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CONFLICT PATTERNS AND COMPROMISE SOLUTIONS IN FUZZY CHOICE THEORY

An analysis and application

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1. Introduction

In modern social choice theory and planning theory a great deal of attention is being paid to conflicting priorities between individuals, decision-makers and interest groups. The intricate nature of interactions between members and groups of our modern society appears to involve a wide variety of spill-over effects such that almost all decisions and actions affect the welfare position of others. External effects are no longer abnormalities in an otherwise rational market system, but they increasingly form a central element of it.

Traditional choice methodologies (single-objective optimization theory, cost-benefit and cost-effectiveness approach, maximum entropy hypotheses etc.) have lost a great part of their operational relevance due to their restricted scope (the naïve assumptions about a single-valued social objective function, the neglect of equity elements, the neglect of institutional and social power elements etc.). The lack of scientific consensus regarding the place of social sciences (especially social choice theory) emerges from a methodological friction between the holistic and the action-oriented approach (see also Cohen [1968], Eyles [1974] and Rex [1961]). The holistic view focusses its attention on the unity of various phenomena and on equilibrating forces in case of substantial differences or frictions among phenomena. This view is reflected inter alia in structural-functional views in social sciences and in systems theories. The action-oriented approach places much emphasis on the way in which and the groups by which social choices and decisions are made. Clearly, in the action-oriented view a wide variety of different views, priority schemes and groups are taken into account.

It is important to notice, however, that the holistic and the action approach are essentially not absolute anti-poles, but complementary views of reality. This implies that a comprehensive view of social choice problems should pay attention to both the structure of the system at hand (by means of an impact analysis, e.g.) and to the divergence in political options or in individual (or group) preferences.

The present paper is an attempt to provide an operational methodology for analysing conflicts among groups, especially in the field of diverging priorities regarding the attributes of discrete public plans (or projects). The attention will also be focussed on the institutional (for example, hierarchical) structure of many decision and evaluation problems. Next, a framework will be developed which takes into account the intangible aspects of choice problems. This framework will be based on some notions from fuzzy set theory, as many choice problems are not so clearly defined and precisely demarcated as assumed in traditional utility theory. This approach appears to result into a qualitative social choice theory. A method will be proposed to solve these qualitative (discrete) choice problems (or at least to identify compromise solutions). Next, an attempt will be made to gauge the social distances between the various groups involved in a qualitative decision problem on the basis of a new application of ordinal multidimensional scaling techniques. Finally, the whole analysis will be illustrated by means of an empirical application to a land use conflict in the Northern part of the Netherlands.

2. Elements of Social Choice Conflicts

An operational analysis of social choice problems is fraught with difficulties. Consequently, it is extremely important to formulate a set of methodological criteria which should be satisfied by social choice theories in general (see Nijkamp [1978a]). The following criteria may be mentioned:

a) a definition of categories and concepts which is relevant from the viewpoint of social choice and planning theory
b) objectifiable information (including qualitative data) which provides a platform for a broader scientific discussion
c) integration of incommensurable and intangible elements of social choice problems
d) integration of all broader aspects of social choice problems (inequality and equity problems, interest conflicts, distributional impacts of uncompensated costs, etc.).
e) a justification of the scale and scope of the analysis concerned (for example, a micro-, meso- or macro-level) as well as an exposition of the depth and width of the analysis
f) an assessment of the degree of uncertainty and of the reliability of influences (via stochastic analyses, fuzzy set methods or simulations, e.g.).
g) a description of the various planning (or policy) levels and of all actors involved, as well as a description of all conflicting priorities.

Several of these criteria are also valid for many other social theories and methods, but in the context of the present study especially the criteria c), d), f) and g) are quite important, as in this study particular attention will be paid to qualitative choice problems in a broader social setting including divergences in priorities at different choice levels.

Assume a social choice problem with N alternative actions or decisions. These alternatives may be various locations of public facilities, various social security systems, various urban renewal plans etc. They will be denoted by $a_1,\dots,a_N$. Each action or decision a_n ($n=1,\dots,N$) can be regarded as a *stimulus* which gives rise to a set of *responses.* For example, the responses (impacts, ~~a~~effects) of an urban renewal project may be *inter alia* an improved housing quality, a better accessibility etc. Each of these responses will be denoted by an impact variable r_{ni} ($i=1,\dots,I$). This implies that there exists a stimulus-response function f which transforms a_n into r_{ni} :

$$f : a_n \longrightarrow r_{ni} \qquad \forall i \tag{2.1.}$$

The latter function incorporates the structure pattern of the system at hand.

The sphere of influence of a stimulus (in other words, the location of the response) may be far removed from the original source. For example, emission of waste in a certain area may cause social costs in surrounding areas. Thus, if the system concerned is divided into compartments (regions or groups, e.g.), a distinction may be made between *internal* (i) and external (e) impacts:

$$\begin{tikzcd}[row sep=small] & r^{i}_{ni} & \\ f : a_n \arrow[ur] \arrow[dr] & & \forall i \\ & r^{e}_{ni} & \end{tikzcd} \tag{2.2.}$$

In other words, each nth action (choice of the nth alternative) gives rises to the emergence of an *internal impact profile* $\underline{r}^{i}_{n}$ and an *external impact* profile $\underline{r}^{e}_{n}$.

In many choice problems, a_n is not the result of a simple and unambiguous evaluation procedure. The judgement of a_n and its resulting impacts is often a matter of political conflicts in which decision groups and interest groups sometimes play a diffuse role, especially because many of these groups are not entirely homogeneous (for example, discrepances among government departments regarding the choice of public facilities). When the various groups involved in a decision problem are denoted as p_j ($j=1,\dots,J$) one may assume an operator function g which transforms the simultaneous, conflicting and interdependent actions of all J groups into the choice in favour of a specific alternative n :

$$g : p_j \longrightarrow a_n \qquad \forall j \tag{2.3.}$$

This transformation function represents essentially the political decision procedure concerning the choice among the alternatives $a_1,\dots,a_N$. For example, the policies of the various groups might be co-ordinated in a hierarchical way by a central decision unit; or, on the contrary, the various political options might lead to serious power conflicts among the groups involved. The foregoing remarks can also be represented in a figurative manner (Fig. 1).

