A DSS FOR COOPERATIVE MULTIPLE CRITERIA GROUP DECISION MAKING

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ABSTRACT

Many decisions in organizations are made, or at least prepared, by multiple cooperating decision makers. A distributed DSS architecture is presented that connects multiple individual DSS to a group DSS. The group decision making process is supported by content-oriented methods based on extensions of multiple criteria decision making methods, as well as by process-oriented techniques using a computerized conferencing system. A prototype of the system is operational on a personal computer configuration.

Introduction

The problem of collective decision making has been extensively investigated by numerous researchers. Most of this work could be classified into two main streams of research. The first approach focuses on the content of the problem, attempting to find an optimal or satisfactory solution given certain social or group constraints, or objectives. Studies by Arrow (1951), Nash (1950), Harsanyi (1955), and von Neumann and Morgenstern (1953) are classical illustrations of this approach. By contrast, the second approach is process-oriented. It is based on the observation that the group goes through certain phases in the group decision making process, and on the belief that there could be an ordered way to effectively deal with these phases. Behavioral studies of Bales and Strodtbeck (1951), Chamberlain and Kuhn (1965), Walton and McKensie (1965), and Warr (1973) are some of the well-known research devoted to this process-oriented approach.

More recently, a third approach to group problem solving has emerged from the decision support system technology. Stohr (1981), Carlson and Sutton (1974), and Holloway and Mantey (1976) present examples of decision support systems that involve multiple decision makers. However, it remains unclear that such DSSs can truly support group problem solving, since they mostly deal with the pooled type of group decision making which is only a minimal form of collective decision making.

This paper describes, evaluates, and discusses the potential of a cooperative group decision support system (CGDSS) that uses a multiple criteria decision model as a vehicle to integrate approaches developed in conventional single user DSS and in computerized conferencing systems (CCS). The CGDSS is motivated by some previous work that (1) advocates extensions of DSS to support not only the choice phase of the decision making process, but also the intelligence and design phases (Bui, 1984), and (2) suggests the use of a multiple criteria decision model as a vehicle to expand the DSS framework to organizational group decision making (Bui and Jarke, 1984).

Bearing in mind that the group decision making process is substantially more difficult than the single person decision process, this paper does not attempt to get into the already large number of theoretical discussions. Rather, it demonstrates that with the aid of a CGDSS the decision makers can alternately use quantitative and behavioral group decision methods to effectively resolve group decision problems, or at least reduce the chances of the decision breakdowns often observed in collective decision situations. Specifically, an integrating framework based on an extension of a discrete multiple criteria decision method, the ELECTRE method (Roy, 1968) is presented that links (1) a conventional DSS model component that includes time series models, explicative models, and simulation models (Bui, 1982), (2) two computerized process-oriented group decision methods, i.e. the delphi method and the nominal group technique (Van de Ven and Delbecq, 1974), and (3) a simple

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computerized conferencing system that supports group communication.

A DSS for Cooperative Group Decision Making

GROUP DECISION MAKING: TERMINOLOGY AND TYPOLOGY

A collective decision making process can be viewed as a decision situation in which there are two or more persons, each of which are characterized by their own perceptions, attitudes, motivations, and personalities, who recognize the existence of a common problem and attempt to reach a collective decision.

One can observe three broad types of group decision making: a single decision maker within a collective decision environment, non-cooperative decision making, and cooperative decision making.

In the first type of group decision making, a particular decision maker ultimately makes the decision and assumes responsibility for his/her line of action. However, the decision can be regarded as a collective one because of the existence of the dense network of influences that surrounds this single decision maker. In fact, other participants in the decision maker's organization can either support or act against the decision. Thus, the identification and analysis of the behaviors and attitudes of other people, indirectly involved in the decision making process, should be analyzed.

In the situation of non-cooperative decision making, the decision makers play the role of antagonists or disputants. Conflict and competition are common forms of non-cooperative decision making. While the former represents a situation in which disputants seek to hurt their opponents for their interests, the latter is characterized by the fact that each competitor is an action candidate, and is trying to outperform others.

Finally, in a cooperative environment, the decision makers attempt to reach a common decision in a friendly and trusting manner, and to share the responsibility. Consensus, negotiation, voting schemes, and even recourse to a third party to dissolve differences, are examples of this type of group decision making.

THE COOPERATIVE COLLECTIVE DECISION ENVIRONMENT

The CGDSS presented in this paper operates in the third type of group decision making environment. In particular, it attempts to support the following decision situation:

1. There are multiple users or decision makers who share an equal weight in the decision making process. The assumption of equal weight excludes, among other things, the hierarchically distributed decision situation, as found, for example, in transportation planning (Edelstein and Melnyk, 1982; Jarke, 1982).

2. The decision makers interact in a cooperative manner and in a trusting environment. For further simplification, there is no attempt to cheat, to seek coalition within a sub-group, and no third party intervention.

