SYSTEMS RESEARCH INSTITUTE * DECISION AND NEGOTIATION SYSTEMS *

IFAC IFORS IIASA TIMS DNS

IFAC/IFORS/IIASA/TIMS

The International Federation of Automatic Control
The International Federation of Operational Research Societies
The International Institute for Applied Systems Analysis
The Institute of Management Sciences

SUPPORT SYSTEMS FOR DECISION AND NEGOTIATION PROCESSES

Preprints of the IFAC/IFORS/IIASA/TIMS Workshop

Warsaw, Poland

June 24-26, 1992

Editors:

Roman Kulikowski
Zbigniew Nahorski
Jan W. Owsiński
Andrzej Straszak

Systems Research Institute
Polish Academy of Sciences
Warsaw, Poland

VOLUME 2:

Names of first authors: **L-Z**

SYSTEMS RESEARCH INSTITUTE, POLISH ACADEMY OF SCIENCES

SUPPORT SYSTEMS FOR DECISION AND NEGOTIATION PROCESSES
Preprints, IFAC/IFORS/IIASA/TIMS Workshop, June 24-26, 1992, Warsaw, Poland

EXPERT KNOWLEDGE AND COMPUTER-AIDED GROUP DECISION MAKING THROUGH DSS: SOME PRAGMATICAL REFLECTIONS

Nicolay Stanoulov
1463 Sofia, ul. Czar Assen 100
Bulgaria

ABSTRACT. The contribution of a simple outranking Multiple Attribute Decision Making (MADM) approach and the relevant DSS to group decision making is discussed. The main topics are: elicitation of expert knowledge via expertise organization, expert analysis, etc.: description of DSS UNIDAS 2, its decision rules, functional architecture and users' decision modes; the group DM paradigm dealing with the pluralism of ideas and formal (group) consensus; the requisites of the interactive group DM and how this DSS utilizes them. The scope of the applications of the concerned MADM approach and the (G)DSS mostly suitable for a fast diagnostics, time pressure, etc., are also mentioned.

Keywords: MADM, outranking preference aggregation techniques, group DM, expert knowledge elicitation, (G)DSS.

1. Introduction

Decision Support Systems (DSS) are still one of the advanced computer emergencies in modern information technology. A lot of contemporary DSSs assist primarily individual decision making (DM). Group DM is the "hardest nut to crake" in decision and social choice theories because the collective outcome sought for has synergistic features. Only few DSS nowadays are capable to tackle group DM issues (Grauer,& (1983), Steeb,& (1984), Gray (1987), Bui, T.X.(1987)). A simple outranking MADM approach and the relevant group DSS (G)DSS are briefly outlined in the next.

2. Eliciting Expert Knowledge

We will point out here only some basic notions. The reader may find papers discussing the elicitation and analysis of expert knowledge e.g. in Larichev (1981), Steeb,& (1984), Rankova,& (1984), Bui, T.X. (1987), Klein (1989), et al.

Organizing the expertises

A principal distinction exists between knowledge elicitation from only one expert, manager, et al. (DMr: decision maker) and a group of DMrs. While the former acts voluntarily via contemplation, research, analyses, or interviews, the latter act as indissociable men in a joint discourse/conversation medium. How to form the expert group(s), how to recruite/select the single experts, how many experts are needed, etc. are typical questions that arise when starting an expertise. The answers heavily depend on the particular DM problem to be resolved, the funds assigned, the local (country) legislation basis, and, last but not least, the specific group technique to be adopted.

Expert analysis

Contrary to decision analysis the expert analysis doesn't require explicit data or evaluation of utility-, value-, and probability. The lack of sufficient information about the complicated DM problem does not allow building and use of strict (mathematical) methods. One must rely in such cases upon subjective judgments, knowledge and experience of the expert(s). After a clear definition of the goal(s) by top DMr(s), a group outranking technique for preference aggregation, see Bui, T. X. (1987), exploits the following triple:

* Selecting the group of experts designated below as Ehs, h=(1,t); t≥2. It involves experienced men-professionalists in the concerned DM problem.

