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THE EUROPEAN SCHOOL OF MCDA:
EMERGENCE, BASIC FEATURES
AND CURRENT WORKS [1]

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Résumé

L'approche multicritère des problèmes de décision a considérablement évolué depuis ses débuts durant les années 60. Au cours de cette évolution, plusieurs écoles de pensée ont vu le jour. Elles se différencient pas les concepts et techniques qu'elles recommandent d'utiliser et, plus généralement, par la façon dont elles conçoivent le processus même de l'aide à la décision. L'une de ces écoles est maintenant bien connue sous le nom d'"Ecole Européenne" ; la plupart de ses membres font partie d'un groupe de travail européen intitulé "Aide Multicritère à la Décision". La première section de cet article retrace les principales étapes qui ont marqué la naissance de cette Ecole Européenne. Ses traits caractéristiques et idées directrices sont ensuite présentés en section 2. On donne finalement une vue d'ensemble des principaux thèmes de recherche étudiés dans le cadre de cette école (section 3).

THE EUROPEAN SCHOOL OF MCDA: EMERGENCE, BASIC FEATURES AND CURRENT WORKS

Abstract

Multiple criteria decision analysis has been evolving considerably since its birth during the 60's. As part of this evolution, several schools of thought have developed, emphasizing different techniques and, more generally, different attitudes as to the way of supporting or aiding decision making. One of these schools is now commonly referred to as the "European School", its members being part of a European Working group entitled "Multicriteria Aid for Decisions". In the first part of this paper (section 1), we follow a historical perspective in order to trace the emergence of the European School. Its distinctive features and main ideas are then outlined in section 2. Finally, we provide a general review of the current major research topics developed within this framework (section 3).

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Introduction

The present paper grew out of a proposal by the editor of the Journal of Multi-Criteria Decision Analysis. In July 1993, Simon French contacted Bernard Roy, inviting him to *write a short article giving your personal view on the history of MCDM/MCDA and the various schools which have grown up and particularly the work stemming from LAMSADE.* Bernard Roy in turn asked Daniel Vanderpooten help in accomplishing the proposed task. The early research and bibliography discussed in sections 1 and 3, as well as the more theoretical work presented in section 2, are the fruits of their combined labours. The text has likewise benefitted from the remarks and observations offered by a number of colleagues who were willing to read and comment on our first version. We would like to express special thanks to Carlos Bana e Costa, Denis Bouyssou, Anna Ostanello, Yannis Siskos, Roman Slowinski, Alexis Tsoukiàs and Philippe Vincke.

1. Emergence

1.1 Multiple criteria: a strange idea

For many years after the birth of OR, it was still considered that the only way to state a problem correctly consisted of defining a single criterion which should represent the effectiveness of the system under study. Consulting one of the most famous OR textbooks from the end of the 50s and the beginning of the 60s, we read (see Churchman *et al.* (1957, p. 13), and again in the 1967 edition): *"O.R. tries to take into account as broad a scope of objectives as possible. In most general terms, the research problem is to determine which alternative course of action is most effective relative to the set of pertinent objectives".* Although this statement could be considered a good introduction to incorporate explicitly different criteria within the analysis process, the authors reach the opposite conclusion: *"Consequently, in formulating the research problem a measure of effectiveness must be specified... The general form of an O.R. model is $E = f(x_i, y_j)$ where E represents the effectiveness of the system, x_i the variables of the system which are subject to control, and y_j those variables which are not subject to control".* Even after the 60s, the obligation to work with a single criterion is accepted as a given evidence in many other textbooks, published in a variety of countries. For instance, in Kaufmann (1972, p. 10), we find: *"... it is necessary to attach an economic function to any organization or operation and, inasmuch as we are looking for its optimum, this function must be unique... In any organization or operation, we can be faced with, or consider, several objectives that we aim at reaching, exceeding, or not exceeding, but the economic function to optimize ... must be unique".*[1]

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[1] *"... Il faut attacher à toute organisation ou opération une fonction économique et, comme l'on se propose d'en rechercher l'optimum, cette fonction doit être unique... Dans toute organisation ou opération, on peut rencontrer ou se donner plusieurs objectifs que l'on se propose d'atteindre, de dépasser, ou de ne pas dépasser, mais la fonction économique à optimiser ... doit être unique".*

This attitude, which was presented as an unquestionable norm, is present throughout economic theory, welfare theory, game theory, decision analysis theory, ... In these fields, one usually considers that, from a rational point of view, there are only two binary relations for comparing two alternatives: strict preference P and indifference I. Both must be transitive. This excludes all cases of incomparability (see Roy (1973)) which can come from conflicting criteria. Fishburn (1970) writes, p. 9: *"Indifference will be defined as the absence of strict preference"*. Under such hypotheses, the alternatives of any set can be ranked without ambiguity (perhaps with ex aequo) from the best to the worst. This involves representing preferences by a single criterion which, as a direct consequence, fully legitimates the search for its optimum.