3. The group shares the same set of feasible decision alternatives (e.g., products, actions, strategies, etc.). These alternatives are subject to a selection of one or more alternatives, or to a ranking according to a given set of criteria. The selected alternatives are called the decision outcome.

4. Each decision maker has his or her own objectives that reflect *a priori* values and aspiration levels. Objectives are concretely expressed by criteria or attributes that are discrete and ordinally measurable. Due to individual differences, individual decision outcome—as opposed to the collective decision outcome of the group—often differs from one decision maker to the other.

DESIGN ISSUES FOR GROUP DECISION SUPPORT APPROACHES

Bales and Strodtbeck (1951) were among the first who observed five main types of functional problems during a group decision making process:

1. *Problem of orientation:* The decision makers often ignore or are uncertain about some of the relevant facts. They seek information, orientation, or confirmation.

2. *Problem of evaluation:* The decision makers—because of their personalities and of the nature of the problem—have different values and interests. They need a framework to analyze the problem and express their wishes and feelings.

3. *Problem of control:* Each decision maker within the group may end up with a different decision outcome. They seek exchanges of points of view and directions to reach consensus.

4. *Problem of tension management:* The frequencies of both negative and positive reactions tend to increase during the group decision making process. The group

seeks to improve understanding, increase compliance, reduce tension, and avoid member withdrawal.

5. *Problem of integration:* The group seeks solidarity during the group problem solving process and collective endorsement of the final agreement.

While the problem of evaluation (type 2) often remains the most frequent activity during a decision making process, the problem of orientation (type 1) is typically prevalent at the beginning, whereas the problems of control (type 3), tension-management (type 4), and integration (type 5) and more frequent towards the end of the process.

The decomposition of problems into five types suggests a division of tasks within the group DSS functions. The rationale of such a division of tasks is two fold. First, despite the efforts of the content-oriented DSS technology to help decision makers structure their initially unstructured problems, some unstructured part will remain. This partial 'unstructurability' is due to uncertainty, fuzziness, ignorance, and inability to quantitatively measure the complexity of decision situations and the decision maker's preferences (Stohr, 1981). Second, the same efforts to resolve a group decision problem are rendered more difficult by human irrationality and emotionality when dealing with group interaction (Pruit, 1981). It is then necessary to search for some process-oriented methods that can support the unstructured part left by the content-oriented DSS, as well as for some communication system that collects, coordinates, and disseminates information within the group.

There is no doubt that defining the boundaries of structurable and unstructurable problems is difficult. It is also difficult to determine whether a process-oriented approach or a content-oriented approach is best suited to solve a particular decision problem. However, since type (2) is likely to be structurable, it could be practically handled by content-oriented methods. Meanwhile, types (1), (3), (4), and (5) that are less or not structurable could probably be best taken care of by process-oriented methods.

THE FUNCTIONS OF CGDSS IN GROUP DECISION MAKING

CGDSS provides support for both the decision maker who is a member of the group and for the group itself. From the point of view of the member of the group, the individual DSS offers two levels of support: (i) generalized decision support for individual decision making, and (ii) negotiation advisory support for assisting the individual in negotiating with other decision makers of the group.

From the point of view of the group, the group DSS assures three main functions: (i) automatic selection of appropriate group decision technique(s), unless the group overrides this procedure, (ii) computation and explanation of a group decision, and (iii) suggestions for a discussion of individual differences or for a redefinition of the problem if attempts to reach consensus fail.

It is worth noting that, according to the design of CGDSS, only individual users interact with the system; the group as a whole is not a user of the DSS (see Figure 1).

