Multicriterion Decision Aid: Methods and Applications

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1. Introduction

Decision aid (DA) is unquestionably based on Operations Research (OR), but it also involves other fields (psychology, sociology, economy, computer science,…) and areas. However, all OR contributions do not necessarily fall within DA's range since there is pure mathematical work in OR which is not directly focused on decision aid (Roy, 1992).

ROADEF, the new French Society of Operations Research and Decision Aid (member of IFORS and EURO) which was created in January 1998 to replace the AFCET and to represent the French OR/DA research community, seems fully aware of this duality.

DA involves a minimal insertion in the decision-making process, working not only *for*, but above all, *with* the actors of the process by developing a true *helping relationship*.

Roy (1992) describes the OR/DA project in these terms:

> "Rely on science to elicit managerial decisions and conduct decision processes in organized systems."

He also points out that a "problem" is not a pre-existing object. The formulation given to a problem cannot generally be totally objective and may not be viewed outside the relationship between the individual and the reality. Roy adds that it is normal to see the formulation evolve in the course of the decision-making process. On the other hand, Landry (1988) states:

"... the key to a successful organizational decision-aid approach lies in a good understanding of the overall decision-making process supported by this aid, which means the ability to fully understand the problem which originally calls for the process and takes it further."

Traditionally, at least until recently, OR has mainly been based on models which postulate the existence of a unique objective (single-criterion) function. It was thus assumed implicitly that in order to help organizations improve their decision-making, there was a general rule, or objective function, which stood out in everybody's eyes to indicate the proper direction in which a given system had to be developed (Roy 1988). By doing this, one obtains a mathematical problem which can be defined as a well-formulated problem (i.e. formulated in such terms that the solution, often called the optimal solution, is entirely determined by its formulation). Therefore, it is the formulation of the problem that determines the existence and the content of the solution, usually achieved through algorithms or heuristics.

There are many real situations where implications are so complex that an objective (single- criterion) function cannot account for all the information required in a global comparison of the alternatives (projects, options, scenarios, etc.). Whatever way one chooses to answer the questions raised to shed light on a decision, one has to look at the implications resulting from carrying out each

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alternative considered. Usually, these implications are numerous and of a very different nature (economical, technical, comfort, prestige,…).

According to Bouyssou (1993), the realistic argument to the effect that since "reality" is multidimensional it is normal that many viewpoints be taken into account to support the decision and therefore that multicriteria methods be used, doesn't solely warrant the use of a multicriterion decision-aid approach. Using such an argument would lead to the single criterion being viewed as a borderline and degenerate form of multicriterion. For Bouyssou (1993), using a single-criterion approach is not only assuming one criterion is efficient "in reality", but, more simply, supporting the decision by exhibiting only one criterion explicitly. For him, any decision-aid multicriterion approach involves an "act of faith" (a conviction) which leads one to believe that building several criteria *explicitly* may have a "positive effect" on the modelling process. This act of faith opens the door to what Roy (1988) has called a new paradigm (the multicriterion paradigm) for decision aid.

Since it relies on the building of several conflicting criteria, its main characteristic, decision aid, is doomed to evolve within the framework of a "ill-formulated" mathematical problem; there usually is no solution providing the optimum on all criteria simultaneously. However, it should be pointed out that even when a decision problem is "properly formulated" from a mathematical standpoint, that does not mean that it is "well-formulated" in regards to the given reality. Multicriterion decision aid appears to be a discipline firmly rooted in its time (Vansnick, 1995), in line with the constructivist approach (and eventually confirmed by the axiomatic approach (Pirlot, 1994)), with a concern for learning while not seeking to find an existing reality external to the actors involved in the process.

