Collective Decision-making through Multiple Criteria Determination, and Preference Aggregation and Disaggregation Methods

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ABSTRACT

Group Decision Support Systems (**GDSS**) can be essential in situations in which multiple persons are involved, each having their own private perceptions of the context and the decision problem to be tackled. In such an environment the conflict amongst the members of the planning group is not an unusual situation. **Multiple criteria decision aid** (**MCDA**) **methods** may be a useful tool in coping with such interpersonal conflicts, being required occasionally the preference aggregation and disaggregation methods to achieve consensus amongst the group members.

Author Keywords
Group Decision Support Systems, Multiple Criteria Decision Aid Methods, Alicia & Sebastian, NEGO, MEDIATOR, SCDAS, UTASTAR, Analytic Hierarchy Process, JUDGES, WINGDSS, NTech–GDSS

1.- INTRODUCTION

Group decision-making is among the most important and frequently encountered processes within companies and organizations both in public and private sector. The process becomes intensely difficult due to the ill-structured, dynamic environment and the presence of multiple decision-makers each one of them having his or her own perceptions on the way the problem should be handled and the decision to be made.

Developments in multicriteria decision making methodology and the increasing popularity of computerized MCDM methods have provided scientists and professionals with a set of tools that can be used in solving problems with multiple criteria. There is, however, evidence that the effectiveness of such procedures when used by multiple decision-makers remains unproven. Therefore, practical preference aggregation methods are necessary to extend the existing MCDM methodology and computing methodology to support group decision problems.

According to the scholar Noori, conflicting objectives often exist among the group members due to interpersonal differences and goal incongruities.

Multiple criteria decision-making methods provide a adequate framework for three important GDSS tasks: (1) representing multiple viewpoints of a problem, (2) aggregating the preferences of multiple decision-makers according to various group norms, and (3) organizing the decision process. MCDM provides a simple but structured framework for controlling the decision-making process while the simplicity of MCDM outputs makes it easier to communicate, co-ordinate, and aggregate individual analyses in the group decision-making process.

Different decision methodologies in the group decision-making context have been developed throughout the last decades, being some of them the following:

1. In 1985 Kersten presented **NEGO**, a two-stage interactive procedure of individual proposal formulation and negotiation leading to compromise based on the generalized theory of negotiations' formulation developed by Kersten and Szapiro in that same year.

2. Jarke and other group of researchers developed **MEDIATOR** in 1987: a negotiation support system based on evolutionary systems design and database-centered implementation.

3. Lewandowski presented **SCDAS** in 1989, which supported a group of decision makers working together on selecting the best alternative from a given finite set of alternatives.

4. Carlsson and other scholars described **Alicia & Sebastian** in 1992: a system for formalizing consensus reaching within a set of decision makers trying to agree upon a mutual decision. The system uses the AHP method in order to model the preferences of each decision maker. Regarding the **Analytic Hierarchy Process** (Saaty 1980), the researchers Dyer and Forman argued in 1992 that it was well suited for group decision-making, offering numerous benefits as a synthesizing mechanism in group decisions. They described four ways that AHP could be applied to the common objective context: (1) consensus, (2) voting, (3) forming the geometric means of individuals' judgements, and (4) combining results from individual models or parts of a model.

5. The authors Colson and Mareschal developed **JUDGES** in 1994, which was a descriptive group decision support system for the cooperative ranking of alternatives.

6. **WINGDSS** is a group decision support software intended to aid one or more decision makers, from different fields but with a common interest, in ranking a predefined set of alternatives that are characterized by a finite set of criteria or attributes.

7. Noori presented a conceptual design of a group decision support system, named **NTech–GDSS**, in 1995, developed to guide management through the process of new technology evaluation and adoption.

8. In 1997 Barzilai and Lootsma applied the multiplicative AHP, a variant of the original AHP, to arrive at a joint decision by incorporating the relative power of the group members.

2.- THE METHODOLOGY

A group faces the problem of ranking a set of alternatives, which are valued by a family of criteria. Let $A=\{a1,a2,...,a_n\}$ be the set of alternatives, $g=\{g1,g2,...,g_m\}$ the consistent family of criteria and $D=\{d1, d2, ..., d_q\}$ the decision makers (DMs).