THE CGDSS SYSTEM ARCHITECTURE

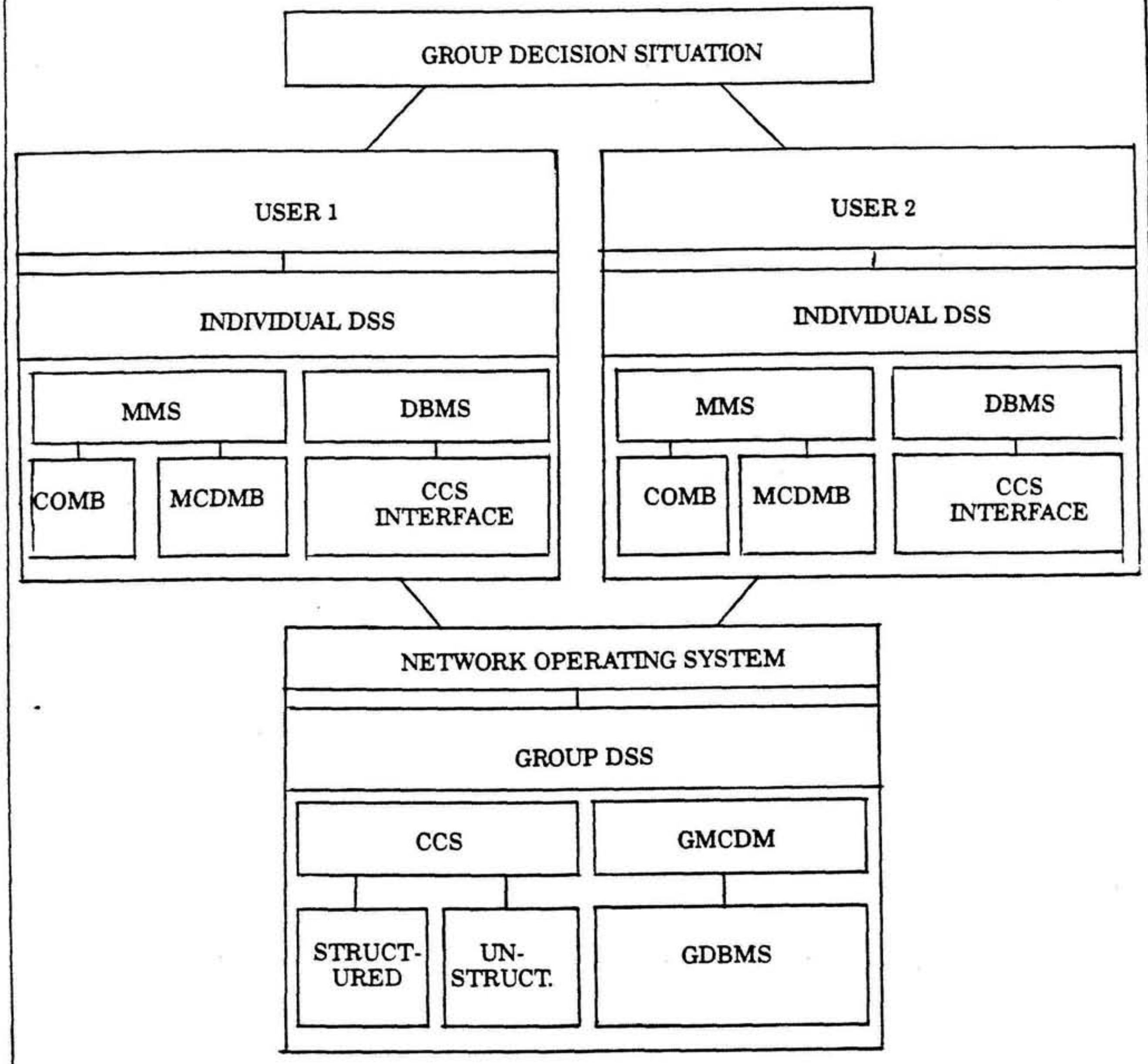
Figure 1 describes the system architecture of a cooperative group decision support system currently operational in a prototype version at New York University. The architecture is based on the assumption of the following hardware configuration:

— Decision makers have their individual DSS installed in their familiar working environment that includes a terminal or a local desktop computer system.

— Each terminal or local computer that hosts the 'individual DSS' is linked to a computer network. Linked to the network operating system (NOS) that provides communication facilities and data transfers, a group DSS supports the group decision activities.

The CGDSS software package is composed of two independent but interrelated modules: the individual DSS and the group DSS. In each individual DSS, the CGDSS user interface component is a menu-driven program package that allows the decision maker to access the model management system (MMS), the database management system (DBMS), and the computerized conferencing system (CCS) interface that, in turn, will connect to the group CCS upon request.

The CCS makes it possible for the decision maker to structure, store, and process written communications among the group. The MMS provides a user-oriented milieu for understanding, selecting, retrieving, and operating the decision models stored in the content oriented model bank (COMB) and the multiple criteria decision model bank (MCDMB). The purpose of the COMB is to provide each individual decision maker with a large set of models to deal with a variety of decision problems. These models can be classified into three broad functional classes: simulation models (e.g., Monte Carlo simulation), explicative models (e.g., linear programming, financial models), and time series models (e.g., regression models, smoothing techniques).



Legend:

MMS: Model Management System
COMB: Content-Oriented Model Bank
MCDMB: Multiple Criteria Decision Model Bank
CCS: Conputerized Conferencing System
DBMS: Data Base Management System
GMCDM: Group Multiple Criteria Decision Methods
GDBMS: Group Data Base Management System

Figure 1

The CGDSS System Architecture

The multiple criteria decision models stored in the MCDMB fall into three main categories: namely, MCDM for selecting (i.e., to choose one and only one 'best' alternative among many), MCDM for ranking (i.e., all alternatives are good but they are ranked according to the decision maker's objectives or needs), and MCDM for sorting (i.e., some alternatives are good, and the remaining are not) (Roy, 1971).