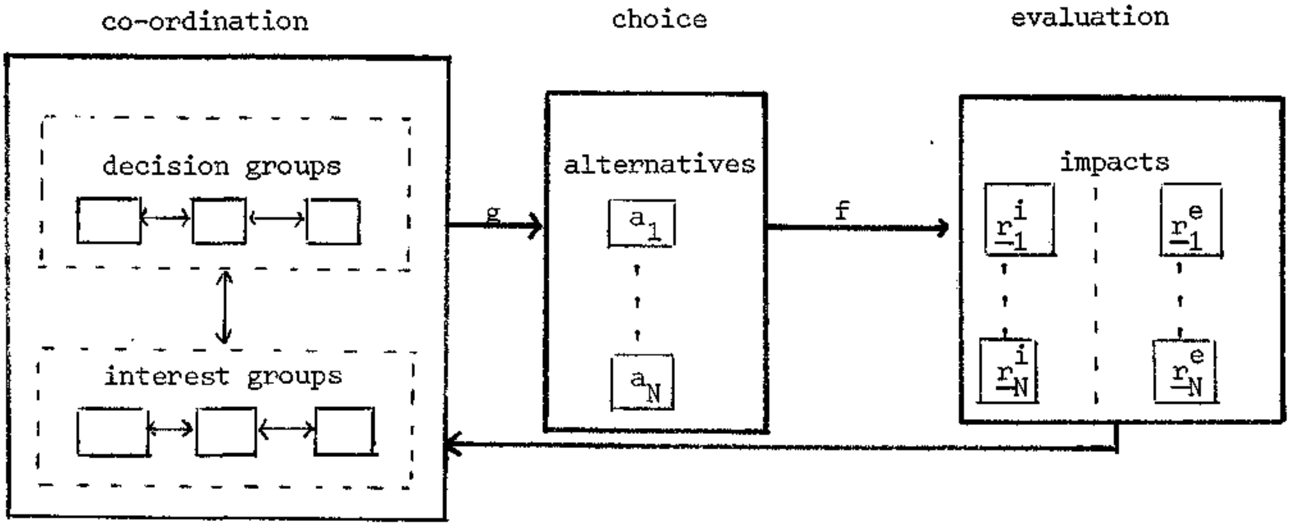


Fig. 1. A decision scheme for social choice problems.

Fig. 1 indicates by means of 3 blocks that a social choice problem may include 3 types of frictions or conflicts, viz. (a) between *decision groups* and/or *interest groups*, (b) between *alternatives* and (c) between impacts. Furthermore, there are 3 additional problems: (a) the decision groups (or interest groups) are not always precisely demarcated sets, (b) the alternatives are not always well-defined and (c) the impacts include many intangible and qualitative elements. The existence of these divergences and uncertainties in a social choice problem implies that such a problem can be characterized as a *fuzzy multi-group multi-criteria analysis*.

Multi-criteria analysis is a recently developed methodology for dealing with choice problems related to discrete alternatives. A basic feature of this method is the existence of a series of various (mainly non-monetary) decision criteria (see for a survey and applications among others Bertier and Bouroche [1975], Blair [1978], Boyce et al [1970], Cohon and Marks [1975], Van Delft and Nijkamp [1977], Guigou [1974], Lichfield et al [1975], and Zeleny [1976]). Multi-criteria analysis will be discussed in more detail in the next section.

A *multi-group choice problem* refers to the existence of multiple groups involved in a decision or evaluation problem. The degree of divergence and of bargaining determines the ultimate result of such a choice problem (cf. Haefele [1973] and Saaty [1977]). Normally, such a result is a compromise solution. The relative distance between decision groups in case of multiple qualitative (or fuzzy) criteria will be further analyzed in section 3.

Finally, a fuzzy choice problem is characterized by the fact that the decision criteria, the decision groups or the alternatives are not sharply defined, so that the decision area as a whole is not demarcated in an unambiguous manner (see for example Bellman and Zadeh [1970]). This will also be discussed more extensively in section 3.

3. A Fuzzy Multi-group Multi-criteria Analysis

A multi-criteria analysis aims at providing a consistent and systematic framework for judging the social value of multi-attribute alternatives by taking simultaneously into account a broad set of heterogeneous (often conflicting) decision criteria. The meaning of a multi-criteria analysis is to find the best alternative from a set of discrete alternatives.

The majority of multi-criteria analyses developed so far was based on a quantitative (mainly cardinal) evaluation procedure. Only a few attempts have been made to incorporate qualitative (mainly ordinal) information. Examples of qualitative multi-criteria analyses can be found among others in Blair [1978], Holmes [1971], Jacquet - Lagrèze [1969],Paelinck [1976] and Van Delft and Nijkamp [1977].

Blair's qualitative multi-criteria analysis centers around constructing a matrix of pairwise comparisons of attributes such that the entries of this matrix indicate the dominance of one activity over another with respect to a specific comparison criterion. By transforming the preference analysis into an eigenvalue problem, the vector of relative weights of the attributes being compared can be assessed. This eigenvalue prioritization model is especially important to derive a cardinal judgement scale, but is not directly appropriate as an evaluation technique, so that then a complementary analysis is necessary.

