COMMUNICATIONS DESIGN FOR Co-oP:
A GROUP DECISION SUPPORT SYSTEM

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Abstract

Decision Support Systems which have been typical single user systems for most of the decade of their existence, are now evolving into tools for supporting groups of decision makers. Thus, they are merging into the mainstream of office information systems. Communication among multiple decision makers has been identified as the major novel issue in such group decision support systems (GDSS). This paper analyzes the communications requirements of GDSS and presents a design architecture which is integrated in the presentation and application layers of the ISO Open Systems Architecture. This design has been implemented on a network of personal computers in Co-oP, a GDSS for cooperative group decision making based on interactive multiple criteria decision making (MCDM) methods.

1. INTRODUCTION

Communications in office systems has played an important role in enhancing performance among office workers. However, most of the research in office information systems has focused on automation of clerical tasks. Higher level managerial tasks have been only supported by single user decision support systems (DSS). Such practice does not support communications activities which occupy most of the managers' time (Mintzberg, 1971, 1973). Moreover, it may lead to reduced commnucations among managers, incoherent environmental scanning, and contradictory decision outcomes (Crozier, 1964; Perrow, 1970).

Only recently, decision support systems for group problem solving have begun to address communications issues in higher level managerial tasks. A Group Decision Support System (GDSS) can be defined as a computer-based system that aims to support collective problem solving. A collective decision making process can be viewed as a problem solving situation in which (i) there are two or more persons, each of them characterized by his or her own perceptions, attitudes, motivations, and personalities, (ii) who recognize the existence of a common problem, and (iii) attempt to reach a collective decision.

Gray (1981, 1983), Stohr (1981), Bui and Jarke (1984), Huber (1982, 1984), Shakun (1984), Bui (1985a, 1985b), DeSanctis and Gallupe (1985), Jarke (1985), Jarke et al. (1985), and Licker and Thompson (1985), among others present a number of issues related to the design of group DSS. Independent of the type of group decision support systems suggested, communications have emerged as the core issue in designing and implementing effective decision support systems for multiple decision makers. In contrast to single user DSS which only have to support man-machine communication, GDSS must also provide an efficient man-machine-man interface.

Field studies of the impact of electronic media on group processes (Short et al., 1976; Johansen et al., 1979; Christie, 1981) found that computer conferences enhance group participation, as compared to face-to-face meetings. Similarly, laboratory studies (Wichman, 1970; Dorris et al., 1972; Short, 1974) indicate positive relationships between the number of communications channels and the efficiency of interaction (e.g., speed and accuracy of communication) on the one hand, and the degree of cooperation on the other. While these findings indicate substantial promise for the usefulness of GDSS, it is obvious that only a well-designed communications component in the GDSS will be able to realize this potential.

The purpose of this paper is twofold. On the one hand, it provides an analysis of the communications types and needs in GDSS. On the other, it presents a design for the GDSS communications component that facilitates integration of GDSS into office systems since it is based on the proposed ISO Open Systems standards (ISO, 1982). The proposed architecture has been realized in Co-oP (Bui and Jarke, 1984; Bui, 1985b), a GDSS for cooperative multiple criteria decision making. Multiple criteria decision making (MCDM) methods were found to be particularly suitable for GDSS, because they are interactive, permit multiple viewpoints of a problem, and focus on the decision process rather than on its outcomes alone. Co-oP has been implemented in Pascal and is currently operational on a network of personal computers.

The paper is organized as follows. Section 2 provides a taxonomy of GDSS architectures by the type of man-machine-man communication they offer. It is argued that GDSS should offer components for individual decision support as well as for establishing the group decision. In section 3, five types of communications requirements for GDSS are identified. Section 4 identifies the major roles and functions of GDSS based on these requirements, and demonstrates how to integrate the corresponding GDSS modules into the ISO Open Systems Architecture as protocols for presentation and application level communication. Finally, section 5 presents the Co-oP system, focusing on the integration of group communication and the methods for multiple criteria group decision making and negotiation.

2. THE EVOLVING NATURE OF DSS COMMUNICATIONS

Group communication situations can be classified along four different dimensions (Jarke, 1985): spatial and temporal distance among decision makers, centralization of control in the group, and degree of cooperation. These decision settings can be supported to varying degrees by any of the six architectures for manmachine-man communication displayed in Figure 1.