In the group DSS, a simple CCS allows the participants of the group to share a group process-oriented model base (GPOMB) and a group MCDM base (GMCDMB). The GPOMB contains two main facilities: a structured CCS that currently includes the delphi and the nominal group technique and a free-discussion CCS that supports informal types of communications among decision makers. The GMCDMB is linked to the individual MCDM via the network operating system. On the request of the decision maker, via the individual MCDMB, the group MCDM computes or updates group results and stores them in the group DBMS. The latter feature ensures that decision makers can freely use their individual DSS before committing to an opinion.

The Role of Electre in the CGDSS

As of this writing, the content-oriented MCDM methods implemented in the group DSS as well as in each of the individual DSS are based on the method ELECTRE (Roy, 1968), extended by the authors to a group decision-making situation. This section discusses the rationale of the use of ELECTRE in the CGDSS and provides a comprehensive description of the method. ELECTRE has been selected for three reasons:

— Multiple criteria decision methods, in general, have proven useful in useful in supporting decision making (Keen, 1977; Zeleny, 1982);

— ELECTRE is conceptually robust, and easy to learn and use. It has proven its usefulness in aiding a number of ill-defined decision situations sucessfully (Pasquier, *et al.*, 1979; Heidel and Duckstein, 1983);

— ELECTRE does not require full information on the decision maker's preferences and assessment of alternatives, and hence, gives more autonomy and control to the decision maker (Crama and Hansen, 1982). This peculiarity makes it easier to expand the algorithm to resolve group decision making.

THE ELECTRE METHOD FOR INDIVIDUAL DECISION-MAKING: BASIC CONCEPTS

ELECTRE is characterized by circumventing the problem of incomplete comparability of alternatives through its concept of outranking relations. Problem and solutions are outlined below.

There are number of things that make it difficult for a decision maker to exhaustively compare all known alternatives. First, the decision maker often cannot compare some alternatives due to uncertainty associated with the measurements and evaluations. Second, the decision maker may be unwilling to compare two alternatives because they are incomparable (e.g., option a_i is better than option a_k by some criteria, whereas a_k is better than a_i by some other criteria). The notion of indifference in utility theory does not reflect this incomparability (Roy, 1971). Last but not least, the ill-structuredness and occasional inconsistency of the decision maker's preferences are serious obstacles to enforcing the complete comparability of alternatives (Saaty, 1980).

The concept of outranking relations seeks to compare decision alternatives only when the decision maker's preferences are well defined. In other words, a_i outranks a_k when the information obtained from the decision maker's preferences safely justifies the proposition that a_i is at least as good as a_k.

The outranking relation can be explained by two further concepts, the presence of concordance, (i.e., for a sufficiently important subset of evaluation criteria, a_i is at least weakly preferred to a_k), and the absence of discordance, (i.e., among the criteria for which a_k is preferred to a_i there is no significant discordant preference that would strongly oppose any form of preference of a_i over a_k).

The ELECTRE algorithm

Given a set of alternatives A, ($A = [a_i \mid i = 1, \ldots, n]$), and a set of evaluation criteria E, ($E = [e_j \mid j = 1, \ldots, m]$), the ELECTRE algorithm consists of the following steps:

1. *Assign weights to the criteria:* $W = [w_j \mid j = 1, \ldots, m]$ with $w_j >= 0$ for all j; and $\sum w_j = 1$;

2. *Define an ordinal-to-cardinal grading table* that allows the decision maker to assign points to each grade: $G = [g_{hj} \mid h = 1, \ldots, 1; j = 1, \ldots, m]$ This ordinal transformation allows the use of qualitative criteria, and gives flexibility in scaling all criteria. Often, the range of grades for important or heavily weighted criteria may be dilated to emphasize the discordance, (i.e., a small difference between a_i and a_k for an important criterion may be more crucial than a rather significant difference between the same two alternatives for a less important or slightly weighted criterion.);

3. *Evaluate the alternatives with respect to each criterion:* s_{ij} assigned to each a_i for each e_j, for $i = 1,\ldots,n$; $j = 1,\ldots,m$;

4. *Compute pairwise compairisons* by calculating concordance and discordance indexes:
The concordance index $c_{a_ia_j}$ $(i, k = 1,\ldots,n)$ is defined as follows:

$$c_{a_ia_j} = \sum_{j=1 \;|\; s_{a_{ij}} \geqslant s_{a_{kj}}}^{m} w_j$$

c_{aiak} is the sum of the weights of the criteria for with a_i is at least as good as a_k. In other words, the concordance index indicates to what extent an alternative is better than another. A perfect a_i will have $c_{a_i a_k} = 1$ for all k.

The discordance index $d_{a_i a_k}(i,k = 1,\ldots,n)$ is defined as follows:

$$d_{a_i a_k} = \frac{\text{Max}\left[\sum_{j=1 \;|\; s_{a_{ij}} < s_{a_{kj}}}^{m} (s_{a_{kj}} - s_{a_{ij}})\right]}{\text{Max}\left[\sum_{h=1}^{1} (g_{hl} - g_{hl})\right]}$$

$d_{a_i a_k}$ is the maximum difference of the scores for which a_k is preferred to a_i. In other words, the discordance index indicates to what extent an alternative contains discordant elements that might make the alternative unsatisfactory. A totally unacceptable a_i will have a $d_{a_i a_k} = 1$.