* Generating the set of alternatives $A=\{a_{ij}\}$, $i=(1,m)$; $m\geq 2$. a_{ij}s are prespecified (or fixed) coherent and mutually exclusive, at all, options-variants that must satisfy or help achieving the goal. a_{ij}s can be cardinal values or ordinal entities, OR both.

* Specifying the set of criteria $K=\{Kj\}$, $j=(1,n)$; $n\geq 2$. Kjs are significant and necessary features-properties of a_{ij}s, the goal, too. Kjs have to be non-interdependent, or accepted to be such for. They can be quantifiable or qualifiable, OR

both. They may be interpreted also as non-equivalent/non-equally by introducing eligible weighing coefficients.

A and K are in principle constrained sets. They should contain both a practically sufficient number of admissible and feasible elements. The completeness of a set is a very sophisticated and intricate problem in mathematics.

3. UNIDAS 2: A Computerized Decision Support

Basic decision rules of UNIDAS 2

This (G)DSS builds workable models of observed or imaginary Eb behaviour. The main concept in the rank theory of individual and group DM, Stanoulov (1984, 1988/9, 1990), underlying UNIDAS 2 is the preference ordered/rank matrix (pom) of "OBJECT (alternatives) - FEATURES (criteria, OR/AND expert judgments)" type. For example, $(a_{ij})=(A^{*} - K)$ is a pom composed by one Eb. A^{*} indicates the column preference ranking of a_{ij}s on each single Kj nonconcurrently done by the expert Eb. The binary preference relational system used in pom encompasses strict and indifference only preferences defined over the set A. The ranking of a_{ij}s is based either on wholistic ideas, i.e. building of Gestalts, see Sage (1981) when a_{ij}s are ordinal, or on a direct comparison of cardinal a_{ij}s-values. Incompatibilities among a_{ij}s do not take place. Occasionally available intransitivities among/between a_{ij}s in a column of (a_{ij}) are signalled automatically and should be eliminated by Eb(s) afterthat. Of course some concepts based on randomness, probabilities and/or utilities, risks, too, may be of pertinent use by specifying quantitative criteria. The corresponding a_{ij}s-values in a pom are ranked automatically while the calculations of such Kjs is an exogeneous expert work. The rank theory utilizes a broad aspect of rationality, see Sage (1981), to the expertise activities, accompanied by making calculations, either neat, or approximate.

The principal decision rule "Dichotomy-sums-of-ranked-alternatives", a dichotomy-cut rule, in short (early known as the DIMCO method, Stanoulov (1984,1989), is as follows:

3.1. "Classical" row dichotomy (ROWD):

$$\max_i \left[\sum_{j=1}^{j=n} \sum_{r_i=1}^{r_i=(m+s)/2} a_{ij} \right]$$

r_i is the rank of a_{ij}s in (a_{ij}); s=0/1 if m is even/uneven.

3.2. Gradation dichotomy (GRADD):

$$\max_i \left[\sum_{j=1}^{j=n} \sum_{r_{mi}=1}^{r_{mi}=m/2} d_{ij} \right]$$

r_{mi} is the middle rank of a_{ij}s, $1 \leq r_{mi} \leq m/2$ whatever m.

$$d_{ij} = \begin{cases} 1 & \text{if } r_{mi} = [m/2] \\ 0.5 & \text{if } r_{mi} = [m/2] + 1 \\ 0 & \text{if } r_{mi} > [m/2] + 1 \end{cases}$$

The dichotomy of pom (dpom) points out to eliminating that part of it which contains the less preferred a_{ij}s. It is very rarely to "lose" some a_{ij}(s), i.e. a part of DM information originally available, by this cut of a pom. In any case such lost a_{ij}(s), if any, are always mispreferred. A second filtration of a_{ij}(s) in dpom occurs when one builds the resultant (preference ordered) sequence R of a_{ij}s (or the direct its graph). R contains the most preferred a_{ij}(s) in its first position, the next less preferred ones in the second position, etc. One should get then some a_{ij}(s) placed in first R-position.