In this context, it is not surprising that the OR community either misunderstood or accepted reluctantly the paper by Roy (1968a). Nine years later, an article by Ackoff (1977) still inspired strong reactions. Let us draw attention to the fact that the main purpose of those two papers was not to advocate substituting multicriteria approaches for the traditional monocriterion approach. The difficulties related to the monocriterion approach, which were put forth clearly in these two papers, are precisely those that the new approaches, whose capacity was not yet fully appreciated at the time, have best contributed to overcome.

The reader will think perhaps that substituting multiple criteria for a single criterion was not such a strange idea in the 60s, inasmuch as in the early 60s multiple goals were explicitly taken into account in mathematical programming (see Charnes and Cooper (1961)). In fact, the goal programming approach, even if it clearly distinguishes a set of goals, remains related to the classical framework of optimization.

1.2 Birth of the ELECTRE methods

Each ELECTRE method has been born of difficulties encountered with a specific, concrete problem. The first of these dealt with a firm's selection of new products. In 1965, SEMA(Metra International)[1] experimented with a method, named MARSAN (Method for Analysis Research and Selection of New Activities, see Laffy (1966)) in various industrial contexts. In this method, 48 criteria were introduced, some quantitative, others qualitative. For obtaining a comprehensive score aggregating the 48 points of view linked to the 48 criteria, a weighted sum was computed. It rapidly appeared that compensation phenomena could lead to assigning a better score to an alternative a which was preferred to an alternative b with respect to many criteria, but which was much worse than b for one criterion. Moreover, the scales associated with qualitative criteria played a fundamental role in the comparison, i.e., figures were interpreted to mean far more than they actually signified. The analysis of such difficulties on the basis of real-world data led to the first ideas (see Benayoun *et al.* (1966)) concerning concordance, discordance and outranking concepts. The acronym ELECTRE (see Roy (1968b)) at that time stood for "Elimination et Choix Traduisant la Réalité". From the outset, this first ELECTRE method was applied to a wide range of problems: see Buffet *et al.* (1967).

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[1] *A European consultant company.*

Before the end of the 60s, an advertiser wished to use ELECTRE for selecting the specific publications in which to place advertisements (see Abgueguen (1971)). In fact, the original version of ELECTRE, oriented towards the choice of a single alternative on the basis of the kernel of an acyclic graph, was not well suited to the new problematic[1] oriented towards building of a ranking. Hence the birth of ELECTRE II (see Roy and Bertier (1973)).

A major difficulty was encountered in the use of ELECTRE I and ELECTRE II, due to the fact that the performances of the alternatives on the different criteria were often imprecise and even ill-determined. This inaccurate knowledge was not explicitly taken into consideration. It was of course possible to do so by introducing probabilistic distributions for representing the dispersion of the possible values of such performances, and having built a utility function on a scale attached to the criterion, to compute an expected utility value for the criterion considered. Without excluding this approach, another has been considered. Its starting point can be found in a paper by Jacquet-Lagrèze (1973) (see also Jacquet-Lagrèze (1975), Charpentier and Jacquet-Lagrèze (1976), and Roy et al. (1977)). In the mid-70s, these works resulted in developing ELECTRE III (see Roy (1978) and Roy et al. (1986)). Compared to ELECTRE II, ELECTRE III presented two new features: *i)* the possibility of working with indifference and preference thresholds, i.e., with the concept of pseudo-criterion (see Roy (1976)), *ii)* the introduction of a fuzzy outranking relation instead of a preference model containing only two crisp outranking relations.

Subsequent ELECTRE methods (see section 3) were likewise grounded in requirements linked to real-world problems.

1.3 Some precursors of the interactive procedures: POP and STEM

The real precursor of the multiple criteria interactive procedures was a method called POP (Progressive Orientation Procedure) developed by Benayoun and Tergny (1969) (see also Benayoun et al. (1970)) in the context of multi-objective linear programming. It is remarkable that the main ideas of interactive procedures were already present in POP. Considering that it is often difficult to define the concept of a "satisfactory solution" due to the heterogeneity of criteria, the lack of information available to aggregate them and/or the fact that the decision maker's preference structure is not well-established, the authors suggest to designing a man-machine system which will enable the decision maker to perform an iterative exploration on a set of solutions based on judgments progressively supplied with respect to the solutions presented.

POP includes two stages: *i)* a choice (or dialogue) stage, where the decision maker, presented with a subset of solutions, must discard some of them and *ii)* an optimization

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[1] *After discussion with several researchers in the field, it has been decided to remain close to the original French word "problématique" even if "problematic" sounds somewhat akward in English; "problem statement", "problem type" or "problem formulation" have been considered but excluded since liable to give the wrong impression.*

(or computation) stage, which consists of generating efficient solutions on a subset of feasible solutions derived from the choice stage.