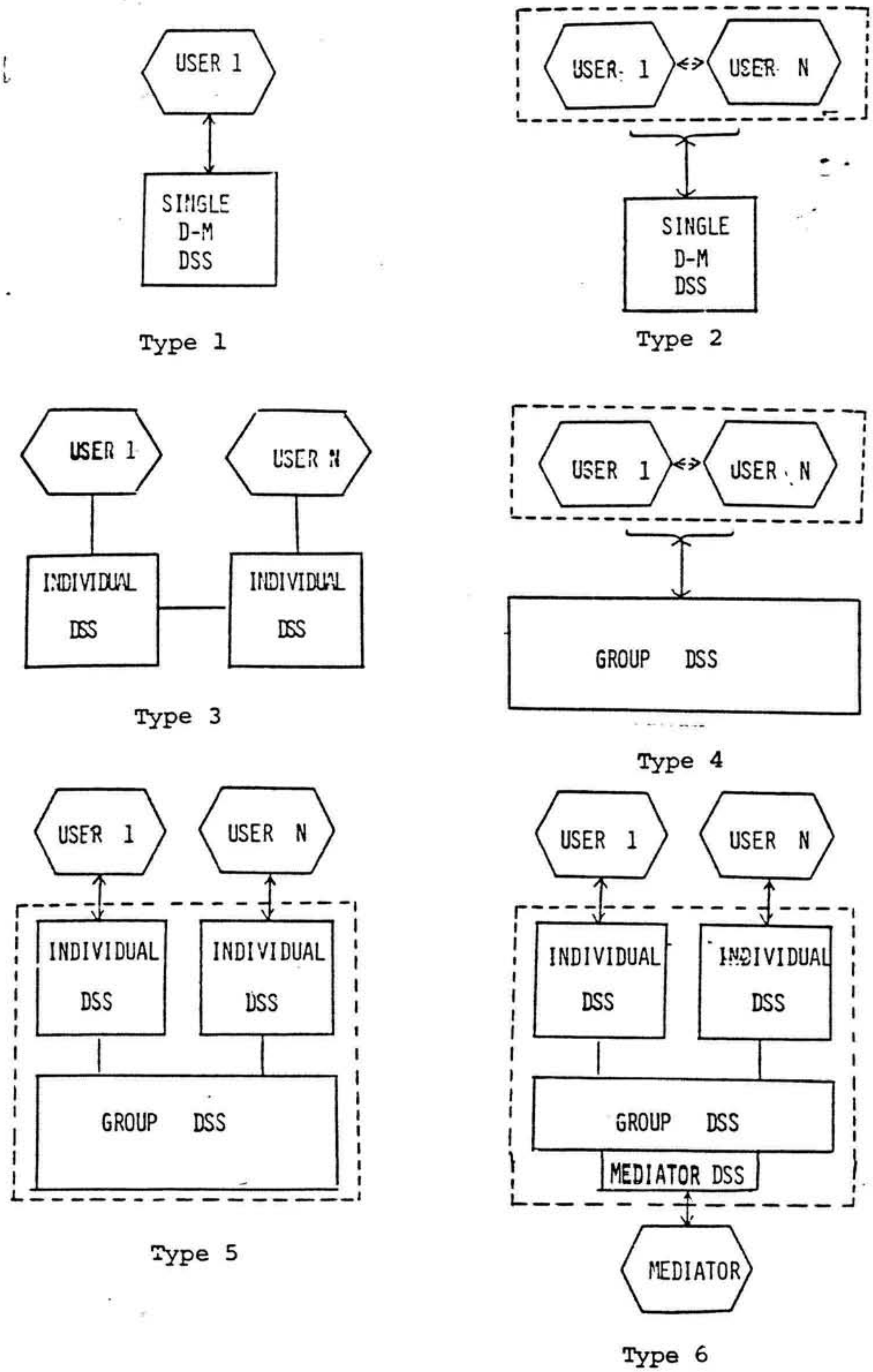

Figure 1. A Typology of Group Decision Support Systems

Type 1 represents the traditional DSS paradigm. The purpose of such a DSS is to enhance the user's cognitive processing capabilities and/or to facilitate the learning process. The bilateral relationship between user and DSS provides no communications support as required in cooperative decision making. In fact, this type of DSS has been criticized for its potential isolating role (Sanders et al., 1984).

In Type 2, a group of users has access to a traditional DSS, typically through an intermediary. The purpose of such a DSS is in essence the same as the single user DSS. The group decision making process (e.g., aggregation of preferences or votes) remains unsupported by the DSS.

The third possible GDSS architecture (Type 3) includes the capabilities of the previous one but also provides computerized or automated group problem solving capabilities (e.g., automated computation of aggregation of preferences, electronic interpretation of individual votes). The relationship between the decision group and the GDSS remains yet bilateral, in that the users share the same man-machine interface. This type of GDSS is exemplified by Huber's (1982) decision room approach, and the single-user, multiplayer DSS by Licker and Thompson (1985).

While the third architecture provides a mechanism for mapping and integrating application-level communications results (i.e., preference aggregation and mediation support), another generalization of the individual DSS framework (Type 4) addresses the need for knowledge sharing among remote individual DSS, for instance, by exchanging data files or mail messages. However, this network of loosely coupled individual DSS lacks knowledge about the existence of a decision group.

Types 5 and 6 suggest a multilateral relationship between members of a group via a network of individual DSS and group DSS. Such a network of DSS is aimed at supporting both the decision maker who is a member of the group and the group itself. Nevertheless, only individual users interact with the system; the group as a whole is no longer a single user of the GDSS. In other words, the fifth and sixth types of GDSS represent a distributed problem solving system composed of a decentralized, loosely coupled group of decision makers.

The last two architectures can be considered true GDSS since they combine the advantages of knowledge sharing among individual DSS (Type 4) with those of supporting group activities such as preference aggregation and negotiation at a high level (Type 3). Additionally, the use of a GDSS as the communications component (not just in the communications component) allows flexible definition and enforcement of group decision making standards and protocols. Whereas this is done automatically in the architecture of Type 5, the Type 6 architecture employs the services of a human group leader or mediator, whose efforts are only supported but not replaced by the GDSS.

To summarize, it can be observed that the six architectures form a logical sequence; the capabilities of Type 1 DSS are contained in Type 2 and Type 4, of Type 2 in Type 3, of Types 3 and 4 in Type 5, and of Type 5 in Type 6.

The remainder of this paper develops the design of a communications architecture for the Type 5 GDSS which is implemented in the Co-oP system. For further discussion of Type 6 GDSS, see (Jarke et al., 1985).

3. COMMUNICATIONS REQUIREMENTS OF GDSS

In the context of distributed group decision making, the demands for information exchange are marked by certain characteristics that should be considered in the design of communications capabilities.

3.1 Need to reduce miscommunications

In a single user environment (Type 1 to 3), a DSS user interface should (i) be easy to learn, use and remember; (ii) be suitable for both novice and expert use; (iii) be efficient in the use of system resources; and (iv) promote effective usage and better decision making (Stohr and White, 1982). Interface requirements in a GDSS are much more stringent, because there is not just a man-machine, but a man-machine-man interface to consider.

Due to the diversity of the decision makers' knowledge, and to reduce misunderstanding during group communication, the Input/Output formats for group decision techniques should be universally recognizable or at least understandable by every member of the group. If the group is small and homogeneous, the group DSS should be able to transfer detailed information between decision makers upon request (e.g., duplication of individual inputs, outputs, intermediate results). On the other hand, if the group is large or heterogeneous, a minimal and standardized form of group information should prevail (e.g., overall group ranking), at least at the first round of the group decision making process.

In addition, the group user interface system should include tools that assist the members in performing various group decision activities. These include:

- initiation (e.g., How does the group start the collective decision making process? Should the group elect a person that leads the discussion?);
- exchanging information (e.g., How can a member request or share information?);
- analyzing group discussions or decisions (e.g., How does the group interpret the results?); and
- consensus testing (e.g., What decision technique(s) to adopt -- democratic vote or weighted majority rule?).

The group DSS interface should be able to provide flexible Help commands that clarify these tasks.

3.2 Need to support both informal and formal communications

According to Pye et al. (1973), the activities associated with group decision problems constitute a mixture of positive and negative reactions, problem solving attempts and 'questions'. Short et al. (1976) suggest that negative and positive reactions could be classed together as person-oriented communications, since they reflect attitudes of one participant of the group towards another. Meanwhile, the search for information and problem-solving attempts could be classified as non-person-oriented communications since they are primarily concerned with the content of the decision problem. Even if the conceptual distinction between person-oriented and non-person-oriented communication can be fuzzy due to the ambiguity of human behavior, it suggests the development of multiple communications channels and provides some assistance in selecting suitable communication channels between individual DSS.

Furthermore, Morley and Stephenson (1970) conducted various experiments to assess the effects of media on conflict resolution. Among other things, these studies support the hypothesis that formal communication (e.g., official telephone conversation, written correspondence) has a greater emphasis on the object of the discussion at the expense of the interpersonal exchange (Short, 1974).

The concept of formal communication leads to the idea of 'structuring' communication, as opposed to letting the group processes occur 'naturally'. The need to structure communication is primarily motivated by the increasing size of the group. As its size increases, the group becomes heterogeneous, loses control of its norms for interactions, and is prone to undesirable interpersonal influences. Among the undesirable behaviors found in a group, one can recognize (i) the 'surveillance effect' (Asch, 1951) that pushes people to go along with the group rather than specify their own ideas, (ii) the individual lack of confidence when facing group pressure (Allen, 1970), and (iii) the 'leadership phenomenon' that prevents equal participation.

Thus, the design of structured communication interfaces, such as fill-in-the-form input/output formats, should

- promote independent generation of ideas or judgments,
- enforce mechanisms for assuring equal opportunity to participate in the discussion, and
- provide organized feedback for group discussion.

Examples for such techniques that have been used in GDSS include Delphi and Nominal Group Techniques (Huber, 1982; Turoff and Hiltz, 1982).

Meanwhile, the availability of unstructured communication interfaces should compensate for some interpersonal communications needs that structured interfaces cannot provide. For instance, under a controlled environment, online and public notepad, electronic bulletin board, electronic mail may enhance interpersonal communications.