A third filtration may come out when one finds the Pareto optimum (PO) a_{ij}(s) in pom, occasionally also, e.g., minmax/maxmin a_{ij}(s), and compare it/them with the preferred a_{ij}(s) in R. It is strongly argued in the rank DM theory that (i) dpom has an "information optimum" property, i.e. dpom contains always the least number of rows from the initial pom, (ii) at least one efficient (i.e. PO) a_{ij} in pom is contained always in the first position of R (UNIDAS 2 can mark so far only weak PO alternatives). The cognitive style DM models realized by the decision rule kinds just described resembles much to the "garbage can" model (see Sage, 1981) which makes use of simple preference assessment procedures in cases of ordinal (verbal, etc.) a_{ij}-values.

Functional architecture of UNIDAS 2

UNIDAS 2 is an interactive centralized PC computer system for assistance of individual and group DM. It has a "sandwich" structure with subunits: dialogue (a menu-driven interface), DM models, and data unit. The latter help user to specify and input in PC all necessary data (A & K). (G)DSS' star-like configuration enables it to represent a localized problem solver composed by a (non)coupled group of Ebs, users, too. The program package is in Turbo Pascal and can be realized by any PC IBM or compatible ones.

Rank theory decision modes of the user(s)

If (A* - K) is the pom of individual DM, so (A* - Eb) will be a pom known of voting; it specifies a criterialess (or simplified) group DM. There is in the rank theory also a complete-multicriteria group DM wherein A,K and E are ALL available - the corresponding "meta" pom will be $(\alpha_{i'b})$=(A* - Rb), $i'=(1,m')$; $m' \leq m$. Here Rbs are the own resultant sequences of the Ebs obtained by individual DM. In a second phase Rbs should substitute for Kjs of any (A* - K) of the single Ebs for to build-in $(\alpha_{i'b})$. The basic decision rule's kind are fully applicable to all DM modes cited.

4. Group DM Paradigm

The group DM conduct of man is discernibly different from the individual DM one. According to the rank theory the group DM satisfies the following points of departure.

a) Pluralism of ideas: a freely expression of the personal opinions.

b) Formal group consensus: Ebs cannot influence the intrinsic group preference aggregation process once their own preference judgments are firmly established through composing the (A* - K)bs poms.

Requisites of the interactive group DM

1. The top DMr entrust the group E with the DM problem. A neutral mediator Mr may be attached to the group to help it.

2. The top DMr gives the statute of E (see Sect. 2).

3. Each Eb should strive to help structuring the DM problem, i.e. specifying A and K, the measurement scales for Kjs, if necessaru, etc. Ebs may interact or not each other.

4. Each Eb should compose the pom $(a_{ij})b$; the dpoms are constituted automatically via UNIDAS 2.

5. The metaresultant sequence mR (analogous to R) is the final outcome of the collective DM process.

6. Ebs can enter into negotiatiations with other Eb(s), or each Eb (or group of them) is apt to act independently. A "pooled-interdependent" DM behaviour (Bui, T.X., 1987) presupposes reuniting of (some) Ebs in one or more homogeneous subgroups when specifying K and/or A. With a "sequential-interdependent" DM behaviour some Ebs or all will specify their own sets $\bar{K}$ and/or A, independently from the other Eb(s).

For the time being UNIDAS 2 can operate with a common only agreement of all Ebs upon the set A (A-coherence). Different ways of performing group communications can be used within this DSS for to reach a concerned DM information structurization.

5. Application Aspects

The potential and actual applications of UNIDAS 2 are very broad (see e.g. Stanoulov, Pavlov, 1984). This (G)DSS helps the users in management and control, economics, technology, ecology, etc., finance and budgeting, systems analysis and systems engineering, social activities - art and aesthetics, at that, in an easy and fast manner. Most of the applications up to now belong to technology, value analysis, assigning resources, etc., time pressing group DM. Special measures can be envisaged in order to avoid or restrict possible cheating and manipulation events.