As claimed by the authors, the concept of "satisfactory solution" should be progressively clarified through this exploration process.

The STEP Method, referred to as STEM, was intoduced by Benayoun *et al.* (1971) and designed in the same spirit as POP. However, STEM is based on different and more effectively interrelated dialogue and computation stages, which favour a more natural exploration process.

The dialogue stage consists of considering the current solution and asking the decision maker to indicate to what extent various criteria could be relaxed so as to improve the other criterion values. This information is exploited, in the computation stage, to generate a new efficient solution. The computation stage is based on the minimization of a Tchebychev norm (and even an augmented norm in a later version of the method presented in Benayoun *et al.* (1973)). It should be noticed that such scalarizing functions have been widely used in subsequent procedures.

In conclusion, STEM is certainly one of the most well-known multiple criteria interactive procedures. It has given rise to many variants and still serves as a basis of comparison for new procedures.

1.4 The scientific department of the SEMA company: a melting pot

In 1957, Jacques Lesourne created the SMA company, which became the SEMA company, and soon thereafter, the mother society of the European Company: SEMA(Metra International). Bernard Roy, as Scientific Director of this group, was in charge of a multi-disciplinary team. This team was fortunate to count among its permanent staff or visiting scholars a wide variety[1] of researchers in the field including Raphaël Benayoun, Patrice Bertier, Eric Jacquet-Lagrèze, Oleg Larichev, Hubert Le Boulanger, Jean de Montgolfier, Hervé Raynaud, Gilbert Sussmann, Milan Zeleny and many others. In addition to the ELECTRE methods cited above, other important research projects, both theoretical and applied, have emerged from within this group inspired by questions from SEMA's consulting engineers, both French and foreign. A few examples are given below.

The selection and the ranking of research development projects in a big firm resulted in research work original in its methodological approach: see Le Boulanger and Roy (1968). The same was true for personnel policy (see Roba *et al.* (1970), and Benayoun and Boulier (1972)) as well as choosing investments (see Holl *et al.* (1973)).

At the end of the 60s, the route of a highway through the forest of the South-West of Paris (see Bétolaud and Février (1973)) provided a very stimulating case (discussed in de Montgolfier and Bertier (1978), and Bana e Costa (1990b)) which gave rise to

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[1] *Only those directly concerned with multicriteria methods are mentioned here.*

"convincing compensation" method (see Roy (1973) and (1974)). This case, as well as other works carried out by the SEMA group (see Bertier and de Montgolfier (1971)), played a fundamental role in developing the general methodology proposed by Roy (1975), (1977), (1985).

1.5 The first multicriteria sessions in an international conference

In 1969 G. Dantzig, then head of the Programme Committee, asked Bernard Roy to organize a session on Inventory Control and Mathematical Programming for the 7th Mathematical Programming Symposium to be held in The Hague. Roy suggested leaving this topic to somebody else, proposing instead to organize not only one, but two sessions, entitled Multiple Objective Functions. He still remembers how difficult it was to make the programme committee understand what he had in mind (see 1.1 above). In the end, G. Dantzig left the arrangements up to B. Roy.

The seven communications selected came from the following authors: R. Benayoun, J. de Montfgolfier, J. Tergny and O. Larichev – G. Boldur – A. Charnes, W. Cooper, M.A. Keane, and A.S. Walters – A.M. Geoffrion – C. Maier-Rothe and M.F. Stankard – J. Philip – B. Roy. A brief presentation of each of them is given in Roy (1971).

1.6 Other works

In addition to the above-mentioned works, multiple criteria analysis has raised an increasing interest in Europe at the beginning of the 70s. This interest was mainly focused on applications in particular for location problems (Guigou (1971), Schärlig (1973)), in regional and architectural planning (Ventura (1973), Michel (1974)), transportation problems (Godard (1973)), investment problems (Camier *et al.* (1974)) and personnel policy (Tanguy and Leclere (1974)).

Moreover, some of the works developed in France at the end of the 60s in support of decisions by public authorities within the framework of the so-called RCB (Rationalisation des Choix Budgétaires), the French counterpart of the American PPBS, was strongly influenced by the multicriteria approach, as is shown in several papers included in Agard (1970).

From a methodological viewpoint, one of the first overviews of several aggregation procedures was undertaken by Bernard and Besson (1971). One of the first books dedicated to multiple criteria analysis was Guigou (1974).

1.7 Birth of the European Working Group "Multicriteria Aid for Decisions"

The organizers of the 1st EURO Conference (held in Brussels in 1975) encouraged participants to create working groups on certain specific topics, among which the multicriteria topic seemed of interest. About 30 people from to 5 different European countries joined the group and attended the first meeting, where Bernard Roy was

designated chairman. It was decided to have two meetings each year (in Spring and in Autumn). This rhythm has been unfailingly respected; the 40th meeting was held in Autumn 1994. Today, the group has nearly 300 members from 23 countries. More than 700 participants have attended, at least, one of the meetings which have taken place in 13 different countries. In these meetings, lectures and discussions can be either in French or in English.