3.3 Need for format-transparent information exchange

Decision makers often demand or generate information in a variety of formats, ranging from un-structured, written notes to structured, numerical tables (Bernard, 1979). The most complex form of information traffic is the situation in which decision makers simultaneously require information exchanges on different subjects from different members using complicated combinations of input/output formats. It would then be necessary to identify, classify and convert heterogeneous information styles into standard message formats. Furthermore, information related to group problem solving techniques must be created and maintained. For instance, aggregation of preferences requires some standardized inputs from various sources of individual results.

Thus, the communications component of a GDSS requires sophisticated format conversion and aggregation techniques to provide maximal freedom to individual decision makers while reaching a group result in finite time.

3.4 Limited versus Free Information Exchange

In some group decision situations, it is conceivable that all shared information is 'public' in that every member of the decision group has the right to access to any information that is sent by a member of the group to another. In other decision situations, only individual-to-individual or private message transfers are authorized. The creation, maintenance, and storage of message routing activities remains crucial to enforce group norms concerning the type of information sharing. Such norms can be consensually predefined by the group prior to the group decision making process in GDSS (Type 5), or monitored by the mediator (Type 6).

3.5 Need to Support Evolving Patterns of Communication

The requirements for information sharing evolve through various phases of the group decision making process. For example, Walton (1969) argues that a group problem solving phase that emphasizes on search and innovation requires more spontaneity, and thus open communication pattern; whereas, bargaining activities that induce a preference for deliberate control of information exchange would be facilitated by using individual-to-individual communication channels.

During the early phases of the collective decision making process, encouraging information exchange between group members is recognized as an effective strategy to resolve individual differences. However, empirical studies have shown that, under certain circumstances communication channels can escalate conflict (Krauss and Deutsch, 1966). Eliminating communication channels in such situations should be enforced to prevent deterioration of relationships. While the decision to whether encourage or discourage communication between decision makers depends on a number of unpredictable situation-dependent factors, the GDSS communications component should be designed in such a way that it can accommodate various communications needs and changes during the group decision making process. In other words, the pattern of communications protocols should vary according to the dynamics of the group decision making process.

4. DESIGNING THE COMMUNICATIONS COMPONENT

To summarize the requirements analyzed in the previous section, the GDSS concept extends the DSS concept of creating an efficient man-machine interface, to designing controlled man-machine-man interfaces that

- avoid misunderstandings among group members by adapting the degree of communication to the group size and decision situation;
- support structured group communication in addition to informal exchange, to reduce negative group effects;
- adjust to formats and methods preferred by individual group members while preserving group consistency;
- monitor the degree and means of communication according to norms set by the group or its leader; and
- evolve these norms during the various stages of group decision making.

Departing from these requirements, one can develop a set of roles and functions a GDSS communications component should have. Subsequently, a communications architecture will be proposed that integrates these roles and functions into the ISO Open Systems Architecture as presentation and application layer protocols.

4.1 Roles and Functions of the Communications Component

The roles of the communications component represent the potential impact it causes on group decision making, and its functions specify the services it offers to its users.

Communication control in computer systems provides protocols that enable data exchange to take place. In turn, communication protocols can be defined as a set of rules and formats permitting the control of communication between two stations (e.g., Puzman and Porizek, 1980). One of the main roles of any communications component is to make it easier for each member of a remote decision group to communicate electronically without having to be concerned about detailed and complicated protocol procedures. This issue of user transparency is particularly crucial given the diversity, and consequently complexity, of the communication requirements and facilities.

However, the effort to obtain ease of communication access is not unique to the design of group DSS. Rather, it has always been one of the most important objectives of computer networks design. From a GDSS standpoint, the analysis and design of communications support should go beyond the usual focus on technical issues of communications control such as network topology, network design, capacity and flow assignment, error detection, etc. A GDSS not only has to indicate to individual DSS how to communicate, but also what information to exchange. One can identify at least three roles that are specific to a communications system in group decision making. At different phases of the distributed decision process, the communications manager can either play the role of a coordinator, a detective, or an inventor.

(1) Coordinator Role: Most problem solving activity begins with situation analysis and problem definition. Situation analysis is characterized by a (common) recognition that there exists an urgent and important problem to be solved. Once identified in the situation analysis, a problem is transformed in the problem definition phase in such a way that solutions can be generated, analyzed and selected (see also Jarke et al., 1985). Eiseman (1977) and Kolb et al. (1984) emphasize that the success of information gathering and problem definition depends on the ability of the group to eliminate mistrust and threat that could cause group participants to withhold or distort information. Walton (1969) suggests that by installing a communication medium that follows some norms of fairness (e.g., equality of participation, preserving autonomy), information exchange will be more abundant and accurate.

The communication component should thus coordinate various protocols to engender participants' confidence. Such protocols could include the ones that (i) assure that each member can successively broadcast his/her ideas given a equal amount of time, (ii) support teleconferencing to synchronize arguments, or (iii) promote information exchange while guaranteeing privacy.

(2) Detective Role: A decision maker's analysis could be distorted by the individual's attempt to 'spy' others' activities, or by the influence of some members who try to take over an individual's responsibility. The communications component should then play the role of detective to prevent unwanted data exchange, temporarily disable all links, or prevent malicious modification of public data. Concurrently, decision makers tend to delay sending their individual results. The communications component should press its users to submit opinions before a given due date.

From a general perspective, the detective role consists of enforcing communications protocols previously defined to drive the collective decision making process.

(3) Inventor Role: The inventor role is an extension of the coordinator role. Given the complex nature of a group

decision problem and the diverse and unpredictable decision approaches of the participants, the communications component should be able to detect incompatible information exchange, and, if possible, propose alternate formats. The inventor role implies on one hand potential for tolerance to uncertainty in requests and needs for data transfers, and on the other, continued search for communications operations that facilitate information exchange (Davis and Smith, 1983). Thus, protocols for GDSS should be able to analyze, evaluate and determine the content of transmissible information, rather than simply perform a transport task.

The functions provided by the communications component in order to play the above roles are at least twofold. First, it monitors a broad spectrum of data transports during a group problem solving process. This transport function ranges from information exchange to information hiding, from selective and personalized routing to collective diffusion of data, from public to private information. Second, the communications component coordinates various activities (i.e., initialization, operation during consensus search, negotiation and mediation).

Figure 2 summarizes the relationships between the roles of GDSS communications components and supporting functions.

Decision Phases	Role	Function
Situation Analysis/ Information gathering/ Problem Definition	Coordinator	provide support for information exchange
Individual Decision Analyses	Detective	enforce communication protocols
Group Decision Analyses	Inventor	search for data compatibility of group algorithms; sort data for diffusion

Figure 2. The Roles and Functions of the GDSS Communications Component

4.2 Relationship to the ISO Open Systems Architecture

The literature supports conceptualization of a DSS as being composed of three main components: the Dialogue manager, the Model manager and the Data manager (e.g., Sprague and Carlson, 1982). Expanding the DSS framework into group problem solving requires the addition of a Communications manager as a fourth component.

The architecture of the GDSS communications component is based on the Open System Architecture OSA-RM (ISO, 1982) which defines a framework for providing data communication links between systems. Specifically, five communication functions are specified: link establishment (generally in a switched network), transmission opening, data exchange, transmission terminating, and link releasing. The reference model proposes decomposition of the communication architecture into seven layers. The services offered by each layer are described in Figure 3. Factors or parameters measuring the performance of the layers are included in parentheses.

