basins. Alternatives 18, 19 and 26 belong to the same family as Alternative 17 and only differ in the size of the dam and complementary release options;
- Alternative 31 is the construction of the third possible site (Laurélie), with partial reallocation of hydroelectric storage upstream of Charlas and Vabre sites.

3.2 PHASE 2: Selecting an alternative

With the 8 previously selected alternatives, we want to refine our analysis so as to be able to seek and find a "satisficing" negotiated agreement. In this paper we propose two approaches. One is based on ELECTRE III concepts, the second one refers to a technique proposed in Yager (1993). Both techniques share the idea that compromise attempts in conflicting situations that are not aggressive may be described in terms of trying to reach a "minimum" agreement. In the ELECTRE III based technique this minimum operator is applied to each DM's concordance tables, that is, we only consider the minimum credibility valuation of the binary outranking relation between pairs of alternatives. In the other procedure (Yager 1993), a minimum ranking operation is performed directly on the qualitative judgement of each alternative, which may lead to a complete preorder.

3.2.1 *ELECTRE III*

I) ***Methodological considerations.***

For each DM, we consider the overall concordance table (Roy, 1985; Vincke, 1992). Let **c(a; b; k)** be the $\mathbf{k^{th}}$ DM's concordance index for action **a** *versus* **b**.

Without computational difficulties, one can calculate:

$$\mathbf{c(a,b)} = \underset{k}{\mathrm{Min}}\ \mathbf{c(a,b/k)}$$

It means that we consider the group as a "super" DM for whom the valuation of the statement ***a is at last as good as b*** is the minimum of each individual DM's degree of certainty in the previous sentence. Then by substituting this aggregated DM, a single ELECTRE III procedure is implemented: taking into account the discordance tables (recall that they are not DM related criteria) one can compute a credibility index so as to get a fuzzy outranking relation that is approximated by two complete preorders.

II) ***Case study application***

To enhance the difference between the eight alternatives in this last phase, the preference threshold has been reduced by one half. We left indifference and veto thresholds unchanged for we considered that both uncertainty and "incomparability" remained in this second stage of the decision process. Table 11 shows the resulting credibility indices; the two preorders of the eight alternatives are depicted in Figure 3. One can notice that non zero credibility indices are very scarce, which expresses a strong influence of the discordance effects.

The combination of the two preorders does not especially favour Alternative 10, i-e, construction of the Charlas large dam, which is the final project that was selected in the real decision process. More precisely, it was decided that if complementary technical, social and economic studies "indicated" that a dam should be built, this dam would be Charlas, the one of Alternative 10. In such a case, Alternative 2, that is the reallocation of existing hydropower resources for other water uses, is still under consideration by the DMs.

The extension of the ELECTRE III technique recognizes a family of preferred alternatives but does not specify any one of them, due to "non-comparabilities" introduced by the veto discordance matrices.

This effect can be mitigated by lowering the veto thresholds. If we do not take into account any veto, the analysis will be based on the overall concordance indices listed in Table 12, using weight set (1,2,3,4). The previous procedure will lead to ranking first Alternative 2 (which is presently a possible decision); that is, the reallocation of existing hydropower resources for other water uses is put forth, as shown in Figure 4. A sensitivity analysis using the other set of weight parameters confirms this final ranking.

3.2.2 *ME-MCDM*

I) *Introduction*

Yager (1993) describes an MCDM technique called Multi Expert - Multi Criteria Decision Making (ME-MCDM), that evaluates and selects alternatives using a non-numeric scale. Each expert evaluates each alternative on each criterion. Criteria can have different degrees of importance for each expert. However, the technique considers only a single DM, not a group DM.

In a first stage, a single linguistic value rating for each expert on each alternative is provided. In a second stage, individual experts' evaluations are aggregated in order to obtain a single linguistic value for each alternative.

Yager considers that the numeric scales, despite their allowing aggregation, are not appropriate to evaluate and to select alternatives in case of multiple experts MCDM problems. In particular, he considers that judgements expressed in a numeric scale often take a "fake precision" that is very far from the actual validity of the evaluation. In fact he suggests an approach which avoids the so-called "tyranny of numbers" but which satisfies certain aggregation requirements.