6. Illustration of Group DM

Some years ago the solution of a typical monetary resource allocation problem in an academic R&D organization was experimentally done by a test version of UNIDAS: How to share reasonably and unprejudicely, at that quickly enough, fixed funds among seven scientific divisions A= {B,C,D,E,F,G,H} of this organization. The top DMr (Director General) was also a member of the staff E (nine in number) of the steering council of the organization. The exogeneous work of the group E covered the specification of the set K. Ebs, b=(1,9) agreed upon the following K-elements: six qualifiable (K1-K6), five quantifiable (K7-K11), In detail: K1 - overall impression on the activity of each alternative B,...,H; K2 - expedient use and maintenance of available computing units; K3 - significance, impact and intensity of scientific publications during the last 5 years; k4 - contribution to practice; K5 - social activity; K6 - responsiveness of the (division) personnel to the scientific activities; K7 - total mean service of length of the division personnel; K8 - mean service length of the personnel in a given division; K9 - published papers, etc. and citations during the last 5 years; K10 - reported papers to symposia, etc.; K11 - number of scientific degrees of the personnel of the division. Two ordinal scales might be used (if needed) for K1-K6 (very good, good, unsatisfied: K1-K5; very good, good, moderate, unsatisfied, poor:K6). The criteria dimensions of K7-K11 were as follows: years/number (of the personnel) - K7,K8; papers and citations/number - K9; reports/number - K10; sci.degrees/number - K11. Ebs have to check (when needed) the non-interdependence of the Kjs specified by means of e.g. (mathematical) logical procedures, etc. For K7-K11 the cardinal a_{ij}s have to be ranked by priority for all nine poms (see Table 1). Such quantitative ranking of a_{ij}s proceeds automatically in UNIDAS 2, the obtained arrangement of a_{ij}s appears in the concerned Kjth column of the pom. One should now turn to the editor for initiating the concerned a_{ij}-quantitative values. The availability of specifying weighing coefficients w_js for Kjs/Ebs is also given in UNIDAS 2. When a pom is ready an intransitivity checking follows done automatically. It concerns wrongfully repeated a_{ij}(s) during the ranking in one and the same Kjth column. In such cases a message appears on the display

Table I. Values of ordinal a_{ij}s to be priority ranked

K7	K8	K9	K10	K11	a_{ij}
30	20	2.5	1.9	0.2	B
26	29	1.9	2.0	0.3	C
28	21	1.2	1.5	0.4	D
18	32	1.8	2.2	0.1	E
20	18	2.0	1.4	0.3	F
22	31	0.8	1.8	0.25	G
22	30	1.0	1.9	0.2	H

indicating the availability and the position(s) of such repeated a_{ij}(s).

In our DM problem a pooled-interdependent behaviour of Ebs was observed as far as it concerned the set K (set A evidently is previously fixed). However when making their judgments for a_{ij}s on K non-concurrently the group members Ebs proceeded sequential-interdependently in that they used all or parts of the set K at their own will. So, only one Eb have used all 11 criteria, another one – 10 criteria, three Ebs - 9 ones, other three Ebs – 8, and one Eb – five criteria. For all Kjs w_js are equal.

The time spent for specifying the nine Kjs from the group E was about 2 h; about 4 h were necessary for obtaining all concerned data in Table I. The author played the role of the Mr before beginning the expertise session of Ebs. His tutorial tooks about 30 min.

Let us depict the pom, dpom and R for E6 in the following example: |A| = 7, |K| = 8 = {K1,K2,K4,K6-K10}, |E| = 9 (The GRADD version of the decision rule was used).

K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11
*	*		*		B	B	E	B	E	
*	*		*		C	D	G	F	C	
*			*		D	C	H	C	H	
E					E	*	C	E	G	
					F	F	F	D	D	
					G	E	D	H	F	
					H		B	G	B	

The asterisk "*" denotes subsets of equal/equivalent a_{ij}s: *(i,j)=(1,1)=BG, *(1,2)=DFG, *(1,4)=BCH, *(2,1)=CH, *(2,2)=BCEH, *(2,4)=EF, *(3,1)=DF, *(3,4)=DG, *(4,7)=GH

$(a_{ij})_{6GRAD} = (A^* - K)_{6GRAD}$

K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11
*	*		*		B	E	B	B	B	
*			>*		C	D	G	F	C	
					D	C	H	C	H	
					>E		>C	>E	>G	

The arrows point out the entries the cut passes accross a row.