The problem: to find a commonly acceptable rank order of the alternatives according to the criteria and the multiple views of each DM. The process consists of six phases (See the global graph in Appendix, page 6):

1. *The setup phase.*

2. *Assessment of group members' preferences.*

3. *Calculation of relative utility values for each alternative and DM.*

4. *Calculation of a group relative utility value for each alternative.*

5. *Setup phase for the measurement of the group's satisfaction.*

6. *Measurement of satisfaction.*

The Setup Phase

The members of the group must decide on an initial set of alternatives and criteria.

Depending on the task at hand, some members of the group are more qualified for the selection of the final decision due to the existence of various factors such as expertise, knowledge, skills, etc. For this reason, each DM is granted with a certain decision power b_k, which reflects the ability of each participant to influence the decision outcome.

The addition of the decision power variables ensures that the decision will be made collectively by the participation and the co-operation of all the members, but it will also respect the particular characteristics and abilities of each DM. This type of weighted scheme is encountered frequently in practical collective decision environments.

Assessing Group Members' Preferences

After the determination and the formulation of the problem -alternatives, criteria and decision powers, the assessment of preferences of each DM takes place. Each DM is able to assign different weights to each criterion. The criteria weights are calculated by the **UTASTAR** method.

The multicriteria UTASTAR method is applied on the preferences expressed on the set of alternatives, in order to capture the preferences of each group member. The method aims to adjust additive utility functions based on multiple criteria, in such a way that the resulting preference structure would be as consistent as possible with the initial structure.

Each criterion is defined under the form of a real-valued monotone function $g_i : A \rightarrow [g_{i*}, g_i^*] \subset R$ in such a way that $g_i(a), a \in A$ represents the evaluation of the action a on the criterion g_i, and g_{i*}, g_i^* respectively the level of the most and the least desirable criterion.

The UTASTAR regression aims to estimate additive utilities:

$$u(g) = u1(g1) + u2(g2) + \cdots + u_m(g_m)$$

satisfying that

$$u_i(g_{i*})=0 \ \forall i$$

$$\sum_{i=1}^{m} u_i(g_i^*) = u_1(g_1^*) + u_2(g_2^*) + \cdots + u_m(g_m^*) = 1$$

The goal of the UTASTAR method is to guide the DM to a process of gradual learning of his preferences. The solution is the one that maximizes the DM's satisfaction.

Calculation of Relative Utility Values

Upon reaching this stage, all group members have agreed a final ranking of alternatives. The problem is that usually there are conflicts and disagreements amongst individual rankings, preventing the selection of a unique and commonly accepted group ranking of the alternatives.

Each DM. by assessing a set of alternatives, assigns utilities which he or she expects to gain from the choice of a particular alternative. These estimated utilities may vary significantly. Thus, a normalization procedure is often required in order to perform a comparison and/or aggregation of these results.

The most simple normalization process is the calculation of relative utilities according to the following additive-type formula:

$$P_{jk} = \frac{U_{jk}}{\sum_{j=1}^{n} U_{jk}}, \quad j = 1, \ldots, n, \quad k = 1, \ldots, q$$

where P_{jk} is the relative utility value of the alternative j according to DM k. U_{jk} the utility of alternative j according to DM k.

The range of utilities -difference between the maximum and the minimum values of the estimated utilities- may be used as a discrimination measure, and expresses the degree of difficulty for the DM to separate the alternatives in subsets of most and least preferable. This measure of discrimination ability is called width of utilities w_k . If w_k has a small value, the DM is unable to discriminate among the subset of the best and the subset of the worst alternatives, while if w_k has a high value then the DM is able to opt for some alternatives as good and some others as bad. Therefore, an alternative normalization formula for the utilities of each DM is the following:

$$P_{jk} = \frac{U_{jk}^{w_k}}{\sum_{j=1}^{n} U_{jk}^{w_k}}, \quad j = 1, \ldots, n, \quad k = 1, \ldots, q$$

where $w_k = \max\{U_{jk}\} - \min\{U_{jk}\}$ is the difference between the upper and lower utility values for the alternative j according to the DM k; the width of utilities.