The reference to such a standard is justified by the fact that it helps to (i) minimize operating systems dependencies, (ii) simplify protocol interfaces, (iii) assure reliability, ease of maintenance and portability, and perhaps most important, (iv) facilitate the integration of communication protocols in GDSS.

When applied to a distributed GDSS architecture (Type 5 and 6), the modularity and hierarchy principles remain, but the internal logic of the upper two ISO layers must be adapted to the GDSS communication requirements discussed in section 3. Starting from the Application level (layer 7), Figure 4 proposes an integration framework for the GDSS communications component into the ISO layering concept. Figure 5 shows the interaction of these components with the IDSS and GDSS. The four new modules will now be described in some detail.

IDSS-1 IDSS-2

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<------------ Layer 7- Application: ------------->
              . GROUP NORM CONSTRUCTOR
              . GROUP NORM FILTER
              . INVOCATION MECHANISM

<------------ Layer 6- Presentation: ------------>
              . IDSS-to-GDSS FORMATTER

<--- Layer 5-4-3-2-1: Network, Link, Physical --->
              . TRANSMISSION PROTOCOLS PROVIDED
                BY SELECTED NETWORK OR LAN
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Figure 4. The GDSS Communications Component and the ISO Model

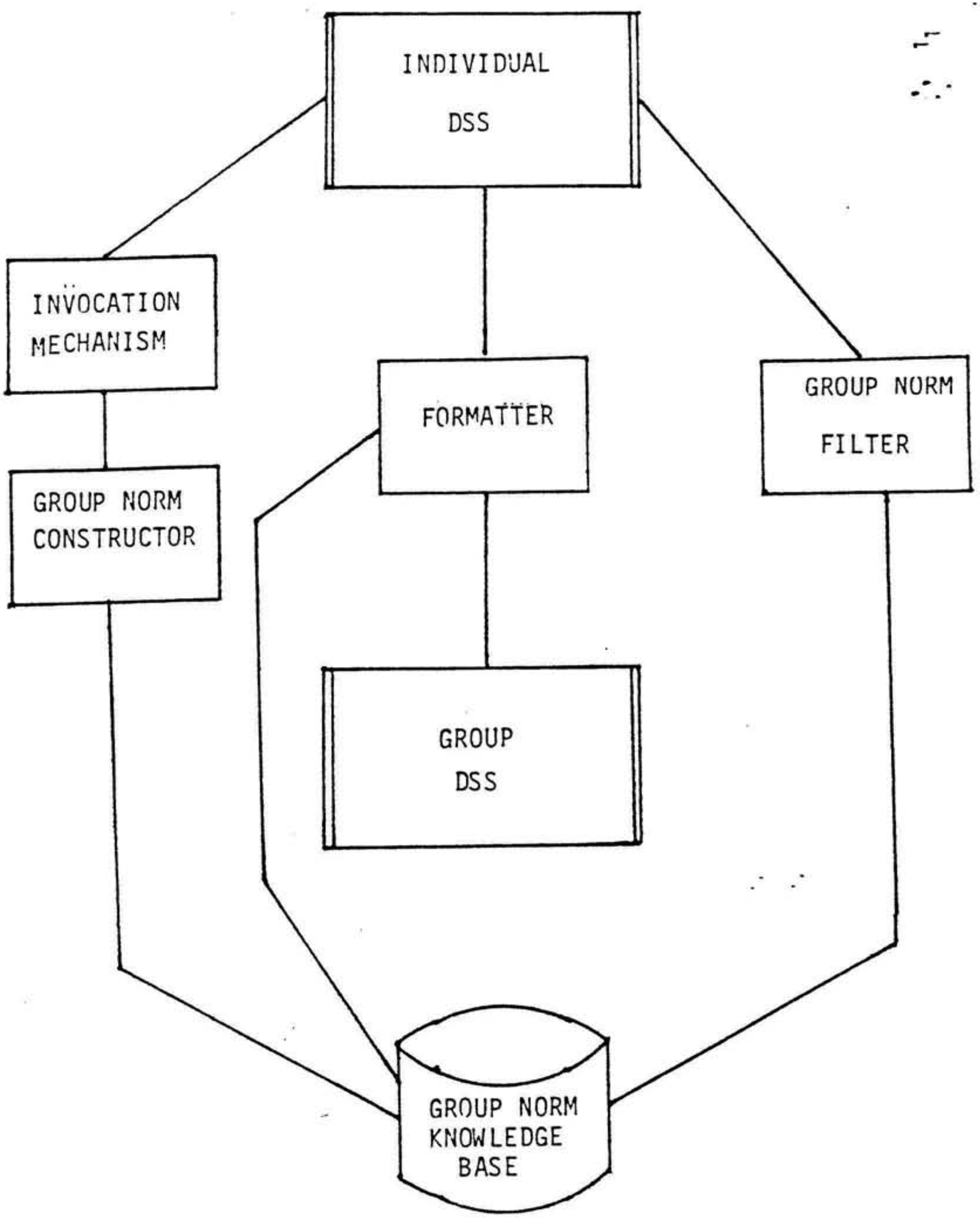

Figure 5. Modules of the Communications Component

4.3 The Application Layer in GDSS

In Layer 7, three new systems components are introduced. The purpose of the Group Norm Constructor is to provide a flexible and adjustable mechanism for monitoring information transfer between individual DSS. This functional specialization is indispensable when a decision group has to define a framework for computer-based group decision making, and the GDSS does not know in advance which type of communications should be invoked in a specific group decision situation. Figure 6 offers checklists of major issues to be defined by the group norm.

The output that the Group Norm Constructor generates is then sent to the Group Norm Filter. The function of this module is to enforce the defined protocols whenever a communication activity is triggered by the GDSS users. When a data transfer is requested, the Group Norm Filter will check whether or not the desired interaction corresponds to the protocols. If the request is in accordance with the protocols, it is transferred to the next communications routine. Otherwise, the Group Norm Filter would notify the user of the violation, and display the current communications protocols pattern, if requested.

DATA TRANSFERS:

- Point-to-point or private data sharing .... ___
- Maximum number of shared files .... ___
- Maximum size allowed for each file .... ___
- File sharing allowed only at the following phases:
  - Problem definition .... ___
  - Individual Decision Analyses .... ___
  - Group Decision Analyses .... ___

- Public data sharing .... ___
- Maximum number of shared files .... ___
- Maximum size allowed for each file .... ___
- File sharing allowed only at the following phases:
  - Problem definition .... ___
  - Individual Decision Analyses .... ___
  - Group Decision Analyses .... ___

INTERACTIVE CONVERSATION:

- On-line talk .... ___
- Maximum number of talks .... ___
- Maximum time allowed for each talk .... ___
- Talk allowed only at the following phases:
  - Problem definition .... ___
  - Individual Decision Analyses .... ___
  - Group Decision Analyses .... ___

- Teleconferencing .... ___
- Maximum number of teleconferences .... ___
- Maximum time allowed for each teleconf. ... ___
- Talk allowed only at the following phases:
  - Problem definition .... ___
  - Individual Decision Analyses .... ___
  - Group Decision Analyses .... ___

Figure 6. Checklists for a Group Norm Constructor

ELECTRONIC MAIL:

. Point-to-point communication .... ___
. Maximum number of messages .... ___
. Maximum time allowed for each message ..... ___
. Mail allowed only at the following phases:
  - Problem definition .... ___
  - Individual Decision Analyses .... ___
  - Group Decision Analyses .... ___