Holmes' method is based on a classification of decision criteria according to importance classes. Next, the alternatives are classified for each criterion according to their degree of performance. The ranking of the alternatives is then based on a lexicographic ordering of the combined importance classes and performance classes. This procedure is a rather simple and straightforward evaluation method, although especially the specification of ordinal equivalence categories may be criticized (see also Lichfield et al [1975]).

Jacquet - Lagrèze's analysis is based on a permutation technique and makes use of the successive rank orders of alternative plans (in terms of performances for each separate criterion). The basic idea is to develop a procedure which investigates the degree at which each plan supports the hypothesis that this plan dominates all others. This analysis requires a simultaneous analysis of weights and performances via successive permutations. In this way, the most probable ranking of plans can be determined. Paelinck's analysis is essentially a generalization of the latter method.

Finally, Van Delft and Nijkamp have developed a purely qualitative analysis in which both the criterion weights and the plan performances are denoted by fuzzy or qualitative statements such as 'good', 'reasonable' etc. By examining for each class of weights the qualitative rank orders of the alternatives, a final conclusion may be inferred regarding the most desirable ranking of the alternatives. A variant of the latter method will be presented here after a brief presentation of some elements from fuzzy set theory.

Fuzzy set theory is based on the assumption that many key elements in human thinking are not numbers, but rather linguistic variables (such as long, very long, not long, etc.). Fuzziness is a type of impression which is associated with categories in which there is no sharp transition from membership to non-membership. In other words, the demarcation criterion of a fuzzy set is linguistic in nature. Consequently, there are grades of membership intermediate between full membership and non-membership.

Let $X = \{x\}$ be a set of objects. Then a fuzzy subset A of X is characterized by a membership function which associates with each element x of X a number $\mu_A(x)$ in the interval $[0,1]$ which represents the grade of membership of x in A. The elements 0 and 1 represent, respectively, the lowest and highest grade of membership. Thus, the inexact concept of fuzziness is described by associating with each object x a number between 0 and 1 via an auxiliary membership function. This function can be used to carry out numerical operations upon fuzzy set problems and it also constitutes the basis of a large set of fuzzy algorithms (see among others Bellman and Giertz [1973], Bellman and Zadeh [1970], Blin [1977], Capocelli and De Luca [1973], Chang and Zadeh [1972], Deloche [1975], Goguen [1969], Jacquet - Lagrèze [1977], Lassibille and Parron [1975], De Luca and Termini [1972], Ragade et al [1976], Zadeh [1971a, 1971b, 1973], and Zadeh et al [1975].

Some of these algorithms, for example, refer to the union and intersection of fuzzy sets. Let A and B be two fuzzy sets, with $\mu_a(x)$ and $\mu_B(x)$ denoting their membership function, then the union U of A and B is usually denoted as:

$$(3.1.) \qquad U = A \cup B ,$$

where the membership function of U is defined by:

$$(3.2.) \qquad \mu_U(x) = \max \{\mu_A(x), \mu_B(x)\}$$

Similarly, when the interaction P of two fuzzy sets A and B is denoted by:

Similarly, the performances (impacts, effects, values of responses) of each alternative can also be classified according to certain fuzzy classes, such as 'very high value' (0000), 'high value' (000), 'normal value' (00) and 'low value' (0). The effectiveness scores can be incorporated in an effectiveness table which represents the outcomes of all criteria over all alternatives (see Table 2).

alternative criterion	1 . . . . N
1	000 00
.	0
.	.
.	.
.	.
.	.
.	.
.	
.	
.	
.	
I	

Table 2. A fuzzy effectiveness table.

The effectiveness table can be used as a frame of reference to construct a paired comparison matrix over all alternatives for each individual criterion. The entries of this matrix have also a fuzzy character, for example, 'great difference' (xxx), 'normal difference' (xx) and 'negligible difference' (x). This implies, for example, that a strong dominance of plan n with respect to n' for a certain criterion i can be denoted as xxx. Clearly, these performance symbols need a certain quantitative background or a frame of reference such that the responses can be classified according to the fuzzy performance classes xxx, xx and x. For each criterion a paired comparison matrix can now be constructed with entries xxx, xx and x (Table 3).

alternative alternative	1 . . . . N
1	
.	
.	
.	
.	
.	
.	
.	
.	
.	
.	
N	

Table 3. A paired comparison matrix.

In case the performance of an alternative is worse than that of a competing one, the symbol - is being used. Because the table is skew-symmetric, only the positive dominance symbols xxx, xx and x will be used in the subsequent analyses.

The next step of the fuzzy multi-criteria analysis is to combine the results from Table 1 and 2 toward a new table which indicates for each pair of alternatives the frequency of the performance classes xxx, xx and x and their distribution over the importance classes +++, ++ and + (see Table 4).

pairwise comparison of alternative n with n'	+ + +			+ +			+		
	xxx	xx	x	xxx	xx	x	xxx	xx	x
1 - 2	r^A_{12}	r^B_{12}	r^C_{12}	r^D_{12}	r^E_{12}	r^F_{12}	r^G_{12}	r^H_{12}	r^I_{12}
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
1 - N	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Σ	r^A_1	r^B_1	r^C_1	r^D_1	r^E_1	r^F_1	r^G_1	r^H_1	r^I_1
⋮									
N - 1	r^A_{N1}	r^B_{N1}	r^C_{N1}	r^D_{N1}	r^E_{N1}	r^F_{N1}	r^G_{N1}	r^H_{N1}	r^I_{N1}
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
N - N-1	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Σ	r^A_N	r^B_N	r^C_N	r^D_N	r^E_N	r^F_N	r^G_N	r^H_N	r^I_N

Table 4. An integrated paired comparison table with fuzzy performance and importance classes.