Calculation of group relative utility values

Using the individual relative utility values, a new group ranking of the alternatives is constructed based on the rank order established from all the group members. The group relative utility value for an alternative j by the group of the k DMs can be computed by:

$$S_j = \sum_{k=1}^{q} b_k P_{jk}$$

where b_k is the decision power of DM k. In the special case, where all the DM's are given the same power:

$$S_j = \frac{1}{q} \sum_{k=1}^{q} P_{jk}, \quad b_k = \frac{1}{q}, \quad \forall k \in D$$

At this point, an ordinal ranking of the alternatives can be constructed, which is supposed to represent the opinions and the preferences of the group. However, the computation of a group ranking does not guarantee the consensus of the group members towards the solution proposed by the method. It is quite possible that some members of the group have a very strong opposition about the proposed solution. In order to ensure consensus, we try to incorporate a method, which attempt to measure and test the group members' satisfaction over the proposed ranking of the alternatives.

In order to assess the satisfaction of the group we apply another multicriteria methodology, which was originally developed and successfully applied in measuring customers' satisfaction.

Setup Phase of the Satisfaction Problem

The DMs have to consider the extent of their satisfaction from the proposed solution. They have to specify a set of criteria -called the satisfaction criteria, which will be used for the assessment of their satisfaction. They have to define two satisfaction levels $E1$ and $E2$: an upper and a lower limit for the measurement of the group's satisfaction.

Assessment of the Group Satisfaction

The DMs are urged to express their subjective preference -opinion- on the ranking proposed by the method, using a new set of criteria -satisfaction criteria. Using this methodology one can assess an average global satisfaction index, which measures the satisfaction of each DM from the proposed solution, as well average partial satisfaction indices which measure the satisfaction of each DM from every satisfaction criterion separately. The value of the global satisfaction index determines the outcome of the process:

- If the average global satisfaction index is greater than the specified level E1 ($GSI \geq E1$), then the solution is considered to be commonly acceptable.

- If the global satisfaction index has a more or less average value ($E2 \leq GSI < E1$) then the DMs are urged to reconsider the satisfaction problem. In an attempt to reach consensus on the proposed solution they can change the values of the $E1$ and $E2$ levels, or the values of the satisfaction criteria, or modify the satisfaction criteria. If the DMs agree the process returns to Phase 5.

- The value of the GSI index is lower than $E2$ ($GSI < E2$). In this case the proposed solution is totally conflicting with the expectations and desires of the group members. If the DMs agree, the process returns to Phase 1 attempting an overall reconsideration of the problem.