. Bulletin board .... ___
. Maximum number of messages .... ___
. Maximum time allowed for each message ..... ___
. Mail allowed only at the following phases:
  - Problem definition .... ___
  - Individual Decision Analyses .... ___
  - Group Decision Analyses .... ___

GROUP DECISION TECHNIQUES:

. Automatic selection of aggregation
  of preferences techniques .... ___

. If NO,
  - Sums of the Ranks .... ___
  - Sums of Outranking Relations .... ___
  - Additive Ranking .... ___
  - Multiplicative Ranking .... ___

. Automatic Computation of the
  Consensus Seeking Algorithm (NAI) .... ___
. Deadline for sending individual results ... ___
  - Date .... __/__/__
  - Time ....   __:__
. Broadcasting of individual results .... ___

Figure 6. Checklists for a Group Norm Constructor (continued)

Finally, the Invocation Mechanism enables any authorized decision maker to request eventual modification of the communications protocols previously set via the Group Norm Constructor. The rationale of such a mechanism is to provide enough flexibility to deal with the inherently dynamic and non-deterministic communications nature of group problem solving processes. Moreover, a request for protocol change cannot be satisfied unless it is approved by the entire group. Triggered by a group member's request, the invocation mechanism checks when and how it can convene the decision makers to debate and vote on the motion.

4.4 The Presentation Layer in GDSS

The particuliarity of the Presentation Layer in the GDSS communications architecture is the IDSS-to-GDSS Document Formatter. This formatter contains presentation protocols for any possible type of data exchange in a group decision situation. Examples of such protocols are those related to data structures that are shared between the IDSS Model Components and the GDSS Model component. For instance, in a voting procedure, data must be compressed before being reported to individual members.

5. AN EXAMPLE: THE Co-oP COMMUNICATIONS COMPONENT

This section illustrates the feasibility of the proposed communications architecture by presenting a communication component designed and implemented in a cooperative multiple criteria group decision support system -- Co-oP. An early version of Co-oP is described in (Bui and Jarke, 1984) and a detailed presentation can be found in (Bui, 1985b).

5.1. Co-oP: System Overview

Co-oP is a network of microcomputer-based process-driven DSS for cooperative multiple criteria group decision support system. Each participant of the group decision making process has his/her own individual DSS whose model base offers, among other tools, multiple criteria decision methods (MCDM). The group DSS contains a set of preference aggregation techniques that can be used in conjunction with individual MCDM.

An overview of the network architecture is given in Figure 7. In each individual DSS, the Co-oP User Interface Component offers a menu-driven window-based environment that allows decision makers to access the Model Base (MB), and the MCDM-specific Data Base (DB). Co-oP employs a standard screen format that displays simultaneously four different windows.

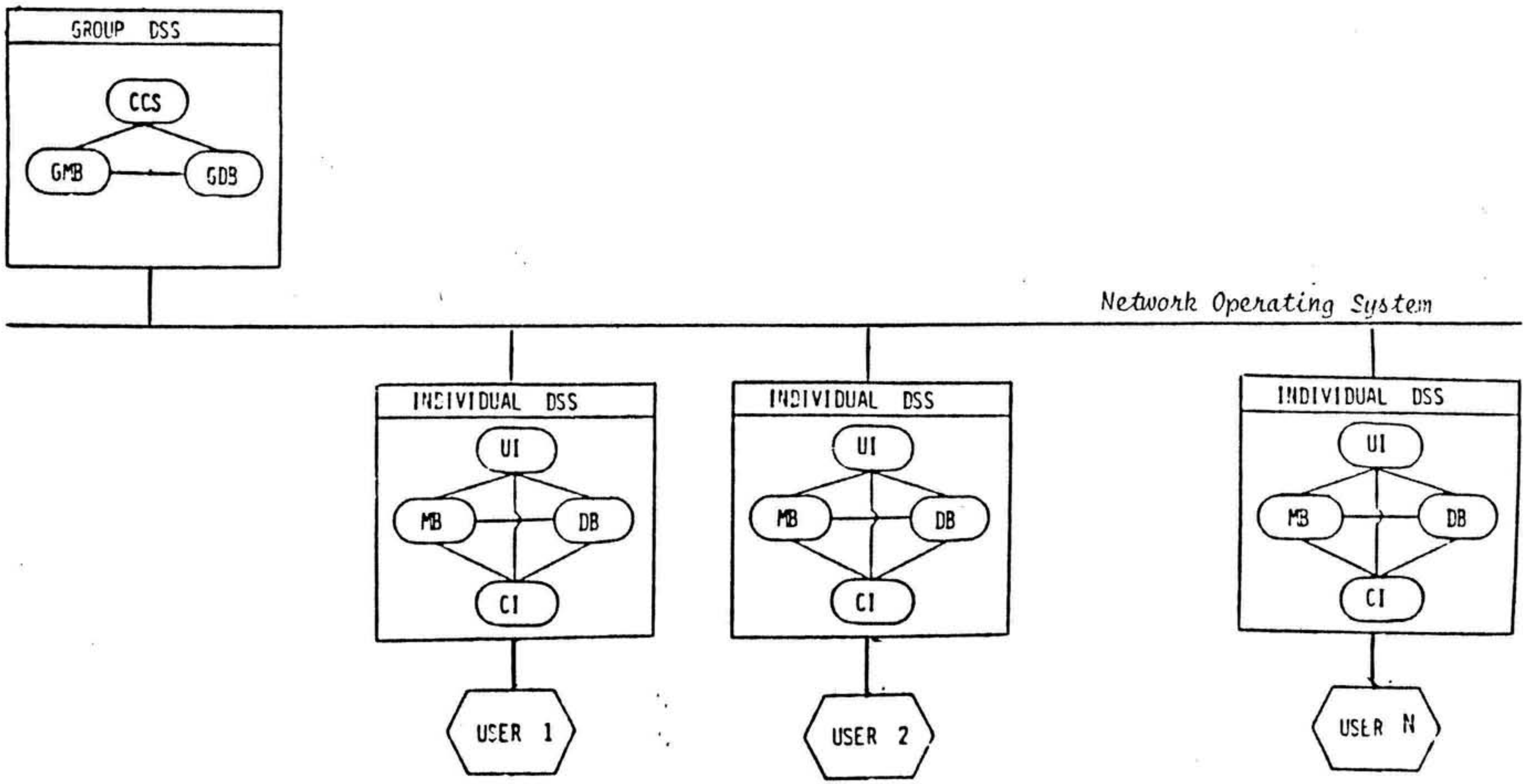

Figure 7. The Co-oP Architecture

In addition, an electronic notepad window can be popped-up at any time to make use of person-oriented and unstructured communications. An example screen is shown in Figure 8.

The purpose of such a design is to provide the user with a synoptic snapshot of the current state of the problem. Throughout the entire Co-oP process, the windows can be recognized by their colors. They vary, however, in size according to the required amount of information displayed (i.e., number of decision makers, number of decision alternatives, and number of evaluation criteria).

The individual DSS are linked by a microcomputer network system using a bus architecture and the Carrier Sense Multiple Access with Collision Detection (CMSA/CD) protocol. In CMSA protocols, each workstation or node is required to 'listen' before transmitting. If a collision occurs during transmission, the Collision Detection protocol forces both sending workstations or nodes back off random time intervals before trying again. The CMSA/CD protocol is known by its relatively good performance, simplicity of implementation, and inherent system reliability (NBS, 1982).