For example, the element r^A_{12} denotes the frequency that alternative 1 has a much better performance (xxx) than alternative 2, given the fact that these performances are related to very important decision criteria (+++). Similarly, the element r^A_1 represents the total dominance of alternative 1 over all other alternatives for both a high performance (xxx) and a great importance of the criteria concerned (+++). Consequently, r^A_1 is defined as:

$$r^A_1 = \sum_{n=2}^{N} r^A_{1n} \qquad (3.5.)$$

Inversely, one may define the degree at which alternative 1 is dominated by other alternatives (for a performance class xxx and an importance class +++) as:

$$(3.6.) \qquad \hat{r}_1^A = \sum_{n=2}^{A} r_{n1}^A$$

Finally, it is a logical step to define a <u>net dominance indicator</u> as:

$$(3.7.) \qquad \hat{\hat{r}}_1^A = r_1^A - \hat{r}_1^A$$

A similar dominance indicator can be constructed for all alternatives n (n=1,...,N) and for all classes A,...,I. The results can be incorporated in a net dominance table (Table 5).

class alternative	A	B	– – – – –	I
1	$\hat{\hat{r}}_1^A$	$\hat{\hat{r}}_1^B$	– – – – – –	$\hat{\hat{r}}_1^I$
⋮	⋮			
N	$\hat{\hat{r}}_N^A$	$\hat{\hat{r}}_N^B$		$\hat{\hat{r}}_N^I$

Table 5. Net dominance table for all alternatives.

The latter table contains all relevant information for an elimination and selection of alternatives based on a fuzzy multi-criteria analysis. For example, it is clear that an alternative n will get a high rank order when $\hat{\hat{r}}_n^A$ is relatively high, whearas this alternative will get a low rank order when $\hat{\hat{r}}_n^I$ is relatively high. Consequently, for each set of importance categories (to be specified by the decision-maker or decision-group at hand) and for each set of performance categories (to be provided by the expert or analyst), in principle a certain rank order of alternatives can be derived.

So far the assumption has been made that only one decision-maker or decision-group had to judge the desirability of the alternatives. In case of a multi-group evaluation problem, one may assume that each group has its own priorities reflected by a specific preference table 1. In fact, a group is also a fuzzy set of individuals. The only demarcation criterion of a group is an imprecise ranking of preferences for the successive decision criteria. Here again the membership function is transformed into a fuzzy qualification of priority rankings of each group. In other words, an adjusted matrix may be constructed which reflects for each group j (j=1,...,J) the priorities for each criterion i (i=1,...,I) by assigning the criteria to the three importance classes +++, ++ and + (Table 6).

criterion group	1 — — — — — — — — I
1	+ +++
'	++
'	
'	
'	
'	
J	

Table 6. Priority rankings of criteria among groups.

This implies that in case of J different groups j (j=1,...,J) a matrix of rank orders can be derived (Table 7) which reflects the priority rank orders of the alternatives. The entries of this matrix are ordinal numbers varying from 1 (highest priority) to N (lowest priority).

alternatives group	1 — — — — — — — N
1	
'	
'	
'	
'	
'	
J	

Table 7. Priority rankings of alternatives among groups.

The information contained in Table 6 and 7 reflects the conflicts among different groups (either decision units or interest groups). Table 6 represents in a fuzzy way the diverging priorities in terms of qualitative (or linguistic) statements concerning decision criteria, while Table 7 represents the final qualitative ranking of alternatives among all groups. Now the question may be posed whether these conflicting priorities may ultimately lead to a compromise solution. To that end it is important to know the relative differences among all alternatives over all decision criteria (see Table 2 and 3), the relative differences in preferences among all groups (see Table 6) and the relative differences in the ranking of the alternatives over all groups (see Table 7). This is briefly summarized in Fig. 2.

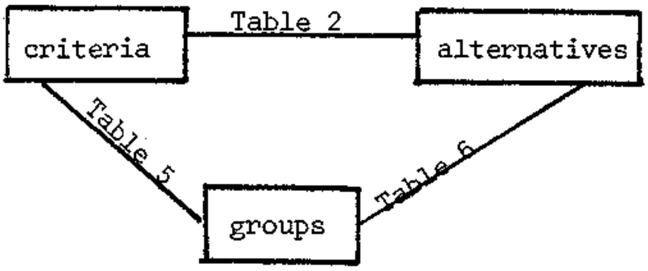


Fig. 2. A figurative representation of all links in a fuzzy multi-group multi-criteria problem.

As the information contained in Table 2 (or 3), 6 and 7 is qualitative in nature, arithmetic operations can hardly be carried out. Thus the judgement of meaningful compromise solutions among conflicting preferences, alternatives and groups requires the use of adjusted methods. This will be the subject of the next section.

4. Multidimensional Scaling Methods for Fuzzy Problems

Many qualitative (or linguistic) statements (such as 'tall', 'very tall' etc.) can be associated with ordinal numbers. These ordinal numbers only reflect a certain ranking, but the differences between ordinal numbers cannot be used as a cardinal measure of discrepancy between the items or attributes. In so far as fuzzy statements can be characterized via ordinal numbers, ordinal rankings or importance classes, multidimensional scaling (MDS) techniques are extremely important tools to draw quantitative (i.e., cardinal) inferences from qualitative data.

MDS methods were originally developed in the field of mathematical psychology (cf. Carroll and Chang [1970], Coombs [1964], Kruskal [1964], Lingoes and Roskam [1971], and Torgerson [1954]), but the spectrum of these methods has been expanded substantially during the last decade (see for a survey among others Nijkamp and Van Veenendaal [1978], Nijkamp and Voogd [1978], and Voogd [1977]).