II) *The initial table of data*

Consider a set of proposals (alternatives) from amongst which one should be selected, a set of experts whose task is to assess each one of the alternatives, and a collection of linguistic evaluations rating alternatives on the basis of the criteria. Let

$i = 1,\ldots\ldots\ldots\ldots,I$	where	I = number of criteria.
$j = 1,\ldots\ldots\ldots\ldots,J$	where	J = number of alternatives
$k = 1,\ldots\ldots\ldots\ldots,K$	where	K = number of experts
$S = \{S_1,\ldots\ldots\ldots,S_Q\}$	where	Q = number of linguistic evaluations.

One assumes that $f(j;i;k) \in \{S\}$, where $f(j;i;k)$ is the evaluation of the j^{th} proposal on the i^{th} criterion by the k^{th} expert, using the scale given by S.

In our case study we assumed that $Q = 5$ so that we have the corresponding evaluations:

S_1 = very low

TABLE 7
CONCORDANCE TABLE FOR THE SIXTH CRITERION

Cost in million of French Francs	Alternatives	Alternatives							
		2	10	11	17	18	19	26	31
938	2	1.00	1.00	1.00	0.91	0.00	0.00	0.00	1.00
1,387	10	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
1,275	11	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.31
814	17	1.00	1.00	1.00	1.00	0.86	0.00	0.00	1.00
702	18	1.00	1.00	1.00	1.00	1.00	0.60	0.00	1.00
583	19	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00
266	26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1,015	31	1.00	1.00	1.00	0.36	0.00	0.00	0.00	1.00

q = indifference threshold - 113 million FF
p = strict preference threshold - 227 million FF

TABLE 8
DISCORDANCE TABLE FOR THE SIXTH CRITERION

Cost in million of French Francs	Alternatives	Alternatives							
		2	10	11	17	18	19	26	31
938	2	0.00	0.00	0.00	0.00	0.37	1.00	1.00	0.00
1,387	10	0.92	0.00	0.00	1.00	1.00	1.00	1.00	0.48
1,275	11	0.45	0.00	0.00	1.00	1.00	1.00	1.00	0.05
814	17	0.00	0.00	0.00	0.00	0.00	0.60	1.00	0.00
702	18	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
583	19	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
266	26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,015	31	0.00	0.00	0.00	0.02	0.79	1.00	1.00	0.00

q = indifference threshold - 113 million FF
p = strict preference threshold - 227 million FF

TABLE 9
AGGREGATED PARTIAL PREORDER "p" FOR THE SET OF WEIGHTS (1,3,5,7)

ALTERNATIVES	ALTERNATIVE 10	ALTERNATIVE 11	ALTERNATIVE 17	ALTERNATIVE 10	ALTERNATIVE 11	ALTERNATIVE 17	ALTERNATIVES
1	1	*	*	1	1	1	20
2	1	*	*	1	1	1	21
3	1	*	*	1	1	1	22
4	1	*	*	1	1	1	23
5	1	1	1	1	*	1	24
6	1	1	1	1	1	1	25
7	1	1	1	1	*	*	26
8	1	1	1	1	*	1	27
9	1	1	1	1	1	1	28
10	0	*	*	1	1	1	29
11	*	0	*	1	1	1	30
12	1	1	1	1	*	1	31
13	1	1	1	1	1	1	32
14	1	1	1	1	1	1	33
15	1	1	1	1	1	1	34
16	1	1	1	1	1	1	35
17	*	*	0	1	1	1	36
18	1	*	*	1	1	1	37
19	1	*	*	1	1	1	38

TABLE 10
A SUBSET "M" FOR THE CASE STUDY

Alternatives	Alternatives						
	2	10	11	17	18	26	31
2	*	-3	-1	-1	-1	-3	-1
10	3	*	2	3	1	3	3
11	1	-2	*	1	2	2	2
17	1	-3	-1	*	1	1	3
18	1	-1	-2	-1	*	0	0
26	3	-3	-2	-1	0	*	-1
31	1	-3	-2	-3	0	1	*