2. Multicriterion formulation of a decision problem

In the terminology developed by Vansnick (1990), multicriterion formulation of a decision problem may be defined in the form of the model "*A*, A/F, E" where:

A is the set of potential (feasible, permissible,…) alternatives. This set may be defined explicitly (finite set), with the constraints being implicit, or implicitly (usually an infinite set), with the constraints being explicit. In the latter case, multi-objective mathematical programming (MOMP) is used and the set of feasible alternatives is often represented by the X symbol;
A/F is the finite set of attributes or criteria (depending on the school of thought), usually conflicting ones, from which the alternatives will be assessed; and
E is the set of performance evaluation of alternatives for each attribute or criterion (i.e. the set of performance vectors, one vector for each alternative).

To this day, literature on multicriterion decision aid has not put enough emphasis on the generation of the set of alternatives, at least in the discrete case (as if this set existed a priori). This might be true for many decision problems, but for others, namely for territory planning and development, it is not the case. On the other hand, some concepts were carefully defined, such as globalized actions (mutually exclusive alternatives) and fragmented actions.

The second element of the triplet, the set of attributes or criteria, is (according to Vincke (1992)) the most delicate part in defining a decision problem using a multicriterion approach. Mainly, two approaches have been proposed to attempt to build a set of attributes or a criteria family. In the "Top-down" approach, a hierarchical structure is built where the first level is the global objective decomposed into sub-objectives, which are in turn decomposed into sub-sub-objectives until a measurable level termed as attributes is achieved (Keeney and Raiffa, 1976). The second approach, the "Bottom-up" approach, identifies all the consequences which may result from carrying out the alternatives, which are structured in dimensions and then in significance axes around which the criteria are built (Roy, 1985). A criterion is a function, defined on *A*, which takes its values in an entirely organized set. As we will see in the next section, those who adopt the second approach use criterion to represent the decision-maker's preferences concerning the implications associated with the criterion. Certain properties must be present in the set of attributes or family of criteria obtained: exhaustiveness, non-redundancy, consistency, independence,... (Roy and Bouyssou, 1993). Furthermore, according to Bouyssou (1990), the family must have two key qualities: *be readable* (i.e. include a number of criteria restricted enough so that it is possible to reason on this basis and eventually to model the inter- and intra-criteria information required to perform an aggregation procedure) and *be operational* (i.e. be acceptable as a working basis for the study).

The assessments (performance, impact,...) of the alternatives for each attribute or criteria may be performed using many approaches (analytical formulas, measuring tools, judgements,...), be more or less subjective, and marred to some imperfections (Roy, 1989).

This formulation is more likely to be adequate if the interested parties concerned by the decision problem get totally involved in the process (Banville et al, 1997; Kenney, 1992). Often, this ensures the process legitimacy. Generally, the decision problem will not entirely be solved and a multicriterion method will have to be used so that the global preferences of the decision-maker may be identified.

In Saaty's (1980) Analytic Hierarchy Process (AHP), the formulation is slightly different. In the hierarchical structure, alternatives are located at the last level of the hierarchy, but are accounted for the exact same way as the elements at all other levels by means of pairwise comparisons.

3. Multicriteria methods

Most multicriteria methods are based on the latter formulation and include more than one step. If the set of alternatives is implicit and defined by a set of explicit constraints, then a MOMP-type multicriterion method will generally be used. Extensive work in MOMP is devoted to finding the efficient set. Identifying this set doesn't take into account the decision-maker's preferences. It doesn't lead to a final solution for the decision problem and is not a compulsory step. Usually, the effective set includes an infinite number of alternatives and, therefore, an aggregation procedure (Evans, 1984) must be used in order to identify the best alternative(s).

There are a great number of multicriteria methods, a situation that may be seen either as a strength or as a weakness (Bouyssou et al. 1993). Most methods fall within the three following operational approaches (Roy, 1985):

1) single-criterion synthesis approach, where incomparability is excluded;
2) outranking synthesis approach, where incomparability is accepted;
3) interactive local judgement with trial and error iterations.