MDS procedures involve ranking of similarities or dissimilarities among alternatives (objects, items, attributes etc.) by individuals or groups and employing a geometric scaling algorithm to generate a geometric representation of the position of the alternatives and of the judges in a space of given dimensionality. By means of this operation metric conclusions can be inferred concerning the relative discrepances between items, attributes or judges. The essential idea of MDS methods is that a representation of ordinal data in a geometric space with fewer dimensions implies that more ordinal conditions are available than geometric coordinates are necessary. Hence, MDS methods use degrees of freedom to transpose ordinal inputs into metric outputs. The coordinates are to be determined such that the interpoint distances between the points in a geometric space do not contradict the ordinal conditions implied by the input data. In other words, this monotonicity condition should guarantee a correspondence between the original (ordinal) (dis)similarities and the Euclidean distances in a geometric space with a lower dimensionality. The technique itself will not be exposed here, but can be found in the references quoted.Only some illustrative remarks will be made here.

For example, assume on ordinal paired comparison table for N objects. This means that we have determined for N objects N(N-1)/2 ordinal statements (or conditions). A representation of these N objects in a two-dimensional Euclidean space requires only 2N numbers, viz. the coordinates of N points in a two-dimensional space. Thus, the N(N-1)/2 ordinal relations can be used to identify 2N cardinal numbers (see Fig. 3).

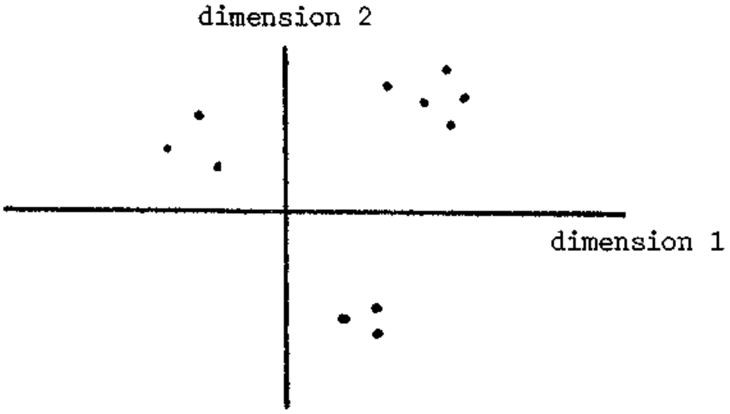


Fig. 3. Figurative representation of MDS results in a two-dimensional space.

Given the coordinates of the points in Fig. 3, quantitative statements can be inferred about the cardinal distances between the successive objects.

In the same way, the position of the judges (at least the relative weights attached by the judges to the items) can be represented in a geometric space. This implies, that the relative differences in priorities of the judges can be assessed, so that the degree of mutual (dis)agreement can be quantified and the degree of cognitive consistency among the judges can be gauged.

In the framework of the present study, the data from Table 2 and 3 can be used to quantify the positions of the alternatives on synthesized major criteria. Table 6 allows us to derive a cardinal measure for the preference position of the judges and the divergences implied by these positions, while finally the results of Table 7 focus on the cardinal evaluation of the alternatives by the judges. On the basis of these results, one may attempt to identify compromise solutions for the conflicting priorities by seeking for an alternative with a minimum discrepancy with regard to the imputed preference positions of the judges. Furthermore, the latter approach identifies simultaneously the ideal alternative, assuming that all judges or groups involved are weighed equally.

In case not all judges (or decision groups) are to be weighed equally, the theory of Shapley and Shubik [1954] may be meaningful to derive importance scores (or power coefficients) for the successive judges or groups involved in the decision process. When there is a great deal of uncertainty about the relative power position of the judges or groups, a parametrization of the power coefficients may be carried out in order to test the sensitivity of the results. The next section will be devoted to an empirical application of the analysis described in section 3 and 4.

5. An Empirical Application to a Land Use Conflict

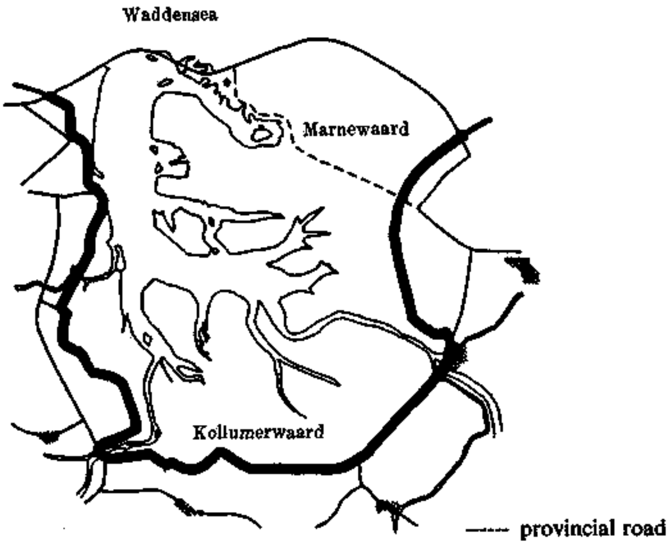
The abovementioned methods may be illustrated by a land use problem in the Northern part of the Netherlands[1]. In 1969 the Lauwerssea-area was captured from the sea to add flood protection and improve the hydraulic situation in that part of the country (see map). A series of different land use designs was proposed, with several interest groups coming forward with varied ideas for the area. The following land use proposals may be distinguished: natural area, recreational area, agricultural area, and military training area. The latter has received particular attention, since the Dutch army, in need of additional military training camps in a densely populated country, at the outset claimed two parts of the Lauwerssea-area, the Marnewaard and the Kollumerwaard. A by-product of the enclosure of this area has been its subsequent development into an ecologically balanced habitat for geese, ducks, and gulls, motivating environmentalists to raise objections to the presence of the army and its camps.