TABLE 11
OVERALL OUTRANKING CREDIBILITY INDEX

Alternatives	Alternatives							
	2	10	11	17	18	19	26	31
2	1	0	0	0	0	0	0	0
10	0	1	0,94	0	0	0	0	0,62
11	0	0	1	0	0	0	0	0
17	0	0	0	1	0,92	0,83	0	0
18	0	0	0	0,57	1	0,96	0	0
19	0	0	0	0	0,69	1	0	0
26	0	0	0	0	0	0,04	1	0
31	0	0	0	0	0	0	0	1

TABLE 12
OVERALL CONCORDANCE MATRIX (NO VETO)

Alternatives	Alternatives							
	2	10	11	17	18	19	26	31
2	1	0,87	0,84	0,86	0,75	0,75	0,69	0,87
10	0,21	1	0,94	0,61	0,76	0,79	0,68	0,62
11	0,20	0,68	1	0,43	0,58	0,85	0,73	0,54
17	0,38	0,61	0,57	1	0,92	0,83	0,59	0,76
18	0,27	0,51	0,61	0,84	1	0,96	0,64	0,52
19	0,27	0,43	0,61	0,53	0,69	1	0,64	0,45
26	0,29	0,31	0,43	0,51	0,53	0,57	1	0,53
31	0,46	0,82	0,78	0,77	0,68	0,68	0,61	1