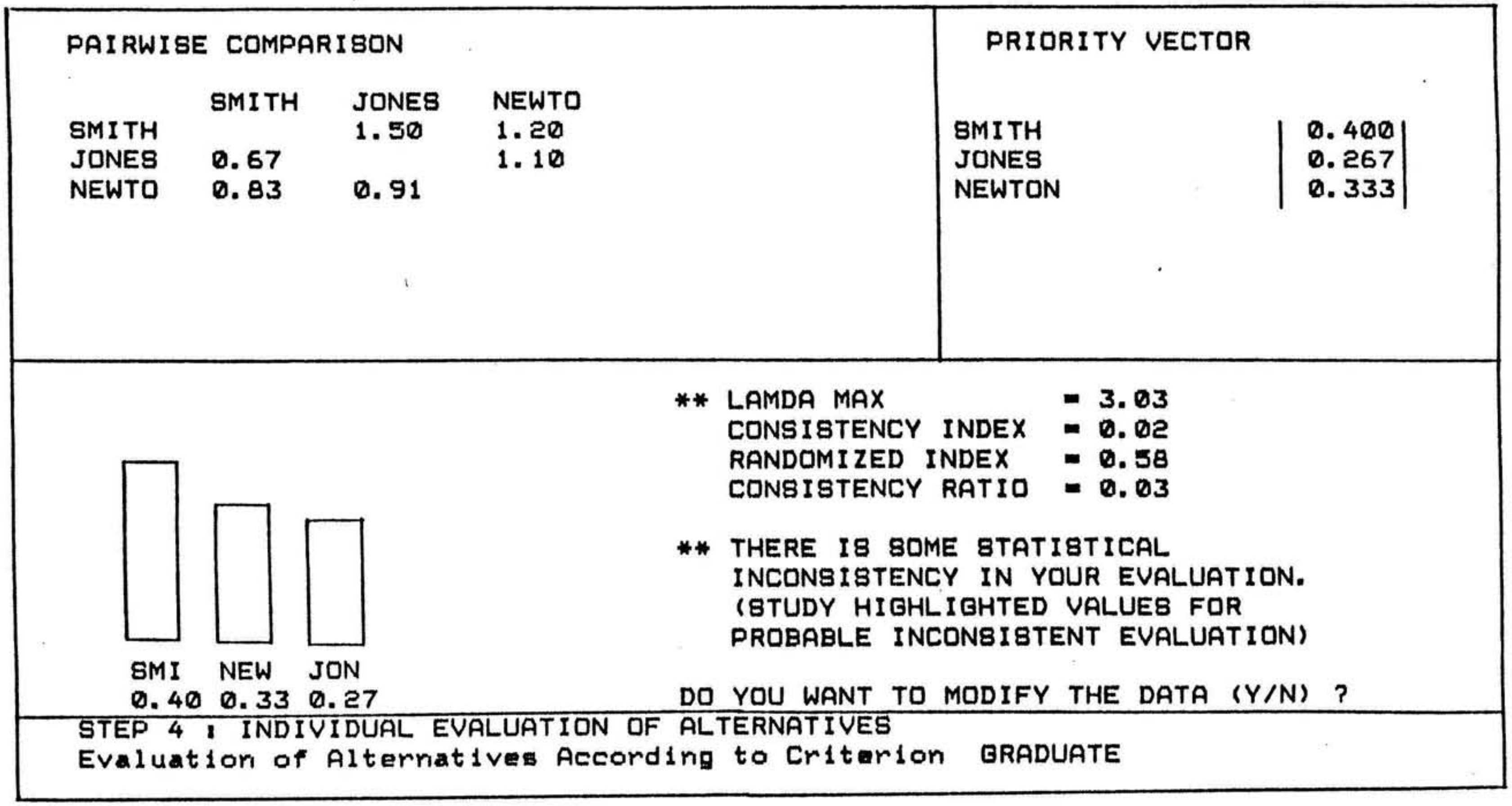

Figure 8.2. An actual Co-oP screen showing the Working windows, Solution window and step window

5.2. Co-oP: Group Decision Making Process

To insure an unambiguous and uniform information flow, Co-oP follows the basic steps of a multiple criteria problem solving process, governed by norms imposed by the group. These steps are:

(i) problem definition,

(ii) group norm definition,

(iii) prioritization of evaluation criteria,

(iv) individual selection of alternatives,

(v) group selection of alternatives, and

(vi) consensus seeking and negotiation.

These six decision processes dictate the sequencing and timing of a Co-oP group problem solving session.

(i) Defining the problem:

The group must collectively identify and define a decision problem. Specifically, all group members share a same decision space, e.g., same alternatives and evaluation criteria. The current version of Co-oP supports up to fifteen alternatives, and one hundred and twenty five evaluation criteria, which may be hierarchically structured. An actual Co-oP input screen of the problem definition phase using an hypothetical faculty selection example is given in Figure 9.

NAME OF GROUP PROBLEM : Faculty Selection

IDENTIFICATION OF ALTERNATIVES:
Type (q) to end definition of alternatives:

1. Jones
2. Smith
3. Newton
4. q

ENTER HIERARCHY OF EVALUATION CRITERIA
Type (1) for first level,
(2) for second level,
(3) for third level, and
(q) to end definition of evaluation criteria:

1. Education
    - 1.1 Undergraduate
    - 1.2 Graduate

2. Experience
    - 2.1 Teaching
        - 2.1.1 Undergraduate
        - 2.1.2 Graduate
    - 2.2 Research

3. Area of specialization

Figure 9. An Input Screen of the Co-oP Group Problem Definition Process. (The underlined text is enter by the group leader).

During the problem definition phase, Co-oP is expected to support decision makers in communicating their opinion regarding the group problem solving process. Teleconferencing and electronic mail are available to facilitate information exchange. From his/her IDSS, the group leader or secretary takes note of the discussion; Co-oP provides 'outline forms' for this purpose.

(ii) Defining the group norm:

The group has to identify its members and assign individual passwords. It also has to agree upon the way it handles data transfers, interactive conversation, utilization of electronic mail, and the type(s) of group decision techniques adopted. The group can also request automatic selection and computation of appropriate decision techniques.

(iii) Determining Priorities of Evaluation Criteria:

The third step deals with the prioritization of evaluation criteria. This process can be either accomplished by requesting the decision makers to directly assign weights to the criteria (e.g., ELECTRE), or by using the AHP hierarchical prioritization scheme. The Co-oP collective prioritization process can be performed in three modes:

- pooled (all group members enter 'collectively' a priority vector),
- sequential (group members assigns priority to a subset of criteria according to their expertise), or
- aggregated (each member assigns individual weights first; then individual priorities are aggregated using a pre-determined computation rule).

(iv) Selecting alternatives individually:

Given a defined problem, the fourth Co-oP process allows the decision maker to individually evaluate alternatives using his/her preferred or familiar MCDM. For comparison purposes, this Co-oP process acts as a single user multiple criteria DSS with data communications support.