Since its creation, four objectives have been assigned to this working group:

– to contribute to the development, at a European level, of an original way of thinking in the field of multicriteria decision-aiding;
– to allow each member of the group to make known to others methodological, theoretical or applied results, to submit its own works and thoughts to the critical discussion of the group and also to sollicitate somme collaborations;
– to develop multicriteria aid for decisions by facilitating contacts with every people interested in the subject and by stimulating continuity and progress in exchanges and works;
– to keep the group alive and open by the mean of bi-annual meetings which must not be mini-conferences but real meetings favourable to exchanges and to emergence of new ideas.

The existence of what is now called the European Multicriteria School is mainly due to the activity and far-reaching influence of this group. It also contributed, in a significant way, to the first EURO Summer Institute organized by Jean-Pierre Brans, in Brussels, in 1984, which gave rise to another EURO Working Group (ESIGMA) interested in multicriteria topics. This group operates entirely in English on different bases and rythms.

2. Main features of the European School

Many concerns are shared by all those working to further progress in the field of multicriteria decision analysis, irrespective of the school of thought to which they belong. In this section, we will try to bring out the distinctive features which we believe characterize the European School today, 30 years after its first beginnings. To do so, we must first emphasize what to us is one of the primary factors orienting research carried out within this school and which has permeated the spirit in which multicriteria decision aid is undertaken: recognizing the limits to objectivity (section 2.1). We will then look at the impact this recognition has had on the general spirit underlying the way of conceiving decision aid and therefore the efforts of researchers (section 2.2). Finally, we will examine some typical concerns of the European School, demonstrating that their specific nature often results from the refusal to put aside the limits to ojectivity (section 2.3).

2.1 Fundamental limits to objectivity

In the perspective of decision-aid, five major aspects have to be taken into account.

i) The borderline (or frontier) between what is and what is not feasible is often vague. Moreover, this borderline is frequently modified in the light of what is found through the study itself.

ii) In many real-world problems, the "decision-maker" as a person, truly able to make the decision, does not always really exist. Usually, several people (actors or stakeholders) take part in the decision process, and it is important not to confuse the one who ratifies a decision with the so-called decision-maker in the decision aid process. This decision-maker is in fact the person or the set of persons for whom or in the name of whom decision-aid is provided.

iii) Even when the decision-maker is not a mythical person, his preferences very seldom seem well-shaped. In and among areas of firm convictions lie hazy zones of uncertainty, half-held belief or indeed conflicts and contradictions. We have to admit, therefore, that the study itself contributes to eliminating questioning, solving conflicts, transforming contradictions and to destabilizing certain convictions. If, within this perspective, we decide or accept to resort to a multicriteria approach, the elaboration of a family of criteria cannot be founded on purely objective considerations.

iv) Data such as the numerical values of evaluations or performances, the characteristics and the analytic forms of probabilistic distributions, weights of criteria, ... are often imprecise, uncertain, or ill-determined. This is the case, for instance, when a cost or a ratio is viewed as a Gaussian random variable, the Gaussian distribution being used afterwards for computing an expected value of the cost or the ratio.

v) In general, it is impossible to say that a decision is a good or a bad one by referring to a mathematical model only. Organizational, pedagogical and cultural aspects of the whole decision-process which lead to make a given decision also contribute to its quality and success.

Those five points underline to how great an extent factors of an objective nature (e.g., the characteristics of alternatives) interact in decision aid with factors of an entirely subjective nature (stemming both from the actors' system of values and the way in which ill-determined consequences are evaluated). It is impossible to deny the importance of the subjective factors and to put them aside in an attempt to use a "totally objective" approach. Such is the stance which has been underlying multicriteria decision aid in research and practical applications.

2.2 General spirit underlying the research

Those, who want to avoid leaving aside the limits to objectivity, must acknowledge the impossibility of providing a truly scientific foundation for an optimal decision (for more details, see Roy (1993, pp. 199-200, Postulate of the optimum, hypotheses 1 and

2). This explains why, in the European School, it seems possible to characterize as follows the guiding spirit behind the majority of our research projects.

1°) The main objective is to construct or to create something (for instance a value or a utility function, a crisp or fuzzy outranking relation, the conviction that a certain alternative is the best, ...) which, by definition, does not completely pre-exist. This entity to be constructed or created is viewed as likely to help an actor taking part in the decision-process either to shape, and/or to argue, and/or to transform his preferences, or to make a decision in conformity with his goals.

2°) Efforts of researchers are oriented towards concepts, models, axioms, properties, procedures which are consequently liable to be used for the following purposes:

– to extract or elaborate, from the information attainable, what appears really meaningful;
– to help to shed light on the decision-maker's behaviour by bringing him arguments able to strengthen or to weaken his own convictions.