$(a_{ij})_{6GRADD} = (A^* - K)_{6GRADD}$

The auxiliary matrix for d_{ij}s is as follows(see Sect.3.2):

K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	SUM	a_{ij}
1	–	–	1	–	1	1	–	1	–	–	5.0	B
1	–	–	1	–	1	1	.5	1	1	–	6.5	C
–	1	–	–	–	1	1	–	–	–	–	3.0	D
–	–	–	.5	–	.5	–	1	.5	1	–	3.5	E
–	1	–	.5	–	–	–	–	1	–	–	2.5	F
1	1	–	–	–	–	–	1	–	.5	–	3.5	G
1	–	–	1	–	–	–	1	–	1	–	4.0	H

$(A^* - K)^{i}_{6GRADD}$

The resultant preference sequence/column for E6 will be

R_{6GRADD}:

C	6.5
B	5.0
H	4.0
EG	3.5
D	3.0
F	2.5

C is the most preferred a_{ij}, B the next (less) preferred one, etc. for E6.

The resultant outcomes R for the other Ebs are given in the following meta pom $(a_{i'b})$, i'=m (composed according to Sect.3) including R6 (all a_{ij}s are now written out):

R1	R2	R3	R4	R5	R6	R7	R8	R9
CH	B	C	E	H	C	C	D	C
B	CG	BH	BF	BCD	B	GH	GH	B
DFG	>DH	E	G	>G	H	>B	CE	>E
E	F	G	C	E	EG	DE	BF	DFH
	E	D	H	F	D	F		G
		F	D		F			

The dichotomic meta pom $(a_{i'b})_{GRADD}$ is also shown. After its processing in the same manner as $(a_{ij})_{6GRADD}$ one obtains the final resultant group outcome-sequence:

mR: B, C, H, G, DE, F
(7.5) (7.0) (6.5) (4.5) (2.5) (1.0)

The weak PO a_{ij}s are B,C,D,E,H. Through the pair-wise matrix one can easily obtain also maxmin/minmax a_{ij}(s). Other interesting conclusions can be drawn from such group expertises and group DM aided by UNIDAS 2. The time spent in PC processing here the group results was about 30 min.

REFERENCES

Grauer, M.A., A.Lewandowski, A.Wierzbicki (1983). DIDASS: Theory, implementation and experiences. In: Interactive Decision Analysis. Springer Verlag, Berlin.

Gray, P. (1987). Group decision support systems. Decision Support Systems, 3.

Klein, G.A. (1989). Critical decision method for eliciting knowledge. IEEE Trans. on Systems, Man, and Cybernetics, 19, 3.

Larichev, O.I. (1981). Decision making as a research branch: methodological problems. In: Systems Research II. M.Gvishiani (Ed.). Pergamon Press, Oxford.

Pankova, L.A., A.M.Petrovskii, M.V.Schneiderman (1984). Organization of Expertises and Expert Information Analysis. Nauka, Moscow (in Russian).

Sage, A.P. (1981). Behavioral and organizational considerations in the design of information systems and processes for planning and decision support. IEEE Trans. on Systems, Man, and Cybernetics, 11, 9.

Stanoulov, N. (1984). Common theory for individual and group DM. In: 9th IFAC Congr., Budapest 1984, 5, Colloqu. 11.5.

Stanoulov, N., Ju.Pavlov (1984). Comparative discrete DM analysis for urban service systems. A two methods supported case study. Syst.Anal.Model.Simul., 1, 5.

Stanoulov, N. (1988). Dichotomic matrix decision support system UNIDAS. Prospectives to a near-expert system. In: Theory and Practice of Computer-Based Decision Making Systems. NITI, VEDA Print. House, Sofia.

Stanoulov, N. (1989. Rank Theory of Individual and Group DM. Print House of the Bulgar. Academy of Sci.,Sofia (in Bulg.).

Stanoulov, N. (1990). Matrix dichotomy variety: How is it used in discrete DM? Syst.Anal.Model.Simul.,7, 4.

Steeb, R., St.C.Johnston (1984). A computer-based interactive system for group decisionmaking. IEEE Trans. on Systems, Man, and Cybernetics, 11, 8.

Bui, T.X. (1987). Co-oP. A Group Decision Support System for Cooperative Multiple Criteria Group Decision Making. Lecture Notes in Computer Science (290). Springer Verlag, Berlin.

ACKNOWLEDGMENT

The author offers his special thanks to the unknown reviewer for the support and the valuable advise to add an illustration to the paper.