The administrative aspects add further conflicts in this example of

[1] The author is indebted to Fred Kolfoort and Wouter van Veenendaal for their assistance in data collection and computer work, respectively. The description of this land use problem is derived from Nijkamp [1977].

regional planning. The Lauwerssea-area is divided among four different administrative municipalities. These municipalities are divided among two provinces, Friesland and Groningen. Since provinces in the Netherlands play a key role in physical planning, the relative preferences of province councils are extremely important for land use design. Unfortunately, these two provinces have different priorities with respect to the Lauwerssea-area: Friesland supports the military use, Groningen prefers the natural and recreational purposes.

At the national level, where ultimately the decision will be made, several ministries are involved in this decision-making process: the Ministry of Defense, the Ministry of Traffic and Hydraulic Affairs, the Ministry of Housing and Physical Planning, and the Ministry of Culture, Recreation and Social Services. Given the diverse interests, a homogeneous decision is unlikely, and so far the ultimate decision has been postponed continuously.



THE LAUWERSSEA-AREA

The intention of this paper is not to provide the final answer to this regional planning problem in the field of land use and environmental design. It attempts to offer a systematic framework on the basis of which the diverse interests can be evaluated and transformed into consistent choices.

The first step was to carry out an impact analysis of different land use proposals. After careful analysis of all possible solutions, a set of six alternative plans, considered to be relevant in the decision-making process by all parties involved, was chosen. These alternative plans are:

1. A military training camp both in the Marnewaard and the Kollumerwaard during 48 weeks every year; the remaining part of the Lauwerssea-area to be divided among natural, recreational, and agricultural uses.
2. A military training camp both in the Marnewaard and the Kollumerwaard during 35 weeks every year, in which case the Marnewaard is intersected by a provinvial road; the remaining part is again divided among the other designations.
3. A military training camp only in the Marnewaard during 48 weeks; the Kollumerwaard receiving an agricultural and recreational designation; the remaining parts to be divided among all other uses.
4. A military training camp only in the Marnewaard during 35 weeks, in which case the Marnewaard is again intersected by a provincial road; the other parts are equal to plan 3.
5. A military training camp only in the Northern part of the Marnewaard during 35 weeks; the remaining parts of the Lauwerssea-area to be divided among natural, recreational and agricultural uses.
6. No military designation; the whole Lauwerssea-area is used as a natural, recreational and agricultural area.

The next step of the analysis is to operationalize the decision criteria related to this environmental design problem. In the present paper, only a limited number of main categories of decision criteria will be distinguished in order to obtain relevant information from the side of the diverse decision-makers and interest groups. After an examination of all aspects of the land use problem of the Lauwerssea-area, the following five main decision categories were: (1) the importance of the area for the Dutch army and the national self-defense system (D); (2) the natural and ornithological value of the area (N); (3) the agricultural aspects of a certain land use design (A); (4) the recreational function of each alternative plan (R); (5) the socioeconomic consequences of each plan (S).

These five main decision categories can be operationalized by dividing them into subsets and by measuring (or assessing) the outcomes of the decision criteria for each subset (see Nijkamp [1977]). In the present study, however, only the fuzzy outcomes of the main criteria will be employed to construct an aggregate table with ordinal effectiveness scores (see Table 8).

alternative criterion	1	2	3	4	5	6
D	4	3	2	2	2	1
N	1	2	3	3	3	4
A	1	1	2	2	3	4
R	1	2	2	3	3	4
S	4	4	3	3	2	1

Table 8. Fuzzy effectiveness matrix

In addition to the effectiveness matrix, a matrix with fuzzy priorities for some decision groups and interest groups involved in the land use problem was constructed based on interviews with representatives from these groups. The following groups were distinguished:
Ministry of Defense (I), Ministry of Culture, Recreation and Social Services (II), the province Friesland (III), the working-group Lauwerssea (IV), the municipality of Kollumerland (V) and the municipality of Ulrum (VI). The priority rankings of these groups are included in Table 9.

criterion group	D	N	A	R	S
I	3	2	1	2	3
II	1	3	1	3	1
III	3	2	3	2	3
IV	1	3	2	2	1
V	2	2	2	2	1
VI	1	2	3	3	3

Table 9. Fuzzy priority matrix

Table 8 was used to create a paired comparison matrix (see Table 3), on which basis an integrated paired comparison table with fuzzy effectiveness and importance classes could be derived (see Table 4). The ultimate results of the dominance analysis described in section 3 are represented in Table 10, which represents the rank order of all alternatives among all 6 groups involved.

group \ alternative	1	2	3	4	5	6
I	6	5	4	3	2	1
II	1	2	3	4	5	6
III	6	4	5	3	2	1
IV	1	2	3	4	5	6
V	6	5	3	4	2	1
VI	2	1	3	4	5	6

Table 10. Priority rankings of 6 alternatives among 6 groups

The entries of Table 10 are related to the successive plans described above. The ordinal rankings are such that the highest values represent the highest priorities.

The results of this table are rather illustrative, because they reflect the existence of serious discrepancies among the parties involved: group I (Defense), III (Friesland) and V (Kollumerland) attach a high priority to a land use by the Dutch army, whereas the remaining parties have more or less reverse priorities.

The next step of the analysis is to apply a multidimensional scaling method to Tables 8 - 10 in order to derive a metric outcome for the discrepancies between priorities, alternatives and parties according to the lines exposed in section 4[1]. The results of the multidimensional scaling techniques applied to Tables 8 - 10 are represented in a two-dimensional pattern in Figures 4 - 6, respectively. The average ideal points on the origin are positive ideal points, so that a closer distance of a certain point implies a higher perceived or estimated value with respect to the origin.

Fig. 4 represents the results of the ordinal impact matrix in a joint space for two dimensions. These results demonstrate quite clearly a ranking of the alternative plans. Plan 1 (the most far-reaching space occupation by the army) is depicted entirely at the left-hand side, subsequently followed by the other plans up to plan 6 (the natural area alternative) at the right-hand side.