As we shall see in the following paragraph, the spirit of this dual orientation influences, not only the nature of work undertaken, but also the way in which we confer meaning on concepts, models, axioms, properties, results and procedures. As soon as we acknowledge that our aim is no longer (or is only secondarily) to describe or discover but is rather to construct or create, we necessarily distance ourselves significantly from the quest for norms or prescribing. Here, the verb prescribe is used in its strong meaning[1] in line with the usage common to many anglo-saxons authors Following this viewpoint, a prescription is elaborated with reference to an ideal, of which the prescription should be a good approximation. The existence of this ideal is taken from a set of axioms which, when examined separately, appear sufficiently natural to be imposed as a norm or constitute an acceptable working hypothesis. It is the existence of such an ideal which confers all its validity and authority upon the prescription conceived of on such bases. The MCDM American School gives priority to this notion, which differs therefore from that favoured by the European School, which seeks to develop recommendations in which the ideal of approximating a pre-existing entity does not play a significant role. This is a crucial difference in attitudes, especially in decision-aid. In a prescriptive approach, the analyst begins with a description and draws up prescriptions based on normative hypotheses validated by the reality thus described. By taking a constructivist approach, researchers help to build a value-judgment model by seeking working hypothesis for making recommendations (see Bana e Costa (1993)). This second path consists of constructing, along with the actors in the decision process, a set of keys which will enable them to go forward, progressing according to their own objectives and their system of values.

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[1] *This meaning of the verb differs from the weaker meaning of prescribe which have been used by Roy until 1990. In the weaker meaning, we will use here the verb "to recommend".*

2.3 Some typical concerns

The concerns of researchers and practitioners working within the framework of the European School may, by many aspects, seem similar to those of any others working in MCDA or in MCDM. They are, however, often conceived of, or oriented or even transformed in a very specific way. A non exhaustive list of such typical manners of tackling or apprehending problems, questions and/or difficulties is given below. These issues are at the heart of decision-aid or decision-making.

a) The meaning and role of axiomatic results

Within the European School, the search for axiomatic results does not revolve around establishing the legitimacy of an ideal that a recommendation would allow us to approximate. The dangers attached to a position which consists of seeking among axioms the foundation for a form of rationality claimed to be clearly set forth and explained are now increasingly acknowledged (see, e.g., Roy (1993)). For elaborating a recommendation in a constructivist approach, we do not expect that some axiomatic results will lead us to believe that, with them, we possess the means of gaining access to truth. We only expect that they will give us a good knowledge of what the consequences are from different points of view of various sets of axioms. It is only in relation to the consequences thus brought into the open within the framework of different axiomatic systems that we are able to understand what a particular axiom really means and, consequently, what role it can play besides some others in the elaboration of a recommendation.

b) The elaboration of a methodology oriented towards the insertion into the decision process

We will limit ourselves here to mentioning only three outcomes of this conception:

– the introduction of the concept of "fragmented actions" which allows to take into consideration potential actions which are not alternatives (alternatives being usually mutually exclusive);
– the importance given, in the way a coherent family of criteria is constructed, to the fact that this family can become an instrument of communication among the various stakeholders involved into the decision process;
– the interest devoted to various problematics (especially selection, sorting and ranking) dealing essentially with the manner in which the aid for decision has to be thought out and implemented in order to be fitted appropriately into the decision process.

c) The attention paid to all sources of imprecision, uncertainty and ill-determination

For discussing the relative merits of potential actions taken into consideration, information is needed on what will happen if one or several of these actions is/are implemented. The instruments used to gather – or, more precisely, in many cases, to construct – this information are lacking, to varying degrees, in precision. Moreover, what they are seeking to apprehend could not yet exist (future and/or reality) and be only very

imperfectly defined (some characteristics of complex reality). Finally, the figures which summarize this information do not necessarily reflect a quantity. They may have only a purely ordinal meaning.

For all these reasons, within the European School, special attention is paid to how these figures are dealt with, as much to elaborate the performances (criterion values) of actions as to aggregate them. Within this school, we do not hesitate to use probability distributions to take imperfect knowledge into account or to use utility functions to manipulate ordinal data, as indeed the American School recommends. We consider, however, that these concepts are not universally appropriate. We therefore use other concepts such as thresholds (indifference thresholds, preference thresholds, veto thresholds), aspiration levels, concordance and discordance indices, ... We likewise endeavor to mobilize the arsenal of concepts and results in fuzzy set theory, possibility theory and rough set theory.

d) The use of a large spectrum of preference model structures

In light of these considerations, taken together with the fact that the decision-maker is not always a single well-identified person whose preferences are not necessarily completely formed and not easily accessible, it seems a natural and logical step to disassociate ourselves from the idea whereby preference models used for decision-aid must reflect, as faithfully and as fully as possible, the ideas, preferences and prejudices of the decision-maker. For us, the preference model cannot be viewed as a simplified description of a reality; it is viewed as a schema built to represent some basic convictions or positions whose objective is to provide suggestions for answers to questions pertinent in decision-aid.