Methods that belong to the third group are mainly developed within the MOMP framework. In these methods, computation steps (providing successive trade-offs) and dialogue steps (additional information on the decision-maker's preferences) alternate. An attempt for unifying these methods may be found in Gardiner and Steuer (1994).

There is a basic difference between the aggregation procedures found in multicriteria methods based on the two first approaches; however, in all methods falling within these two categories, preferences are introduced a priori. In the first approach, derived from the American stream of thought, local preferences (at each attribute's level) are aggregated into a unique (utility, value) function which is then optimized. Work on multicriteria methods belonging to this approach discuss aggregation conditions, specific forms of the aggregating function and function building procedures (locally and globally). Key methods within this approach include: MAUT, SMART, UTA, TOPSIS, AHP and G.P.

The second approach, derived from the French school, is first aimed at building binary relations (called outranking relations) in order to represent the decision-maker's preferences (based on the available information). In some of the multicriteria methods from this category, before the outranking relations can be built, discrimination (indifference, preference) thresholds and even veto thresholds, at each criterion level, must be introduced to model the decision-maker's preferences locally. Usually, these relations are neither transitive nor complete. The relations are then used to help formulate a recommendation that can solve the decision problem. This formulation is developed according to the given decision problematic. Aiding the decision doesn't necessarily or strictly mean answering the problem of the best solution's choice. Decision aiding can be applied to problems other than choice (Bana e Costa, 1996).

This approach includes methods that don't have a very good axiomatic basis, but show a pragmatic realistic quality in regards to the decision settings often encountered. Many new concepts are found in this approach such as decision problematics, discrimination power of a criterion, etc. Key methods or method families associated with this approach are: ELECTRE, PROMETHÉE, ORESTE, QUALIFLEX, some of these methods being strictly ordinal.

These are only a few of the multicriteria methods discussed in the literature. For instance, several methods address various imperfections of information found in the assessments (E), these imperfections being either of a probabilistic, fuzzy or mixed nature (Chen and Hwang, 1992; Martel, 1998; Munda, 1995; Slowinski and Teghem (eds), 1990).

4. Applications

A review of the existing literature shows that multicriterion decision aiding tools have been used for various applications in areas such as: environment, territory planning and development, natural resource management, mining, energy management, waste management, localization, economic planning, financial management and banking, urban management and transportation, project assessment and selection, production and supply management, human and material resource management, defence system management and military planning, international development, and so on. Not only is this list far from being complete, but it is also well-known that real world applications for decision aiding tools are not always referenced in published work.

5. Conclusion

According to Korhonen (1997), even though multicriterion decision aid has experienced a significant breakthrough since the beginning of the 70's, its biggest challenge in the future will be to gain further recognition, especially in North America. To get an idea of the activity level in that discipline between 1987 and 1992, the reader is referred to Steuer, Gardiner and Gray (1996). For those readers who do not work in the field of MCDA, we should also mention three recognized international workgroups that meet regularly:

1) The *European Working Group "Multicriteria Aid for Decisions"* has been holding meetings twice a year since 1975 (a meeting was organized in Quebec City at Université Laval in September 1998). To get an idea of the work done by this group, see Roy and Vanderpooten (1996);

2) *The International Society on MCDM* publishes the newsletter MCDM-Worldscan and has been organizing a regular conference since the beginning of the 80's;

3) *ESIGMA: European Special Interest Group on Multicriteria Analysis* meets once a year within the OR European Conferences. For more details about this group, see Bana e Costa, Stewart and Vansnick (1997).

Several national and international organizations may be added to this list (e.g. The International Conference on Multi-objective Programming and Goal Programming, whose third edition took place in Quebec City in June 1998), as well as meetings on specific topics such as AHP and the International Summer School on MCDA organized every three years (the 4th edition was held in Quebec City on August 18-31, 1991).

Since 1992, the Journal of Multi-Criteria Decision Analysis is dedicated to the publication of papers on multicriterion decision aid. MCDA has a rich history - let's all do our best to ensure its success in the future.

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