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Fuzzy Multiple Criteria Decision Making - MCDM

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***Abstract* –Fuzzy MCDM has been developed by means of the following methods: (i) the outranking, (ii) the value and utility theory based, (iii) the multiple objective programming, (iv) group decision and negotiation theory based methods. Fuzzy-set theory enabled a great numnber of novelties. The most important methods have been considered below as well as the new MCDM method- interdependancy.**

***Keywords* –fuzzy,MCDM -multiple criteria decision-making**

I. Introduction

Multiple Criteria Decision Making was introduced as a promising and important field of study in the early 1970'es. Since then the number of contributions to theories and models, which could be used as a basis for more systematic and rational decision making with multiple criteria, has continued to grow at a steady rate. A number of surveys, cf e.g. Bana e Costa [1], show the vitality of the field and the multitude of methods which have been developed.

Bana e Costa and Vincke [2] argue that with MCDM the first contributions to a truly scientific approach to decision making were made, but find fault with the objectives to carry this all the way as we have to deal with human decision makers who can never reach the degree of consistency needed.

They introduce multiple criteria decision aid MCDA as a remedy; this approach can be given the aim "to enhance the degree of conformity and coherence" in the decision processes carried out among (predominantly groups of) decision makers - this is done with a cross-adaptation of the value systems and the objectives of those involved in the process. Even if there are some distinctions between MCDM and MCDA the overall objective is the same: to help decision makers solve complex decision problems in a systematic, consistent and more productive way.

There are four major families of methods in MCDM:

(i) the outranking , (ii) the value and utility theory based (iii) the largest group is the interactive multiple objective programming approach with pioneering work (iv) group decision and negotiation theory introduced new ways to work explicitly with group dynamics and with diferences in knowledge, value systems and objectives among group members.

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The first category contains a number of ways to find a ranking: degree of optimality, Hamming distance, comparison function, fuzzy mean and spread, proportion, left and right scores, area measurement and linguistic ranking methods.

The second category is built around methods which utilize various ways to assess the relative importance of multiple attributes: fuzzy simple additive weighting methods, analytic hierarchy process, fuzzy conjunctive / disjunctive methods, fuzzy outranking methods and maximin methods.

The category with the most frequent contributions is fuzzy mathematical programming. Inuiguchi et al give a useful survey of recent developments in fuzzy programming in which they work with the following families of applications: flexible prgramming, possibilistic programming, possibilistic linear programming, using fuzzy max, robust programming, possibilistic programming with fuzzy preference relations, possibilistic linear programming with fuzzy goals.

In order to introduce some of the key issues in fuzzy multiple criteria decison making we will work through a number of examples with a novel approach we have recently introduced, a method in which we allow the criteria to be interdependent. Then we will a give a brief overview of the contributions to this issue and close with a fairly comprehensive list of recent publications on fuzzy MCDM problems

II. Decision-making with interdependent criteria

P.L. Yu explains that we have habitual ways of thinking, acting, judging and responding, which when taken together form our habitual domain (HD)[3] . This domain is very nicely illustrated with the following example ([3] page 560):

Example1.

A retiring chairman wanted to select a successor from two finalists (A and B). The chairman invited A and B to his farm, and gave each finalist an equally good horse. He pointed out the course of the race and the rules saying, "From this point whoever's horse is slower reaching the final point will be the new chairman". This rule of horse racing was outside the habitual ways of thinking of A and B. Both of them were puzzled and did not know what to do. After a few minutes, A all of a sudden got a great idea. he jumped out of the constraint of his HD. He quickly mounted B's horse and rode as fast as possible, leaving his own horse behind. When B realized what was going on, it was too late. A became the new chairman.

Part of the HD of multiple criteria decision-making is the intuitive assumption that all criteria are independent; this was initially introduced as a safeguard to get a feasible solution to a multiple criteria problem, as there were no means available

to deal with interdependence. Then, gradually, conflicts were introduced as we came to realize that multiple goals or objectives almost by necessity represent conflicting interests[5,6]. Here we will "jump out of the constraints" of the HD of MCDM and leave out the assumption of independent criteria. Decision-making with interdependent multiple criteria is a surprisingly dificult task. If we have clearly conflicting objectives there normally is no optimal solution which would simultaneously satisfy all the criteria. On the other hand, if we have pairwisely supportive objectives, such that the attainment of one objective helps us to attain another objective, then we should exploit this property in order to find effective optimal solutions.
In classical text Theory of Games and Economic Behavior John von Neumann and Oskar Morgenstern (1947) described the problem with interdependence; in their outline of a social exchange economy they discussed the case of two or more persons exchanging goods with each others :
then the result for each one will depend in general not merely upon his own actions but on those of the others as well. Thus each participant attempts to maximize a function ......of which he does not control all variables. This is certainly no maximum problem, but a peculiar and disconcerting mixture of several conflicting maximum problems. Every participant is guided by another principle and neither determines all variables which affect his interest.