To support this process, Co-oP provides each IDSS with a model base (MB). The MB provides a technique-driven milieu for understanding, selecting, retrieving, and operating the decision models stored in a Content Oriented Model Bank (COMB) and a 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 support the process of finding his personal solution to the group problem. These models can be classified into two broad functional classes: explicative models (e.g., linear programming, financial models), and time series models (regression models, smoothing techniques).

The main purpose of the MCDM model bank is to provide the decision makers with a set of decision models that can solve the most common types of decision problems. Currently, two MCDM methods are stored in the MCDMB to support two types of decision: the ELECTRE method (Roy, 1968) for selecting (i.e., to choose one and only one 'best' alternative among many) and, the Analytical Hierarchy Process (AHP) (Saaty, 1978) for ranking (i.e., all alternatives are good but they are ranked according to the decision maker's needs). The screen example from Figure 8 above shows the results of an individual selection process using AHP.

(v) Computing group results:

The next phase of the Co-oP process is the computation of group results using appropriate aggregation of preferences techniques. They use the individual MCDM outputs to compute group results. Co-oP also allows weighting of users' decision power.

The Co-oP group model bank contains four techniques for aggregation of preferences and some negotiation support modules. The former include additive ranking, multiplicative ranking, the sums-of-the-ranks approach, and the sums-of-the outranking-relations approach (Bui, 1985b). A weighted majority rule is also implemented to account for the distribution of power or expertise among decision makers.

Unless specified otherwise by the group norm filter, the Co-oP group module automatically searches for all aggregation techniques that are compatible with the MCDM methods used by any individual decision maker. If AHP were adopted by every group member for individual assessment of alternatives, all of the four implemented techniques will be computed, since the latter are compatible with the AHP in that they are based on cardinal preferences. However, the ELECTRE method can work only with the sums-of-the-outranking-relations and, to a certain degree, the sums-of-the-ranks algorithms. When both available MCDM are used concurrently, the Co-oP model manager in conjunction with the IDSS-to-GDSS formatter automatically searches for group decision techniques that can accept inputs from both AHP and ELECTRE.

(vi) <u>Seeking consensus or concessions</u>:

Finally, if unanimity is not obtained, a consensus seeking algorithm can be evoked in the sixth and last phase. If impasse still prevails, decision makers can attempt to revise their problem by going back to any of the previous steps.

Co-oP supports several methods for consensus-seeking and concession-making. In the ELECTRE context, it attempts to perform sensitivity analyses on the ELECTRE parameters. In the AHP context, it applies an algorithm called the Negotiable Alternatives Identifier (NAI, see Bui, 1985a) which employs an expansion/contraction/intersection mechanism in order to search for possible negotiation clues.

The decomposition of the group decision problem into processes permits the users to interrupt their analysis at any Co-oP process; they can log back into the decision support without having to start from the first process again.

During any phase of the group decision making process, the Group Communication System (GCS) interface will connect individual DSS to the group GCS upon request. The Co-oP GCS uses an electronic notepad (Borland, 1985) that can be used concurrently with other Co-oP modules. This electronic notepad makes it possible for each decision maker to store, move and process written communications or data among the group either in formal or informal mode.

5.3 Communications Modules in Co-oP

Figure 10 illustrates the interaction of the four GDSS communications modules identified in section 4 with the six Co-oP processes.

(1) The Co-oP Group Norm Constructor:

The Group norm constructor allows Co-oP users to define a framework for group decision making and communications exchange (Figure 11). At the beginning of the group MCDM process, a group member must be elected as a group leader. The primary role of the leader is to help group members formulate a collective decision situation and a mutually acceptable norm. The latter is then stored in the Co-oP group norm constructor. Identification of decision makers -- i.e., name and password -- is necessary to coordinate group decision activities. Since the group leader is the only member who defines the norms, he/she can enter his password during the group norm definition process. Other members of the group will be requested to provide their password from their individual workstation.

The group has to agree upon the way group decision techniques have to be computed. Co-oP needs to know what techniques of aggregation of preferences it must use to compute group

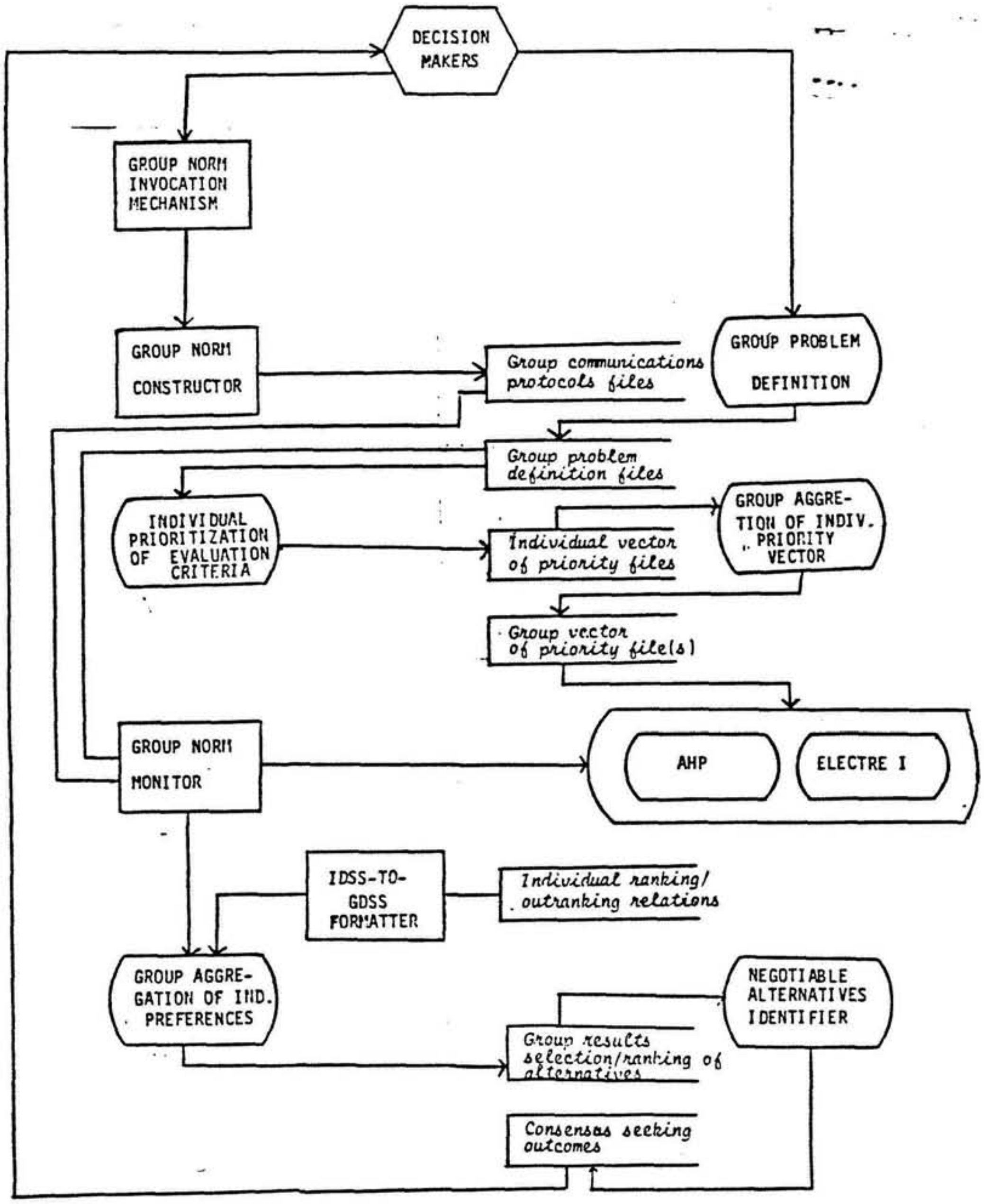

Figure 10. Communications Modules and Co-oP Processes

results. It also needs to know what weighed majority rule it has to follow.