5. *Identify non-dominated alternatives* by deriving outranking relations between alternatives. The outranking relation $o_{a_i a_k}$ $(i, j = 1,\ldots n)$ is defined as follows:

$$o_{a_i a_k} = \begin{cases} 1 \text{ if } c_{a_ia_k} \geqslant p \text{ and } d_{a_i a_k} \leqslant q \\ 0 \text{ otherwise} \end{cases}$$

where p and q are, respectively, concordance and discordance thresholds. They are arbitrarily chosen by the decision maker in [0, 1]. The concordance threshold p is more severe as it approaches 1; the discordance threshold q is more severe as it approaches 0. The decision maker can start with a less severe set of threshold values, and then sharpen them to reduce the number of outranking relations.

6. Based on the outranking relations, *draw a directed graph* in order to identify a subset of A that contains non-dominated alternatives.

7. If the decision maker thinks that the non-dominated alternative(s) are consistent with his or her preferences, stop the computation.

8. Otherwise, re-start the algorithm. If the decision maker wants:

—to select new thresholds, go to step (5),
—to re-consider the weighting scheme, go to (1),
—to re-evaluate alternatives with respect to certain criteria, go to (3).

A GROUP DECISION VERSION OF ELECTRE

The safest and unquestioned principle in dealing with group problem solving is the min-max concept in game theory (von Neumann and Morgenstern, 1953). Applied to the concordance/discordance concept in ELECTRE, a_i 'collectively' outranks a_k when its lowest concordance and its highest discordance given by the group satisfies the outranking condition sanctioned by the highest concordance threshold and the lowest discordance threshold also given by the group.

Given u decision makers, the group concordance index, $c^G_{a_i a_k}$, the group discordance index, $d^G_{a_i a_k}$, the group concordance threshold, p^G, and the group discordance threshold, q^G, can be respectively computed as follows to identify collectively non-dominated alternative(s):

$$c^G_{a_i a_k} = \min\,[c_{a_i a_k l} \;|\; l = 1,\ldots,u]$$

$$d^G_{a_i a_k} = \max\,[d_{a_i a_k} \;|\; l = 1,\ldots,u]$$

$$p^G = \max\,[p_l \;|\; l = 1,\ldots,u]$$

$$q^G = \min\,[q_l \;|\; l = 1,\ldots,u]$$

In a cooperative decision making environment, the minimum of concordance/maximum of discordance concept often helps reduce the number of non-dominated alternatives found in individual analyses to a smaller set of—or even to a unique—collective non-dominated alternative(s).

The min-max principle, however, works only when individual opinions are not extreme, and/or the number of alternatives is sufficiently large to generate consensus. Each group member can block a decision by setting a low discordance threshold (q) or by disagreeing completely in the evaluation of the alternatives. One solution for this problem would be to choose a group method that would come closer to a voting scheme, yet could still take into account strong discordances. For example, instead of the maximum or minimum, one could choose the average of the two or three largest or smallest values. If no non-dominated alternative can be reached in the first round of the group ELECTRE, negotiations become necessary to resolve individual differences.

Negotiations aim to either resolve or dissolve conflict. When individual differences exist, conflict resolution consists of finding concessions among members in order to reach a consensus. The current version of CGDSS partially supports the process of concession making. On the user's request, the group DSS identifies the decision maker(s) who assigned extreme scores to the alternatives (i.e., low concordance and high discordance) that are responsible for the empty set of group non-dominated alternatives. The group ELECTRE also indicates how much concessions the group should obtain from the 'extreme' decision maker (i.e., the difference between the individual extreme concordance (discordance) index and the group concordance (discordance) threshold. This constitutes a point of departure for the group to start exchanging points of views and directions to reach agreement, and reduce tension. The group can then temporarily exit from ELECTRE, and use the CCS to informally resolve these problems of control (type 3) and of tension management (type 4). If some concessions can be obtained, the participants can return to ELECTRE and modify evaluation scores accordingly. By switching back and forth between the individual DSS and the group DSS, the participants can perform 'sequential concessions.' During this sequential process, the group MCDM can also be changed, moving from a consensus approach towards a voting scheme. (This is, for example, the method that many countries use for their presidential elections, e.g., France or El Salvador.)

Conversely, when attempts to obtain concessions from the decision maker(s) fail, conflicts should be dissolved. The idea underlying conflict dissolution is characterized by the process of adaptive change. The decision makers not only attempt to re-define their objectives, but also search for new alternatives (Shakun, 1981a, 1981b). Concretely, the decision makers can utilize the structured CCS to revise their objectives and expectations, and to generate new alternatives and criteria.