This conception of a preference model explains the importance given to intransitivity and incomparability. Let us remark that by concluding to incomparability between two actions, some help is also provided to decision since this brings to the fore phenomena such as ignorance or conflicts. This conception of preference modelling stands behind such notions as weak preference, outranking, credibility of a preference assertion, ... It also explains the interest for such structures as partial preorders, semi-orders, pseudo-orders, ...

e) The characterization of the specific role devoted to each criterion

The criteria which intervene in an aggregation procedure used for modelling comprehensive preferences do not generally play the same role, nor do they have the same importance.

The preceding considerations about the decision-maker's personality, the nature of data and the vision of what a model is have led us to reconsider this notion of importance and, consequently, the manner in which it is characterized. This importance remains characterized by some parameters such as weights, scaling constants, substitution rates and also veto thresholds. But, except in some very particular cases, the technique for giving a value to each such parameter must not be grounded in the existence of a true value which must be estimated. The objective is not to obtain a

single (or the best) value for each parameter, but to choose convenient values not necessarily unique for each parameter. An interesting objective can be the delimitation, with the active participation of some stakeholders, of a domain containing all combinations of such values which can reasonably be taken into consideration.

f) The study of interactive procedures

In some specific contexts, an appropriate interactive procedure, if it is sufficiently user-friendly, can play a fundamental role for guiding the decision process. Many interactive procedures have been proposed in and out the spirit of the European School. But few real-world applications have yet appeared. It seems important now to specify clearly, for each procedure, the conditions which should be verified by the context in order for the procedure to be usefully implemented. These conditions are related to organizational aspects, abilities required from the user, underlying assumptions as to the role of interaction, ... Among those conditions, let us underline that, for the European School, those needed to guarantee the convergence towards an optimal pre-existing solution do not play a decisive role.

g) The systematic use of a robustness analysis

In order to ground a recommendation on bases which take into account the debatable nature of certain data (values too hastily imputed, uncertainty concerning the future, value systems not shared by all parties, etc.), it is essential to establish robust conclusions. By this we mean conclusions which remain valid, if not for all the values which can reasonably be assigned to the data of a debatable nature, at least for a clearly delimited range of such values. Which is to say that the robustness analysis, even if at times it seems to follow the traditional path of sensitivity analysis, it often diverges significantly from it. It may be useful, in order to appreciate the extent of the robustness of certain conclusions, to study, for instance, the sensitivity of the position of a given action in a ranking to values of specific parameters. Nonetheless, this sort of approach hardly lends itself to taking into account simultaneous variations of several parameters. Moreover, it is only appropriate to some kinds of elementary conclusions.

3. Expansion and current works

Our purpose in this section is to give a representative, albeit not exhaustive, overview of some research fields and works directly related to the European School. Additional references can be found in particular in the textbooks which emphasize this stream of thought (Roy (1985), Schärlig (1985), Vincke (1989), Bana e Costa (1990a), Pomerol and Barba-Romero (1993), Roy and Bouyssou (1993), Maystre *et al.* (1994)). A large number of real-world applications have been developed in various contexts (location problems, water resources and waste management, transportation and logistics, production and inventory control, manpower planning, marketing, finance, ...). However, due to space restrictions, the corresponding papers will not be indicated here. The interested reader can consult e.g. the above-mentioned textbooks. Likewise we shall not

mention the software packages (for a description of some of them, see, e.g., Pomerol and Barba-Romero (1993)).

3.1 Towards a general decision aid methodology

In section 2, we presented the general ideas which underlie our conception of decision aid. In order to make this conception operational, it has been necessary to lay the foundations for a general methodology.

Promoting the use of multiple criteria to support decisions clearly requires that a great deal of attention must be devoted to the design of techniques for aggregating criteria. It should be emphasized, however, that a decision aid methodology must also provide concepts and guidelines for structuring and modelling decision problems. Such a methodology is presented in Roy (1976), (1985). Important features of this methodology include the way of identifying and defining alternatives or actions (see also Norese and Ostanello (1989) and Ostanello (1990)), the techniques for constructing criteria (see also Bouyssou (1990) and on specific problems Grassin (1986) and Roy and Slowinski (1993)) and the way of stating the decision problem by selecting an appropriate problematic (see also Bana e Costa (1995)).

The necessity of taking into account socio-political and organizational aspects, as well as the influence of all stakeholders, is widely recognized in the literature (see also Pellegrin (1994)). Banville *et al.* (1993) suggest various ways of integrating the stakeholders at different stages of the decision aid study, in particular for generating alternatives and defining criteria.