The criteria demonstrate also a fairly clear spatial pattern. The criteria positioned at the right-hand side are related to recreational, environmental and agricultural destinations, whearas the criteria at the left-hand side are

[1] The method applied here is an adjusted version of the Minirsa program described in Roskam [1975].

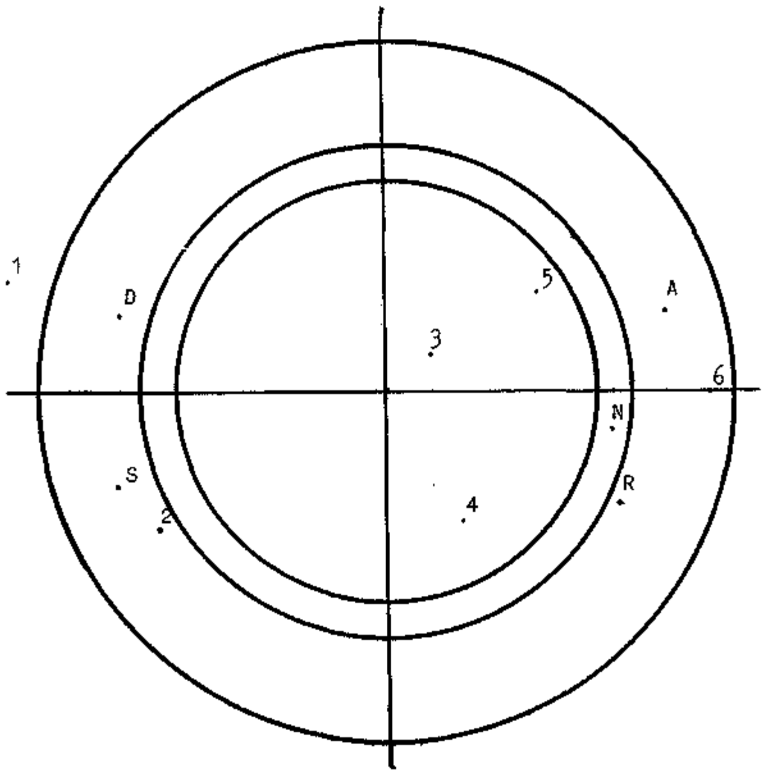


Fig. 4. Joint space of plans and criteria.

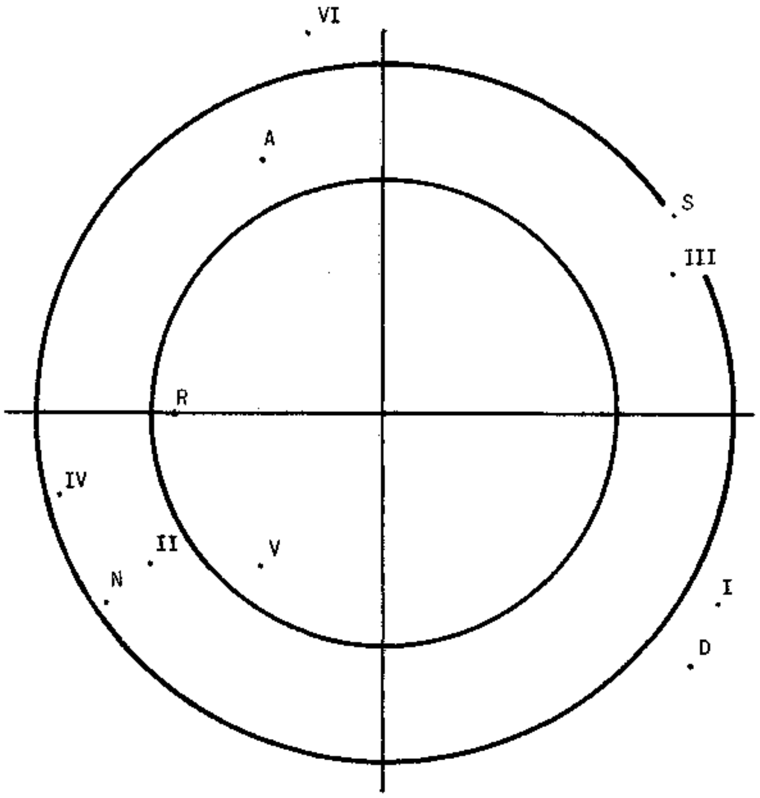


Fig. 5. Joint space of groups and criteria

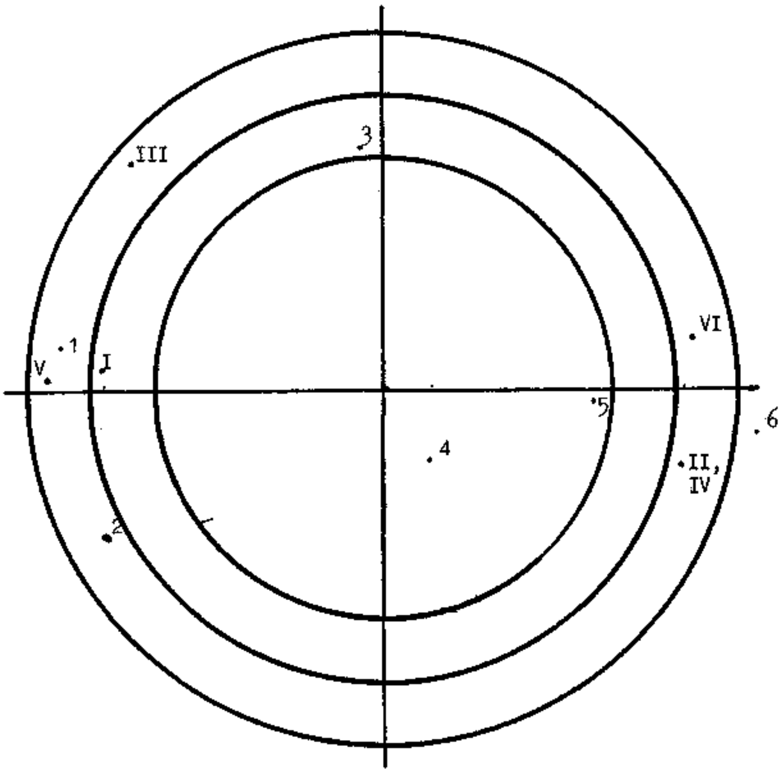


Fig. 6. Joint space of groups and plans.