Parameters governing the nature of information exchange must also be defined. Co-oP supports broadcasting of individual outputs. If this option is selected, individual outputs are public in that they are diffused to every group member's workstation. Otherwise, only group results are broadcast throughout the network.

The group members have to elect the possibility to allow its members to modify individual analyses after diffusion of group analyses. The number of modifications must be given to the group norm constructor.

Finally, time limits can be set to press the group members to reach a decision. Via its group norm filter, Co-oP will warn the decision makers that beyond the time limit late submission of individual results will be ignored.

During the definition of the group norm and throughout the entire Co-oP decision processes, a bulletin board system or electronic notepad can be concurrently used to allow decision members communicate their opinion regarding various organizational aspects of their collective problem.

```
---------------------------------------------------------------------

ENTER THE NAME OF THE GROUP NORM : Norm1

1. IDENTIFICATION OF GROUP MEMBERS:
   1.1  Enter number of decision makers :  2
        -  Enter name of decision maker No. 1 : Faculty1
        -  Enter name of decision maker No. 2 : Faculty2

   1.2  ENTER THE PASSWORD OF USER  Faculty1  : password1

2. GROUP DECISION TECHNIQUES:

   2.1  Weighted majority rule:
        -  EQUAL Weights (Y/N)                   :     Y

   2.2  Automatic selection of techniques of
        aggregation of preferences (Y/N)         :     N
        -  R1 : SUM-OF-RANKS (Y/N)               :     Y
        -  R2 : SUM-OF-OUTRANKING-RELATIONS (Y/N):     N
        -  R3 : ADDITIVE RANKING (Y/N)           :     Y
        -  R4 : MULTIPLICATIVE RANKING (Y/N)     :     Y

   2.3  Automatic computation of NAI (Y/N)       :     Y

3. INFORMATION EXCHANGE

   3.1  Broadcasting of individual outputs  (Y/N)   :  Y

   3.2  Permission to modify individual analyses
        AFTER group analyses (Y/N)                  :  Y
        3.2.1 How MANY times                        :  3

   3.3  Time limit to submit individual results:
        3.3.1  How MANY days                        :  3
        3.3.2  Hour                                 :  12:00
---------------------------------------------------------------------
```

Figure 11. The Co-oP Group Norm Definition Process (The underlined text indicates the user input using a hypothetical example)

(2) The Co-oP Group Norm Filter:

The function of the Co-oP Group Norm Filter is to enforce the norms defined by the group norm constructor. It performs three functions. First, the Co-oP Group Norm Monitor grants access to group DSS facilities to an user only if his identification and password are valid. It also warns the users if the time is running out. Second, it keeps track of the numbers of data transfers from individual DSS to the group DSS. This allows Co-oP to deny unauthorized request to the group module. Finally, the group norm filter monitors computation of group decision techniques in conjunction with the Co-oP Model Manager. Some of the routines of the Co-oP Group Norm Filter are illustrated in Figure 12.

(3) The Co-oP Invocation Mechanism:

The invocation mechanism allows the users to change some previously defined norms that become unrealistic or unfeasible. Co-oP allows the group leader to modify a pre-defined group norm. It also permits creation of alternate norms, e.g., new group members, different distribution of decisional power, extension of new due dates. Thus, many norms can be sequentially applied to a given decision problem, or a given norm can be used for various problem situations.

```
IF   results-member-1 = "received"
     results-member-2 = "received"
THEN select-group-algorithm
ELSE check-deadline
ENDIF

IF   ind-result-deadline = "YES"
THEN date                = set-date
     time                = set-time
     IF    current-date > date  and  current-time > time
     THEN  select-group-algorithm
     ELSE  wait
     ENDIF
ELSE wait
ENDIF


IF   auto-selection-of-AP = YES
THEN select-appropriate-group-algorithm
ELSE group-algorithm = set-group-algorithm
     compute-group-result
ENDIF


IF   MCDM-member-1 = AHP     AND MCDM-member-2 = ELECTRE OR
     MCDM-member-1 = ELECTRE AND MCDM-member-2 = AHP
THEN number-of-feasible-group-result = 1
     group-algorithm-1 = "Sums-of-Outranking-Relations"
     data-conversion(AHP-Sums-of-Outranking-Relations) =
       "necessary"
     compute-group-result
ELSE number-of-feasible-group-results = 4
     group-algorithm-1 = "Additive"
     group-algorithm-2 = "Multiplicative"
     group-algorithm-3 = "Sums-of-the-ranks"
     group-algorithm-4 = "Sums-of-Outranking-Relations"
     data-conversion(AHP-Sums-of-Outranking-Relations) =
       "necessary"
     compute-group-result
ENDIF
```

Figure 12. Some Routines of the Co-oP Group Norm Filter

(4) The Co-oP IDSS-to-GDSS Formatter:

The Co-oP IDSS-to-GDSS Formatter converts individual MCDM outputs to data formats that are compatible with the techniques of aggregation of preferences. The current version of Co-oP consists of two individual MCDM methods (i.e., AHP and ELECTRE) and four aggregation of preferences techniques (i.e., sums-of-the-ranks, sums-of-outranking-relations, additive function, and multiplicative function). At the individual level, AHP outputs consists of a vector of cardinal rankings. If the sums-of-the-ranks techniques is requested by the group, individual AHP outputs will be converted into ordinal ranking by the Formatter. Similarly, whenever necessary, the Co-oP Formatter transforms the ELECTRE matrix of outranking relations into vector of outranking relations and ordinal ranking.

6. SUMMARY

This paper proposed a framework for designing a communications component that serves as an integrated system linking decision support systems via a computer network to support group problem solving. Such an approach is a result of gradually increasing needs to integrate communications facilities into DSS. In a group decision situation, the communications facility must (i) reduce miscommunications among geographically dispersed decision makers, (ii) support formal and informal communications, (iii) simplify data transfer protocols, (iv) offer flexibility in setting various levels of information sharing ranging from limited to free exchange, and (v) accomodate various communications changes during the group decision making process.

The communications component can be built by embedding a Group Norm Constructor, a Group Norm Filter, a Invocation Mechanism, and a circumstance-shaped IDSS-to-GDSS Formatter in the application and presentation layers of the ISO Model. As opposed to the lower levels of the ISO model that attempt to provide reliable connections, the modules of the GDSS communications component help define and preserve problemsolving protocols.

The implementation of Co-oP, a GDSS for cooperative group decision making has proven the feasibility of the proposed framework in the context of multiple criteria decision methods. Its current use suggests that the combined service of the four communications modules can satisfy many of the requirements regarding remote information exchange.

In an extension currently under development, distributed knowledge bases are being added to the system to improve further the coordination of man-machine-man interaction and of strengthen the inventor role of the GDSS communications component. Yet, further experimental investigation will have to prove that a well designed and implemented communication component in a GDSS could contribute to a multi-function and distributed office information system that supports collective managerial tasks in addition to clerical activities.

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