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Group Decision and Negotiation Support – A Methodological Survey*

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Zusammenfassung. Der Beitrag gibt einen Überblick über neuere Entwicklungen auf dem Gebiet der Entscheidungsunterstützenden Systeme für Gruppen. Ausgehend von einem hierarchischen Modell, das zwischen individuellen Entscheidungsprozessen und Prozessen der Gruppenebene unterscheidet, werden zunächst unterschiedliche Formen der Unterstützung auf diesen beiden Ebenen sowie Systeme zu deren Realisierung betrachtet. Daran anschließend werden Ansätze zur Integration der beiden Teilprozesse wie Gruppen-Evaluationen und Rückkopplungen zwischen Gruppen- und Individualebene vorgestellt. Den Abschluß bildet ein Überblick über weiterführende Forschungsbereiche.

Summary. The paper surveys recent developments in Group Decision Support Systems. We first consider a basic hierarchical model widely found in the literature, which distinguishes between individual and group processes. Using this model, we identify different classes of support for both levels and discuss the corresponding systems presented in the literature. We then consider non-hierarchical approaches, mainly those based on a joint problem evaluation by the group and explicit feedbacks between group and individual levels. From the issues raised in this survey, we then identify some topics for further research.

1. Introduction

Group decision making is a frequent as well as complex way of solving problems. These aspects make group decision and negotiation problems an important application area for interactive support. This was recognized at an early stage in each of the many strands of research concerned with decision support. In the Decision Support Systems literature, the early work of Scott Morton [59] dealt with a situation in which a group of managers jointly specified production plans. Group decision support has since become an important branch within the DSS movement [26, 12, 24].

At approximately the same time as the DSS literature, the research area of multi-criteria decision techniques evolved. These methods were also frequently applied to support group decisions [76, 28, 54, 42, 44] and as individual support components in group decision support systems [8, 47].

Group decision support efforts evolving out of decision support systems for single users have recently been surveyed in [12, 24] and others. Other, more theoretically oriented approaches, however, have not been part of these surveys. Overviews of this literature are given e.g. in [17, 18]. In this paper, we provide a comprehensive survey encompassing both approaches to group decision support.

We start by identifying process issues as the central theme of decision support. Section two discusses the basic aims and functions of different approaches to group decision support. By comparing the different objectives and methodologies persued, we identify several possible levels of process intervention, which form one dimension of the classification developed in this paper. The second distinction is derived from the mainstream of current decision support literature, which is based on a hierarchical view of the entire process. This hierarchical view strictly separates individual and group stages. In this survey, we therefore

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distinguish between systems following this hierarchical point of view and systems trying to integrate the hierarchical stages.

Section three is based on the hierarchical point of view and further differentiates sub-processes at group and individual stages. Each of these sub-processes can be considered as a target for support, and section three relates the types of support suitable for the sub-processes to different levels of process intervention. While section three considers the phases separately, section four presents consistency requirements concerning the use of different levels of support across phases.

In section five, we employ the hierarchical model to briefly review and classify existing group decision support systems. Section six deals with attempts to integrate the two stages of individual and group processes more closely than the hierarchical model, and with systems in this category. Section seven then develops some topics for further research on group decision support.

2. Levels and Objectives of Group Decision Support

The problem of group decision making and fair compromises in groups has been studied extensively in many areas. When we try to develop a decision support method, we are not only concerned with the question which solution a group shall or will choose for a given decision problem, but also with the process by which this solution is reached.

Consequently, group decision support deals with the issue of improving the group process and its outcome. Unlike individual decisions, however, the meaning of "improving" or the definition of a "good" outcome is not obvious. Issues as the efficiency and effectiveness of a solution interact with considerations of equity and fairness, and these two objectives might be conflicting [41]. Even in axiomatic approaches to group decisions the set of axioms to be used is the subject of intense discussions.

To provide a broad basis for this survey, we will not limit the underlying concept of group decision support to a specific interpretation of solution (or process) quality or a specific paradigm of support. Instead, the survey will be based on the following broad definition of a group decision support system:

A group decision support system is a potentially computerized system supporting individuals, who are members of a group, in jointly solving a decision problem through an ongoing process.

This definition is based on elements of the definition of a decision group as formulated by DeSanctis and Gallupe [12] as well as of decision support systems widely found in the literature e.g. [34]. We regard our definition as an idealized one, not all systems we will discuss actually fulfill all its points. We also deviate from the traditional view of DSS as formulated e.g. by [63] or in other GDSS surveys [12, 24], including approaches with a stronger normative orientation.

This survey therefore encompasses a broad spectrum of systems: from systems which are mainly directed towards improving the efficiency and effectiveness of the group interaction process to systems that directly provide a normatively founded solution to the decision problem.

These different concepts and objectives of support can also be used as a classification criterion. In this survey, we will distinguish four different levels of support:

1) No support,
2) Process Facilitation,
3) Interactive Guidance,
4) Normative Guidance.

Since most of this survey will deal with hierarchical systems, which by far form the main body of the literature, the first level in our classification considers the possibility that a system does not offer any support for some hierarchical stage of the decision process.

Next we distinguish between support which is mainly aimed at *facilitating* a process (e.g. by providing communication channels) or aimed at *guiding* it. While facilitation might introduce a change in the way a particular process is carried out, such changes do not necessarily occur nor is the direction of change determined by the system. Guiding systems, on the other hand, impose a certain structure of the process.