This kind of problem is nowhere dealt with in classical mathematics. We emphasize at the risk of being pedantic that this is no conditional maximum problem, no problem of the calculus of variations, of functional analysis, etc. It arises in full clarity, even in the most "elementary" situations, e.g., when all variables can assume only a finite number of values.

This interdependence is part of the economic theory and all market economies, but in most modelling approaches in multiple criteria decision making there seems to be an implicit assumption that objectives should be independent. This appears to be the case, if not earlier then at least at the moment when we have to select some optimal compromise among a set of nondominated decision alternatives. Milan Zeleny and many others - recognizes one part of the interdependence ,
Multiple and conflixting objectives, for example, "minimize cost" and "maximize the quality of service" are the real stuff of the decision maker's or manager's daily concerns. Such problems are more complicated than the convenient assumptions of economics indicate. Improving achievement with respect to one objective can be accomplished only at the expense of another.
but not the other part: objectives could support each others.

In spite of the significant developements which have taken place in both the theory and the methodology MCDM is still not an explicit part of managerial decision-making [5]. By not allowing interdependence multiple criteria problems are simplified beyondrecognition and the solutions reached by the traditional algorithms have only marginal interest. Zeleny also points to other circumstances [5] which have reduced the visibility and usefulness of MCDM:
time pressure reduces the number of criteria to be considered; (ii) the more complete and precise the problem definition, the less criteria are needed; (iii) autonomous decision makers are bound to use more criteria than those being controlled by a strict hierarchical decision system; (iv) isolation from the perturbations of changing environment reduces the need for multiple criteria; (v) the more complete, comprehensive and integrated knowledge of the problem the more criteria will be used - but partial, limited and non-integrated knowledge will significantly reduce the number of criteria; and (vi) cultures and organisations focused on central planning and collective decision-making rely on aggregation and the reduction of criteria in order to reach consensus.

Felix [7] presented a novel theory for multiple attribute decision making based on fuzzy relations between objectives, in which the interactive structure of objectives is inferred and represented explicitely.
With the following example in [45] he explains the need for a detailed automated reasoning about relationships between goals when we have to deal with nontrivial decision problems.

Example 2.
Let us suppose that there is a decision maker who wants to earn money (goal 1) and to have fun (goal 2) simultaneously, and the only way to earn money is to work. Then at least two situations are possible:
Situation 1: The decision maker does not like to work. Therefore, while working he will not have fun. The alternative working supports goal 1 but hinders goal 2.

Situation 2: The decision maker likes to work. Therefore, while working he will have fun. The alternative working supports both goal 1 and goal 2.

Relationships between two goals are defined using fuzzy inclusion and non-inclusion between the support and hindering sets of the corresponding goals. Felix [45] also illustrates, with an example, that the decision-making model based on relationships between goals can be used as a powerful MADM-method for solving vector maximum problems.
In multiple objective linear programming (MOLP), application functions are established to measure the degree of fulfillment of the decision maker's requirements (achievement of goals, nearness to an ideal point, satisfaction, etc.) on the objective functions (see e.g. [10, 11]) and are extensively used in the process of finding "good compromise" solutions.
In [9] we demonstrated that the use of interdependences among objectives of a MOLP in the definition of the application functions provides for more correct solutions and faster convergence. Generalizing the principle of application functions to fuzzy multiple objective programs (FMOP) with interdependent objectives, in [9], we have defined a large family of application functions for FMOP and illustrated our

ideas by a simple three-objective program. Let us now discuss our approach to interdependent MCDM.

III.CONCLUSION

In spite of the significant developements which have taken place in both the theory and the methodology MCDM is still not an explicit part of managerial decision-making. By not allowing interdependence multiple criteria problems are simplified beyond recognition and the solutions reached by the traditional algorithms have only marginal interest.

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