related to economic and Defense aspects. Consequently, the horizontal axis may be interpreted in terms of the degree of defense efforts varying from intensive efforts (at the left axis) until little efforts (at the right axis). The vertical axis may be interpreted in terms of passive or neutral land use of the environmental area concerned (at the lower axis) until active land use (at the upper axis).

The metric results for the discrepances between the successive plans and between the successive criteria outcomes are included in Table 11a and 11b, which once more illustrate the abovementioned comments.

	D	N	A	R	S
D	-				
N	1.98	-			
A	2.12	.51	-		
R	2.09	.28	.77	-	
S	.68	1.95	2.24	1.96	-

Table 11.a. Metric distances between criteria outcomes.

	1	2	3	4	5	6
1	-					
2	1.15	-				
3	1.68	1.24	-			
4	2.03	1.17	.67	-		
5	2.08	1.73	.49	.95	-	
6	2.80	2.22	1.11	1.12	.78	-

Table 11.b. Metric distances between plans.

Table 11.a shows that the socio-economic criteria are fairly closely related to the Defense criteria, whearas the agricultural criteria have a

maximum discrepancy with respect to the Defense criteria. Similarly, the environmental and recreational criteria show a big discrepancy with respect to the Defense criteria.

Table 11.b indicates the obvious result (in metric terms) that the natural area alternative is far remote from a complete land use by the army, while the other plans have an intermediate position.

Fig. 5 depicts in a two-dimensional joint space the priority schemes of various decision and interest groups involved in the ultimate land use decision.

It turns out that the groups II and IV are fairly close to each other which is in agreement with their reluctant attitude regarding a Defense destination of the area concerned. The reverse statement holds true for the groups I and III which are supporting a Defense destination. Intermediate positions are taken by group V and VI.

The environmental, agricultural and recreational criteria are depicted at the left-hand of the vertical axis, whereas the remaining criteria are depicted at the right-hand side. This implies that the horizontal axis may be interpreted in terms of environmental quality priorities varying from relatively high priorities (at the left axis) to low priorities (at the right axis). The vertical axis may be related to land use conflicts varying from a completely agricultural land use (upper axis) to a Defense land use (lower axis). The remaining criteria, viz. agricultural, environmental and economic do apparently not exclude the most extreme land use priorities, so that they are positioned as intermediate points.

The cardinal differences between the groups as well as between the preferences for the decision criteria are represented in Table 12.a and Table 12.b. The results of this table can be regarded as a measure of conflict (or potential compromises) between the groups involved, as far as their revealed preferences are concerned.

	D	N	A	R	S
D	-				
N	1.84	-			
A	2.07	1.45	-		
R	1.79	.63	.82	-	
S	1.41	2.13	1.28	1.66	-

Table 12.a. Metric distances between criteria outcomes.

	I	II	III	IV	V	VI
I	-					
II	1.76	-				
III	1.03	1.84	-			
IV	2.08	.38	2.02	-		
V	1.43	.32	1.58	.67	-	
VI	2.17	1.72	1.34	1.61	1.68	-

Table 12.b. Metric distances between groups.

Table 12.a indicates again that the discrepancy between the D- and S-criteria is lowest, whereas the remaining discrepances are much higher.

The results of Table 12.b demonstrate that the degree of correspondance between group I and III is fairly low (which is in accordance with the prior information), whereas the measure of conflict between I on the one hand and groups II, IV and VI on the other hand is fairly high. All these results are very plausible.

Finally, Fig. 6 represents the graphical outcomes of the multicriteria analysis.

The successive plans are indeed depicted in the logical order varying from plan 1 (at the left-hand side of the vertical axis) to plan 6 (at the right-hand side). The optimal choice rankings of the decision and interest groups show a picture which is largely in agreement with the revealed preferences from Fig. 4.

The metric differences between the groups, in terms of choice conflicts between alternatives are included in Table 13.a and Table 13.b. These results are in agreement with the information from the previous chapters and support the abovementioned conclusions.

	I	II	III	IV	V	VI
I	-					
II	2.13	-				
III	.71	2.67	-			
IV	2.13	.00	2.67	-		
V	.19	2.31	.81	2.31	-	
VI	2.13	.47	2.11	.47	2.32	-

Table 13.a Metric distances between groups.

	1	2	3	4	5	6
1	-					
2	.73	-				
3	1.27	1.69	-			
4	1.39	1.22	1.13	-		
5	1.95	1.86	1.25	.65	-	
6	2.53	2.40	1.76	1.19	.58	-

Table 13.b Metric distances between plans.

Therefore, the final conclusion may be drawn that multi-dimensional scaling methods are extremely meaningful tools to deal with qualitative of fuzzy information of the type specified above. In the framework of the abovementioned qualitative multicriteria analysis it can be regarded as a powerful analytical tool for practical policy conclusions.

Evaluation

This paper has been devoted to the development of new multicriteria techniques based on qualitative information. This ordinal multicriteria analysis can be regarded as a useful tool in plan evaluation problems characterized by 'soft' information. The use of multi-dimensional scaling techniques appears to provide an operational tool to measure in metric terms the quantitative discrepances and conflicts between plans, decision criteria and decision groups.

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