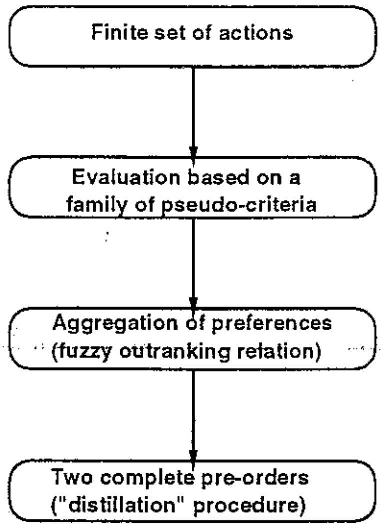

FIGURE 2
SCHEMATIC VIEW OF ELECTRE III

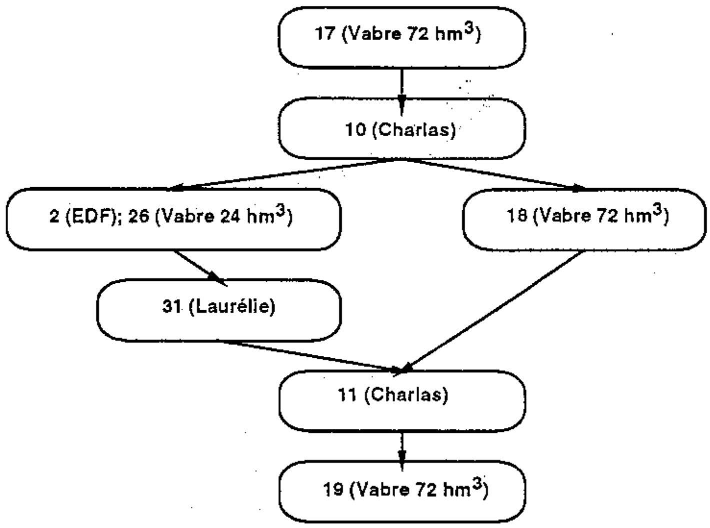

FIGURE 3
ELECTRE III FINAL OUTRANKING

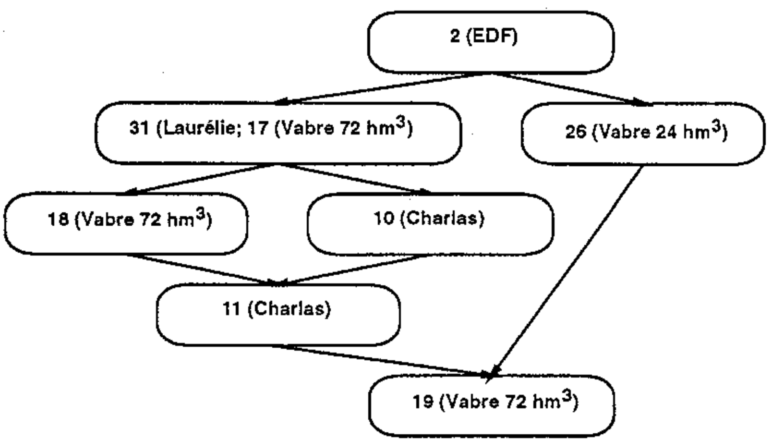

FIGURE 4
OUTRANKING GRAPH WITH NO VETO THRESHOLDS

S_2 = low
S_3 = medium
S_4 = high
S_5 = very high

Taking into account symmetry considerations, Yager also defines the operation "negation of importance" as:

$$\text{Neg}(S_q) = S_{Q-q+1}.$$

With Q = 5, we have:

Neg (very low) = Neg (S_1)= S_{5-1+1} = S_5 = very high
Neg (low) = high
Neg (medium) = medium
Neg (high) = low
Neg (very high) = very low

III) *How does a DM elucidate a preference alternative?*

In the first stage of his approach,Yager proposes the definition of a unit score of each alternative by each expert, i-e, the elimination of the criterion dimension. The methodology in this stage could be summed up as follow:

$$F_{jk} = \text{Min}_i\,[\text{Neg}(P_{(k;i)}) \vee f(j;i;k)]$$

where:

F_{jk} = overall judgement by expert "k" for alternative "j" ($F_{jk} \in \{S\}$).
$P_{(k;i)}$ = importance of each criterion "i" for each expert "k" ($P_{(k;i)} \in \{S\}$).
$\vee$ = max operation

In other words, an expert rates an alternative highly if no poor rating is assigned to the alternative on the "main" criteria (as defined by the expert himself).

In order to apply this methodology, we have made the following simplifications:

- for the eight selected alternatives, the scores ("consequences") in each criterion were transformed from numeric values to a qualitative evaluation by:
  .. considering the worst score as a "very low" (S_1) evaluation and the best score as "very high" one (S_5),
  .. dividing the numeric differences between the best and the worst scores into four equal numeric intervals corresponding to the linguistic evaluations,

- the four-level linguistic evaluation of the assessment of the importance of each criterion (Table 4) was transformed into a five-level linguistic evaluation as shown bellow:

Four-level scale	Five-level scale
none	very low (S_1)
low	low (S_2)
(*no correspondence*)	medium (S_3)
medium	good (S_4)
high	very high (S_5)

Note that this transformation as we have done mainly for illustration purposes is subjective: its influence on the results should be checked further by a sensitivity analysis. Table 13 shows the results obtained for our case study. One may note that all alternatives present a low performance for every group. The reasons for such a performance have been discussed in Section 3.2.3.

IV) ***Combination of DM judgements to arrive at a compromise alternative***

As proposed by Yager (1993), the second stage of the approach consists of the elimination of the multiple expert dimension in order to select a compromise alternative.

A first run yields an aggregation function which may be considered as a general notion of the proportion of favorable ratings that makes an alternative acceptable. This approach can be described as follow:

$$Q_{A(n)} = S_{b(n)}$$

where:

$Q_{A(n)}$ = evaluation needed for an alternative to be considered acceptable by "n" experts ($Q_{A(n)} \in \{S\}$) (in our case, we do not consider experts, but DMs).

$S_{b(n)}$ = linguistic evaluation ($S_{b(n)} \in \{S\}$, $1 \leq b(n) \leq 5$, in our case).

$$b(n) = \text{Int}\,[1 + (n * (Q-1)/K)]$$

where:

n = number of "groups" (experts or DMs) considered for the definition of a compromise action ($1 \leq n \leq 4$).

K = number of experts (in our case, the number of DMs, $K = 4$).

Q = number of linguistic evaluations (in this case, $Q = 5$)

Int[a] = integer closest to "a".