Examples

This section illustrates two applications of the CGDSS in group decision making. The first example, the faculty candidate selection problem, is hypothetical but based on observations of the actual use of a CCS in that process. It particularly demonstrates the usefulness of the CCS, considering the difficulty to reunite all the faculty members in the department at the same time and at the same place. The second example is a simplified description of an actual application of an early version of our system. It describes how the CGDSS assisted the managers of a medium size wood-related business to select an investment project. This example demonstrates the need to combine the group MCDM with the conventional OR/MS methods stored in the COMB.

EXAMPLE 1: FACULTY CANDIDATE SELECTION

Annually, there are a large number of faculty candidates among whom only a few will receive an offer. The selection process has been supported for some time by the use of an informal CCS facility. We expect the following advantages from using the group DSS in the process, as illustrated in Figure 2:

1. The large number of candidates and criteria often leads to confusion, sometimes creating fast, irrational decisions. The ELECTRE approach should help rationalize this process and offer each decision maker a structured way to express his or her opinions.

2. It has been a general rule that a very strong individual discordance concerning a particular candidate has a strong impact on the group decision. Unlike other OR models, the group MCDM outlined earlier supports this practice.

3. However, the use of MCDM alone would be insufficient. The right column of Figure 2 demonstrates the importance of formal and informal CCS communication, in particular, for transforming the goal space by providing additional information.

EXAMPLE 2: THE SAW MILL INVESTMENT PROBLEM

The saw mill case, which is based on a real life application of the method ELECTRE, will be used to demonstrate the content-oriented aspects of the group DSS. For the sake of brevity, only the final round of the ELECTRE application is discussed.

A medium size furniture corporation, managed by two brother, planned to build a new saw mill to replace the existing one that was no longer cost-effective. Figure 3 exhibits sixteen criteria that the two decision makers agreed to consider for evaluating the investment alternatives. Three alternatives were considered: status quo (STQ; i.e., the decision makers decide to maintain the current situation, and defer the investment decision to a later date); building a saw mill capable of producing