A crucial issue in many decision aid methodologies is the way parameters representing the relative importance of criteria are evaluated. Vansnick (1986) specifies the concept of weights within a non-compensatory framework and gives some guidelines on how to elicite such information. Roy and Mousseau (1995) study the concept of importance and propose a general framework to analyse this concept. A procedure for evaluating weights, in the case of outranking methods, is described in Mousseau (1995).

3.2 Modelling preferences including imprecision, uncertainty and inaccurate determination

As indicated in section 2.3.c, much attention has been devoted to the sources of imprecision, uncertainty and inaccurate determination and their impact on preference modelling (Bouyssou (1989), Roy (1989)). The use of thresholds for modelling such aspects is analyzed in Bouyssou and Roy (1987). The concept of pseudo-criterion, which makes use of two thresholds for representing indifference, weak preference and strict preference situations, is studied in Roy and Vincke (1984), (1987). Preference modelling based on different types of criteria is investigated in Roubens and Vincke (1985), Roy (1985), Doignon *et al.* (1988).

Another way of handling these difficulties consists of modelling preferences through fuzzy binary relations (Dubois and Prade (1980), (1985), Zimmermann (1991), Perny

(1992), Perny and Roy (1992), Fodor and Roubens (1994)). In the context of mathematical programming under uncertainty, fuzzy approaches are compared with stochastic approaches in Slowinski and Teghem (1990). The use of stochastic dominance is explored in Martel and Zaras (1995).

Extended preference structures allowing to represent lack of information, uncertainty and ambiguity using a multi-valued paraconsistent logic were studied in Tsoukiàs and Vincke (1992), (1994).

The use of rough sets for dealing with ambiguity is investigated in Slowinski (1992) and Pawlak and Slowinski (1994).

Also of interest is a procedure developed by Munier (1986) for handling uncertainty when the knowledge about all possible scenarios can be expressed ordinally in terms of likelihood.

3.3 The outranking approach: a large family of methods

Outranking methods are certainly the most specific multiple criteria procedures which are developed by the European School. The ELECTRE methods, which are the first representatives of this family (see section 1.2), have been evolving to satisfy new requirements. Besides the ELECTRE I, II and III methods previously mentioned, ELECTRE IV has been developed in conjunction with a real-world problem, namely the ranking of line extension projects for the Paris metro system (Roy and Hugonnard (1982)). This method, which provides a ranking of alternatives, has been designed for cases in which it is particularly difficult to indicate the relative importance of each criterion (which does not amount to assigning an equal importance to each criterion).

Two other ELECTRE methods have been designed so as to evaluate the intrinsic value of each alternative by assigning it to predefined categories (sorting problematic). This assignment process makes use of outranking tests which are embedded either in a decision tree (see Moscarola and Roy's (1977) segmentation procedure) or in filtering procedures (ELECTRE TRI, see Yu (1992)). For a general overview of outranking methods see Roy (1990) (modelling stage) and Vanderpooten (1990a) (exploitation stage).

Outranking relations or, more generally, relational systems of preferences have been used in many other methods:

- QUALIFLEX (Paelinck (1978)),
- ORESTE (Roubens (1982), Pastijn and Leysen (1989)),
- MELCHIOR (Leclercq (1984),
- PROMETHEE (Brans *et al.* (1984), (1986), Brans and Vincke (1985)),
- TACTIC (Vansnick (1986)),
- MAPPAC and PRAGMA (Matarazzo (1988), (1991),
- N-TOMIC (Massaglia and Ostanello (1991)),
- ELECCALC (Kiss *et al.* (1994)).

We should note that some outranking methods were developed to deal explicitly with uncertainty (see Martel *et al.* (1986), d'Avignon and Vincke (1988)).

An approach for constructing outranking relations using rules which convey ordinal information about the importance of coalition of criteria was also proposed by Pasche (1991).

3.4 Synthesizing through a single criterion: some contributions

Within the European School, little attention has been devoted to the construction of a value or utility function to model preferences. A major feature of most contributions in this area is that the methods propose a framework for constructing and adjusting a single criterion rather than claiming to assess a function which would precisely describe the decision maker's preferences.

One of the most significant contributions is the Preference Disaggregation Approach initiated by Jacquet-Lagrèze and Siskos at the end of the 70s and the UTA method (see Jacquet-Lagrèze and Siskos (1982)). The general aim of disaggregation analysis is to determine an aggregation model representing overall preferences expressed on a set of reference alternatives (ranking, pairwise comparisons, ...). In the case of UTA, the purpose is to construct additive value functions which are as consistent as possible with a ranking of reference alternatives. An ordinal regression procedure based on special linear programming techniques is used to derive the parameters of the value functions. UTA was implemented and improved in the following methods: PREFCALC (Jacquet-Lagrèze and Shakun (1984), Jacquet-Lagrèze *et al.* (1987), Jacquet-Lagrèze (1990)), UTASTAR (Siskos and Yannacopoulos (1985)), MINORA (Siskos (1986)). In these methods, an iterative adjustment process is emphasized so as to construct and modify the value function.