With $K = 4$ and $Q = 5$, we have:

$$b(n) = \text{Int}\,[1 + (n * 4/4)] = \text{Int}\,[1 + n]$$

$Q_{A(1)} = S_2 =$ low
$Q_{A(2)} = S_3 =$ medium
$Q_{A(3)} = S_4 =$ high
$Q_{A(4)} = S_5 =$ very high

Having selected $Q_{A(n)}$, a method called OWA (ordered weighted averaging) is proposed to aggregate the expert opinions. Considering F_{jk} (overall judgment of expert "k" for alternative "j") and "K" the number of experts, a final evaluation of alternative "j" is evaluated as:

$$F_j = \text{Max}_k\,[Q_{A(n)} \wedge B_n]$$

where:

B_n = n^{th} highest score among the experts unit scores for the alternative (in our case, n = 1, 2, 3 or 4 and $B_k \in \{S\}$).
$\wedge$ = min operation

Considering in our case the alternative "2", we have:

F_{21} = very low; F_{22} = low; F_{23} = very low and F_{24} = low (see Table 13).

Reordering those scores we get:

B_1 = low
B_2 = low
B_3 = very low
B_4 = very low

Considering the function $Q_{A(n)}$, with $1 \leq n \leq 4$:

F_2 = Max [low $\wedge$ low; low $\wedge$ medium; v. low $\wedge$ high; v. low $\wedge$ v. high]
F_2 = Max [low; low; very low; very low]
F_2 = low

Table 14 shows the overall evaluation of each action applying such an approach. All actions are equally evaluated as "poor"! We are thus left with this dilemma. The inefficiency of this technique applied to our case study may be partially due to the particularly limited scale adopted here. In his paper, Yager chooses Q=7. To consider such a refined scale, it is necessary to enter into thorough discussion with the members of each group, which was not possible in our case because we only considered at the beginning of the decision process the same data as in ELECTRE III in order to compare the two techniques. We did not have the opportunity to schedule several meetings with DM groups before the actual decision process started.

Another reason for which this technique failed to work in our case study may be traced to our specific adaptation. In fact, the ME-MCDM technique was originally designed by Yager (1993) for the case of a single DM, whos is to aggregate multiple experts' advices, and then to make a final decision.

TABLE 13
OVERALL EVALUATION OF EACH ACTION BY EACH GROUP

Actor	Action	Overall Jugement
AGS	2	very low
	10	very low
	11	very low
	17	very low
	18	low
	19	low
	26	low
	31	very low
EGS	2	low
	10	low
	11	low
	17	very low
	18	very low
	19	very low
	26	low
	31	very low
WUO	2	very low
	10	low
	11	low
	17	low
	18	medium
	19	low
	26	very low
	31	low
EPO	2	low
	10	low
	11	very low
	17	very low
	18	very low
	19	very low
	26	low
	31	very low

TABLE 14
OVERALL EVALUATION OF EACH ACTION

ACTION	GROUP				Overall
	AGS	EGS	WUO	EPO	Evaluation
2	very low	low	very low	low	low
10	very low	low	low	low	low
11	very low	low	low	very low	low
17	very low	very low	low	very low	low
18	low	very low	medium	very low	low
19	low	very low	low	very low	low
26	low	low	very low	low	low
31	very low	very low	low	very low	low
OWA	low	medium	high	very high	

4 DISCUSSION

4.1 Assumptions

The particular context of this case study has allowed us to construct a simple and coherent multiple expert multi-criteria framework. Our first assumption is that the pay-off matrix is uniquely determined by a rational consultant who is not involved in the decision process and whose technical expertise is accepted by all DM. This could be the case in feasibility studies of large dam projects although the skill and impartiality of engineers in charge of environmental studies has sometimes been contested.

As a second hypothesis, the DM's behavior is supposed to be fully encoded into a set of weights assigned to objective criteria. Even if it were the case, the numerical valuation of criterion importance may lead to significant bias in the study and its conclusions. In the case study, it has been assumed that DMs had a linear value function with two moderate gradients, A sensitivity analysis cannot always counterbalance this bias, for it never eliminates completely the subjective choices of the system analyst. For instance, one could have used a numerical value "zero" to encode the subjective coefficient of importance "none". Moreover one can imagine that the DM preference attitude is also related to his own perception of the criteria importance. The value of a one million $ difference between two projects may be quite different for the agricultural administration and the ecological interest group. Even if a value function were assessed for each group, the problem of "intercomparison" of group value functions would remain.