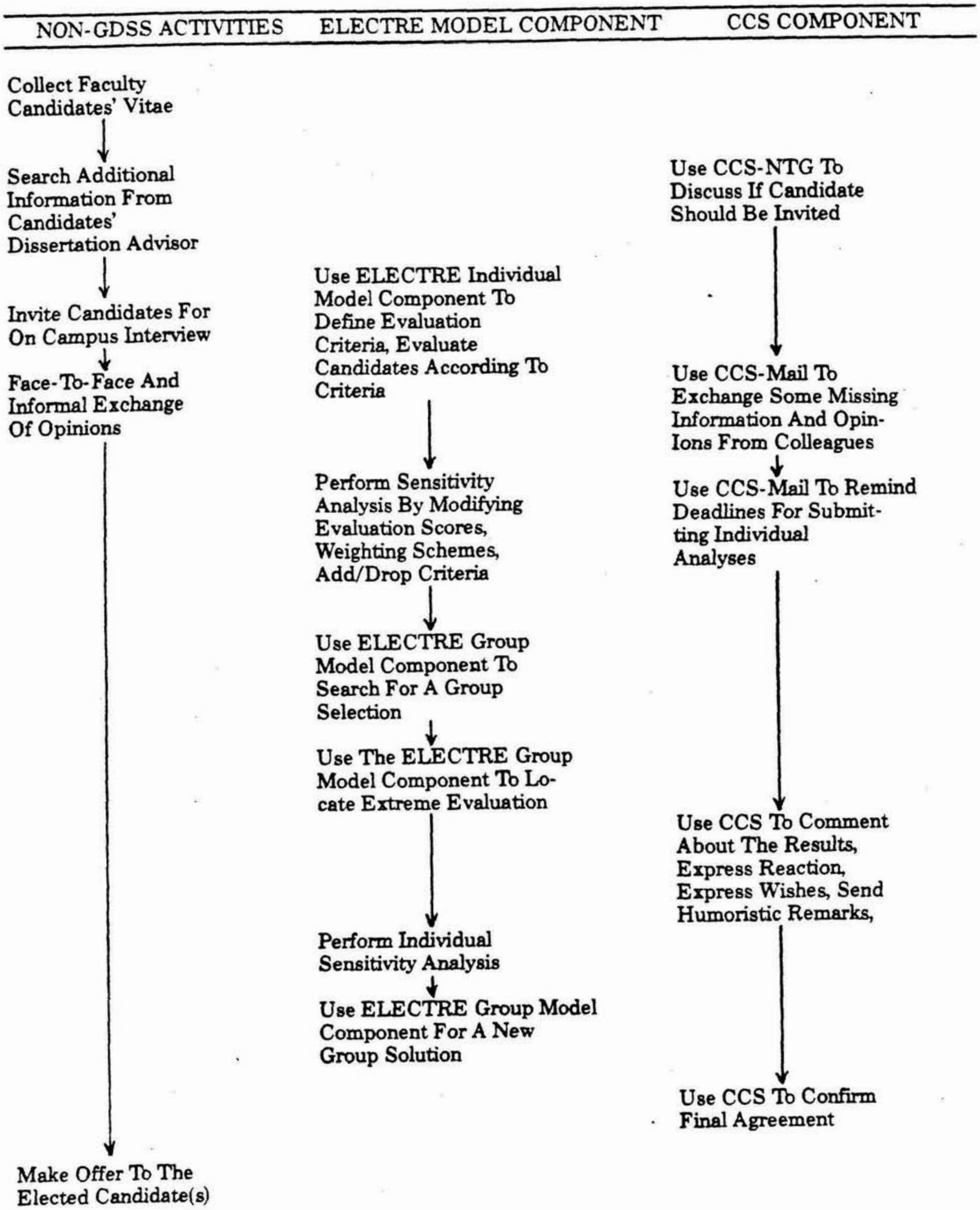


Figure 2

The Faculty Candidate Selection Process

A. FINANCIAL AND ECONOMIC CRITERIA

1. Average total cost at full capacity
2. Break-even point
3. Internal rate of return
4. Financing
5. Risks associated with the financial criteria
6. Probability to achieve sales that match the break-even point
7. Temporal opportunity of the investment
8. Possibility to control risks associated with the investment
9. Possibility to satisfy market demands

B. TECHNICAL AND MANAGERIAL CRITERIA

10. Labor
11. Ability to finance future investments
12. Production bottlenecks
13. Production Management
14. Technical efficiency
15. Extent to which the family is affected
16. Satisfaction and prestige associated with the size of the investment

Figure 3

List of Evaluation Criteria

ORDINAL-TO-CARDINAL GRADING SYSTEM

CRITERIA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
EXCELLENT	20	20	20	20	20	10	10	10	10	10	10	10	10	10	10	10
VERY GOOD	17	17	17	17	17	9	9	9	9	9	9	9	9	9	9	9
GOOD	13	13	13	13	13	7	7	7	7	7	7	7	7	7	7	7
AVERAGE	10	10	10	10	10	5	5	5	5	5	5	5	5	5	5	5
WEAK	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3
VERY WEAK	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2
BAD	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1

EVALUATION TABLE

ALT./CRIT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
STQ	4	1	4	17	17	10	1	10	5	2	2	2	3	3	2	9
M30	17	17	17	13	10	7	9	3	7	9	9	7	9	7	7	5
M50	13	13	13	10	1	5	7	2	9	9	9	10	9	7	7	5
WEIGHT	20	16	20	10	8	6	2	3	3	3	1	2	2	2	1	1

ORDINAL-TO-CARDINAL GRADING SYSTEM

CRITERIA	1	2	3	4	5	6	8	9
EXCELLENT	5	5	5	5	5	5	5	5
GOOD	4	4	4	4	4	4	4	4
AVERAGE	3	3	3	3	3	3	3	3
WEAK	2	2	2	2	2	2	2	2
BAD	1	1	1	1	1	1	1	1

EVALUATION TABLE

ALT./CRIT	1	2	3	4	5	6	8	9
STQ	2	2	2	4	3	3	2	2
M30	4	5	4	4	3	2	1	3
M50	4	5	4	3	3	1	1	4
WEIGHT	15	15	15	15	10	10	10	10

Table 1

Grading and Evaluation Tables for Decision Maker 1 and Decision Maker 2

300,000 cubic yards (M30); building a saw mill with a capacibty of 500,000 cubic yards (M50).

Tables 1 reproduces the ordinal-to-cardinal grading tables, the evaluation tables, and the weighting schemes of the two decision makers. The first decision maker evaluated the three alternatives with respect to the sixteen criteria. He also used a larger grading scale for the financial criteria. He ran the break-even point program of the COMB to estimate the cost-volume-profit performance of the alternatives. In contrast, when the second decision maker assigned the scores to the investment strategies, he felt that some of the criteria—in particular those related to the management issues—were irrelevant to compare the alternatives. He finally selected criteria 1, 2, 3, 4, 5, 6, 8, and 9 for his evaluation. The second decision maker also adopted a 'standard' grading system. Aware of the fact that he could not obtain accurate and complete information about the possible consequences of the alternatives, he refused to commit himself to a precisely tailored grading system. However, he used the discounted-cash-flow program—also stored in the COMB—to compute the net present value and the internal rate of return of the projects.

The computer output of the concordance indexes, discordance indexes, outranking relations, and the nondominated alternatives graph of the individual decision makers and of the group are presented in Table 2. The min-max condition has eliminated the indetermination of the second decision maker between M30 and M50; M30 was finally selected.