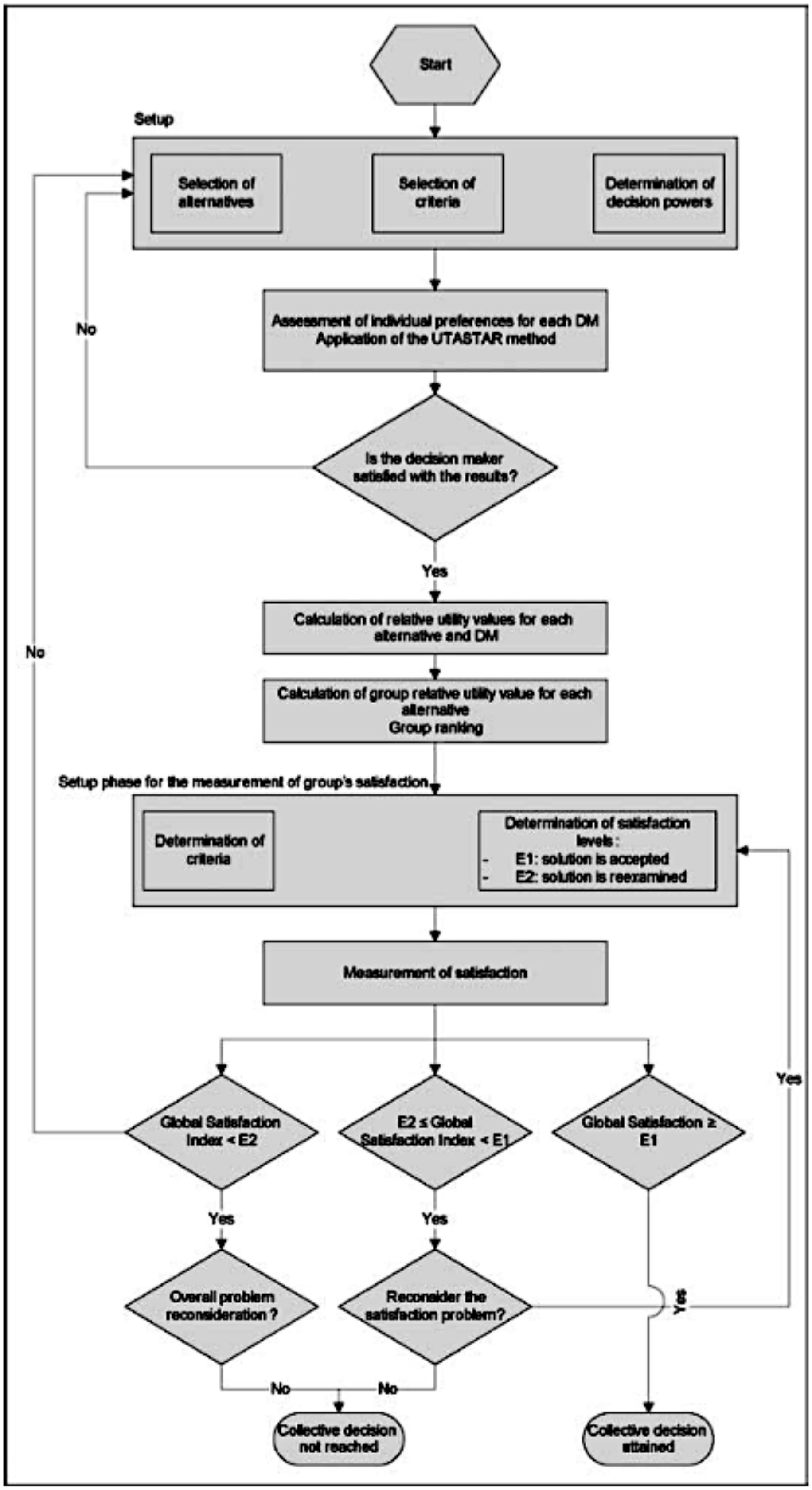
3.- FINDINGS

By the combination of two multiple criteria decision-making techniques a structured process for group decision-making is formulated. Both methods can be programmed and implemented within an interactive computer environment.

The adoption of the UTASTAR algorithm ensures that each DM is completely consistent with his or her initial weak order of alternatives.

A main assumption of the UTASTAR method is that the model of DM's preferences is additive; although it is not a perfect approach, since of course it is not true in all decision problems. Nonetheless, **the assumption of a linear preference system simplifies the problem and makes the assessment of the DM's preference system easier and feasible**.

APPENDIX



Start
Setup
Selection of alternatives
Selection of criteria
Determination of decision powers
Assessment of individual preferences for each DM
Application of the UTASTAR method
Is the decision maker satisfied with the results?
No
Yes
Calculation of relative utility values for each alternative and DM
Calculation of group relative utility value for each alternative
Group ranking
Setup phase for the measurement of group's satisfaction
Determination of criteria
Determination of satisfaction levels:
- E1: solution is accepted
- E2: solution is reexamined
Measurement of satisfaction
Global Satisfaction Index < E2
E2 ≤ Global Satisfaction Index < E1
Global Satisfaction ≥ E1
No
Yes
Yes
Yes
Yes
Overall problem reconsideration ?
Reconsider the satisfaction problem?
No
No
Collective decision not reached
Collective decision attained

REFERENCES

N.F. Matsatsinis, E. Grigoroudis, and A. Samaras, *Aggregation and Disaggregation of Preferences for Collective Decision-Making*. Decision Support Systems Laboratory, Technical University of Crete, University Campus, Chania, Crete, Greece