Taking a different approach, Lootsma (1987), (1993), considered some of the criticisms expressed with regards to the AHP method of Saaty (1980) and proposed the REMBRANDT method. The latter is based on alternative scales of measurement justified by certain psychometrical arguments; it uses a different aggregation procedure based on a logarithmic regression.

Let us also mention the MACBETH method developed by Bana e Costa and Vansnick (1994), (1996) which aims at constructing cardinal value functions from judgments concerning the relative attractiveness of alternatives. A value function is then derived and adjusted using a series of linear programming problems.

3.5 The interactive approach: an alternative conception

Supporting an interactive exploration of a set of alternatives has been a constant concern in multiple criteria analysis. We have already mentioned the pioneering work of Benayoun *et al.* (1971) (see section 1.3). However, the main contribution of the European School in this field is certainly the development and promotion of an alternative conception of the role devoted to interactivity (see Roy (1987), Vanderpooten

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(1989), (1992)). A major distinctive feature of this conception is the rejection of any assumptions about the decision maker's preferences (e.g., the assumption of a pre-existing value function which guides the decision maker's preferences). Therefore, interactive procedures must be designed so as to support learning of preferences; they must also tolerate, even favour, the evolution of these preferences. As a result, trying to impose mathematical convergence for such procedures is quite meaningless. However, trying to incorporate devices which aim at reinforcing the decision maker's confidence in the interest of the final proposal is quite meaningful.

Most of the procedures developed within the European School follow this perspective (e.g., Vincke (1976), Korhonen and Laakso (1986), Lévine and Pomerol (1986), Korhonen and Wallenius (1988), Climaco and Antunes (1989), Slowinski (1990), Teghem (1990), Vanderpooten (1990b), Henggeler et al. (1992), Jaszkiewicz and Slowinski (1994), (1996)). Some representative multiple criteria interactive procedures are described and analysed, with this perspective in mind, in Vanderpooten and Vincke (1989).

3.6 Legitimation of procedures: from axiomatization to experiments

Trying to legitimate or validate the body of knowledge produced by the use of a multiple criteria methodology or procedure is a desirable objective when aiming at adopt a scientific attitude in decision aid. Considering that most decision making contexts involve a number of participants who interact with reality and partly contribute to its creation and evolution, any legitimation or validation is a complex process with several different facets (see, e.g., Landry et al. (1983), Oral and Kettani (1993), and Roy (1993)).

One of these facets consists of trying to establish axiomatic results concerning the proposed procedures. The significance of such results has been outlined in section 2.3.a. Even if the legitimation of a procedure cannot be founded solely on such results, the availability of an axiomatic characterization for a specific procedure clearly provides a better understanding of this procedure. A series of results has been proposed in this perspective (see, e.g., Debord (1984), Arrow and Raynaud (1986), Bouyssou (1992a), (1992b), Bouyssou and Perny (1992), Perny (1992), Pirlot (1995), (1996), Bouyssou and Vincke (1996)). When an axiomatic characterization is too difficult, it is also interesting to study the properties of methods as done in Vincke (1992).

Another way of sheding some light on the assumptions underlying different procedures and on their respective behaviours is to perform comparisons on case studies (see, e.g., Roy and Bouyssou (1986), Climaco and Antunes (1990)).

Findings from experimental studies concerning the decision maker's behaviour is another source of legitimation. In making use of such studies, however, we must take care to avoid the pitfall of proposing methods reduced to a mere imitation or mimicry of the decision making process. Nevertheless, these results are helpful when designing a decision aid procedure (see, e.g., Korhonen et al. (1990)), particularly in developing ways of eliciting information from decision makers (see, e.g., Larichev (1992)). Such

studies have been performed and/or interpreted in this perspective, e.g., by Jaffray and Cohen (1982), Jaffray (1989), Achiakh (1993), Mousseau (1993).

4. Conclusion

Many contributions and papers have been left unmentioned owing to the limited length of this survey. In our opinion, however, the variety of those mentioned gives a representative overview of the activity of the European Multicriteria School. The two working groups "Multicriteria Aid for Decisions" and "ESIGMA" (see section 1.7) reflect this activity. They act not only as forums but also as places where original ways of thinking and new ideas can take shape and be developed in the spirit of this European School. Moreover, those two groups remain open to approaches, procedures and results belonging to other schools. More generally, it is important not to lose sight of the fact that multicriteria decision aid is a discipline with multiple facets. The Manifesto (see Bouyssou *et al.* (1993)), published by five among the most active European researchers in our field, gives a good illustration of those various facets. As shown by successive programmes of the meetings of the two groups, the European School is interested in all those facets. There is every sign that the European School will continue to be as creative in the future as it has been in the past.

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