Conclusion

The CGDSS has demonstrated the potential of a computerized and intertwined utilization of both content-oriented and process-oriented methods for cooperative group decision making. First, the use of the multiple criteria decision method, ELECTRE, as a uniform framework to support all phases of a group decision making process has proven useful. A second advantage of the CGDSS is its ability to facilitate group communication by allowing remote group meetings (possibly distributed over time) via a computer network. The CCS provides an unprejudiced forum that allows each participant of the group to succinctly air his or her opinions on various aspects of the decision problem. The two examples seem to confirm some of the earlier findings on the advantages of a CCS, i.e., the ability to (1) support geographically dispersed decision makers (2) enhance equality of participation in the group discussion, (3) allow time to mediate on discussion topics, and (4) facilitate technical information exchange (Ferguson and Johansen, 1975; Short *et al.*, 1976; Spelt, 1977). Furthermore, the proposed architecture combines the advantages of sharing a common data and model base in the group DSS with those of the privacy provided by a local DSS. However, empirical studies will be required to test the above observations once the system has reached a sufficient degree of maturity.

The CGDSS is currently being extended by enhanced MCDM and communication facilities. First, the minimum concordance-maximum discordance principle allows for little divergence within the group. Therefore, we are investigating other techniques for aggregating individual concordance and discordance indexes and thresholds. These techniques are intended to limit the impact of extreme individual opinions.

Second, the outranking relation concept of the ELECTRE method is only appropriate when one from a given set of alternatives is to be selected. If more than one alternative must be selected, the second and subsequent choice might not necessarily be nondominated (Starr and Zeleny, 1977). Moreover, this same concept does not support the ranking of alternatives. The ELECTRE II (Roy and Bertier, 1973) and ELECTRE III (Roy, 1978) algorithms which support sorting and ranking problems are currently being integrated into the CGDSS.

Third, when the group possesses more information than ELECTRE would require, MCDM that provide a more precise, cardinal measurement of preferences can be employed, e.g., the multiattribute utility theory methods (Keeny, 1976; Wendell, 1978; Shenoy, 1980; Moskowitz, 1981). However, the decision makers might be discouraged by the complexity of such methods.

Fourth, the process of generating alternatives is currently left to the process-oriented methods, i.e., to the decision makers. The system can provide some assistance in this process using artificial intelligence methods (Reitman, 1982) or preference mapping techniques (Jacquet-Lagreze and Siskos, 1982) to generate alternatives from information stored in individual and group databases.

Finally, the current version of CGDSS is a stand-alone software package. Since the system requires extensive hardware and software capabilities to deal with telecommunications and distributed databases, it would be useful from the system design, as well as from the user standpoint to have an existing office information system (OIS) to host the CGDSS.

DECISION MAKER 1:

**** Concordance Matrix:**

	STQ	M30	M50
STQ	—	28	28
M30	72	—	95
M50	72	15	—

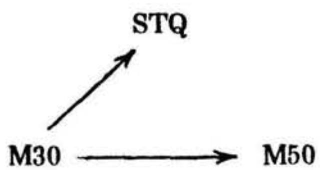
**** Discordance Matrix:**

	STQ	M30	M50
STQ	—	80	60
M30	35	—	15
M50	80	45	—

**** Outranking Matrix:**

...for P = .7 and Q = .35

	STQ	M30	M50
STQ–>	0	0	0
M30–>	1	0	1
M50–>	0	0	0



GROUP:

**** Concordance Matrix:**

	STQ	M30	M50
STQ	—	28	25
M30	72	—	90
M50	65	15	—

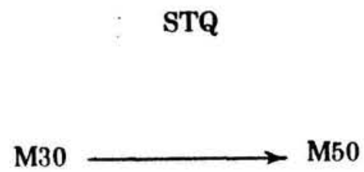
**** Discordance Matrix:**

	STQ	M30	M50
STQ	—	80	75
M30	35	—	25
M50	80	45	—

**** Outranking Matrix:**

...for P = .75 and Q = .35

	STQ	M30	M50
STQ–>	0	0	0
M30–>	0	0	1
M50–>	0	0	0



DECISION MAKER 2:

**** Concordance Matrix:**

	STQ	M30	M50
STQ	—	45	45
M30	80	—	90
M50	65	75	—

**** Discordance Matrix:**

	STQ	M30	M50
STQ	—	75	75
M30	25	—	25
M50	50	25	—

**** Outranking Matrix:**

...for P = .75 and Q = .25

	STQ	M30	M50
STQ–>	0	0	0
M30–>	1	0	1
M50–>	0	1	0

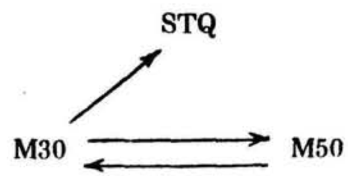


Table 2

The ELECTRE Results for the Saw-Mill Example

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