If the actors are really willing to accept their responsibilities and select by consensus a plan or project, then a decision will be reached after a negotiation process of which may be quite different from a combination of DMs individual options. Here, we chose a minimum operator to represent the concordance that the group will elicit: this form of consensus rule should be tested with our DMs. Of course, this last assumption is undoubtedly too optimistic. Here, game theoretic techniques may then provide suitable models (Fraser and Hipel, 1991).

One should note that Yager (1993) proposes a methodology for the case of a single DM and multiple experts. Our case does not follow the same framework, as it is concerned with a single expert and multiple DMs. In order to apply Yager's approach, we have made a strong hypothesis stating that the methodology could be used for a multi-actor problem (for both multiple DMs and multiple experts). On the other hand, we deliberately accept some information loss in order to fit Yager's framework, which is a very questionable step, even though we are dealing with very imprecise numerical data collected from subjective human judgements. Still the main drawback of Yager's technique, at least as it was applied in the second phase of this study, is the loss of information incurred when evaluating already quantified effects using qualitative ratings. Nevertheless, it seems that it could be of interest in the first phase of the analysis designed to screen the alternatives. Some other techniques could eventually be applied after collecting more information concerning DMs' preferences, such as fuzzy composite programming or a combination of fuzzy numbers representing expert opinions.

4.2 From the study to an actual policy

Discrepancies between theory and practice are bound to occur. From a theoretical point of view, we must recognize that our final selection may not have been Alternative 10 (Charlas) which is presently studied in great detail as a possible site. Alternative 2 (reallocation of hydroelectric water storage) and Alternative 17 (Vabre) appear as possible competitors in our investigation. The Vabre alternative was considered to be too harmful to the environment by the ecological group DM and then by the Expert Commission, which convinced the Ministry of Environment not to consider that project.

Alternative 2, i-e, EDF providing an annual contract of complementary resources in case of drought, has been put aside because of the difficult financial negotiations between the EDF and representatives of Agriculture and Environment ministries (high transaction costs). Presently, an agreement has been obtained concerning a ten-year contract called "*waiting for Charlas*": EDF reallocates its water reserves in case of occurrence of low flows downstream (at a river point upstream of irrigation withdrawals). The renewal of such a contract is considered possible by EDF, but with other financial conditions: an increase of hydroelectric production costs is expected. We may consider that Alternative 2 is still a possible one.

5 CONCLUSIONS

At the expense of small modifications of phase 2 of ELECTRE III, individual preference, indifference and veto thresholds can be embedded into the general scheme presented in this paper. Another difficulty may be that DMs interfere with one another. In the present case study, the decision process is sufficiently slow that we can neglect, in a first approximation, such temporal effects.

The main result found in this paper concerns the setting of a general MCDM problem framework including all decisional elements (38 alternatives, 13 criteria and 4 DMs) and an approach to reduce the problem to a simpler choice situation (8 alternatives). Linking two ELECTRE analyses in series seems to provide a good way to achieve this goal. At this point, with the available data and no further hypothesis on the DMs behavior, we cannot go further in recommending a solution.

In any of the two tested techniques,

- the computational burden is reasonable,
- the underlying assumptions are easy to explain to the decision makers,
- the procedures are easily understandable, with no "black box" results: this feature may result in further complementary discussions between actors so as to cast more light on the decision process.

The concept of pseudo criterion in ELECTRE III is well adapted to this kind of desk top analysis with uncertain or vague values of the various effects. The main drawback of ELECTRE III is that it is more sensitive to the veto thresholds than the weights of each criterion set, making it impossible to propose a general agreement on the basis on a minimum concordance extension but showing clearly why and how the leading projects are selected, which may be just as important.

The methodological issues developed in this paper do not consider operational concepts for negotiation such as possible trade-offs between actors, asymmetry of information or coalitions. In spite of these drawbacks, the proposed extensions of MCDM techniques can be used as a reasonable starting point, based on an easily "implementable" analysis, for a further negotiation phase.

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