Interactive multi-criteria procedures, which might form the basis of the individual component of a GDSS, are an example for guidance that determines a process structure. Systems that offer only a structure for the decision process will be classified as providing *interactive guidance*. They can be distinguished from systems that do not only guide the process but determine its outcomes, for example by generating a game theoretic solution. Systems that provide a solution and are not based on a concept of interactively adapting it will be called *normative guidance* systems.

This classification scheme extends that of Jarke and Hahn [31], who distinguished between communication systems, database-oriented systems and proper GDSS. The first two groups of Jarke and Hahn correspond to facilitation in our framework, while the third encompasses both interactive and normative guidance. Similarly, DeSanctis and Gallupe [12] distinguish between "Level 1" systems providing technical features to remove communication barriers, "Level 2" systems reducing uncertainty and noise similar to a single user DSS and "Level 3" systems exhibiting machine-induced communication patterns. Levels 1 and 2 correspond to facilitating systems, level 3 to (interactive) guidance.

Systems providing different levels of support also correspond to different objectives in GDSS development. Facilitation closely corresponds to the goals of increasing decision process effectiveness found in the DSS literature. Typically, these systems can only be evaluated in terms of their influence on the decision process [35]. Translating these process changes into outcome effects would need more models of human decision processes based on empirical research than are currently available.

Higher levels of support are more likely to be oriented towards decision outcomes. Normative guidance approaches are often based on an axiomatic characterization of desirable outcomes and provide a solution fulfilling those axioms. The objectives involved in the design of interactive guidance systems can be seen as a combination of both aspects: it can often be shown that the solution generated by using such systems fulfills (but not uniquely) certain desirable properties, but interactive concepts are often also justified and judged by process issues such as ease of use and user confidence.

Given these different objectives, we will not use one uniform evaluation system in this survey to compare different approaches to group decision support. While a comprehensive survey like this provides an opportunity to look at approaches from the point of view of completely different concepts, the main criteria used in evaluating different approaches will be those commonly used for systems in their particular level of support.

3. Decision Support in a Hierarchical Framework

3.1. Introduction

The overall perspective embodied in the definition given in section two can be decomposed into a two-stage hierarchical view of the group decision problem widely employed in the GDSS literature e.g. [8, 67, 72, 54, 27]. The first stage is the formation of individual preferences, the second stage their aggregation to a group opinion. The two stages themselves are complex processes and can be structured further into different phases, which might be targets for support. In this section, we will discuss those sub-processes in detail, relating them to appropriate levels of support and methodologies.

3.2. Individual Decision Processes

Within a hierarchical framework, the formation of an individual opinion can be regarded as similar to the situation of a single decision maker who faces the same choice problem as the group. Therefore, approaches developed for supporting individual decision makers can be applied at this stage.

This does not imply that the decision process at the individual stage can be ignored in research on group decision support. While the ultimate goal of group decision support is the resolution of differences at the group stage, these differences originate in the individual choice processes. By influencing the individual processes, individual opinions could be brought closer to each other before the group interaction has begun. Consensus at the group stage can then be reached more easily.

From standard decision theory, we know that in more complex decision situations involving, for example, risk and/or multiple criteria, two factors influence an individual's decision: facts about decision alternatives and subjective values like risk attitudes or trade-offs between criteria. In group decisions, both components are important sources of differences.

3.2.1. Factual Information. To form an individual opinion about decision alternatives, group members need factual information about consequences. Following the DSS literature, we can further separate the generation of factual information into data base access and modeling phases. Both common databases [30, 32] and the common development of formal models [52, 27, 16, 62] have been used in supporting group decisions.

Since the process of obtaining information is a prerequisite, any intervention concerning the information base can have only indirect influence on the decision process itself. It therefore can provide only process facilitation and no higher levels of support.

The advantages of speedier and more precise information are similar to those obtained for individual decision makers [2, 3, 34]. Empirical investigations have shown that the goal of improving the efficiency and effectiveness of the decision process usually can be achieved by current decision support technology [61].

From a group-decision-support point of view, the importance of a common base of factual information lies not only in the efficiency of individual processes, but also in a possible convergence of individual opinions.

Support through common information bases also leads to specific problems in a group context. In negotiation situations between adversaries, problems of hiding information and distrust may impede support based on common information except through a neutral and trusted outside mediator. Even in a cooperative situation, group members might not be willing to participate fully e.g. in joint modeling efforts to retain exclusive ownership of information [15].

A common information base might also cause the group members to deal with aspects of the problem that they would otherwise not consider, thus increasing problem complexity for members. This effect might be counter-productive for the original purpose of group decision making, the combination of expertise from different, specialized individuals.

3.2.2. Subjective Evaluation. In order to obtain an evaluation of decision alternatives, the group members have to combine the available data with their own subjective attitudes, e.g. towards time, risk or different outcome dimensions. The measurement and operational representation of these types of preferences have been the subject of considerable research, both empirical and theoretical [73]. All this research relates to the individual stage of a hierarchical decision process.

Evaluation processes can be *facilitated* by applying interactive technology like graphical displays and user friendly, interactive data transformation techniques. The benefits and problems of this approach have been extensively studied in the decision support literature [5, 45].

Decision support methodologies corresponding to *higher levels* take individual preferences explicitly into account. They might either obtain and apply preference information interactively, leading to interactive guidance, or statically, corresponding to normative guidance.

In addition to benefits encountered for single decision makers, approaches offering interactive or normative guidance might have additional advantages in a group context. These techniques are intended to lead to a more consistent evaluation and application of preferences. Greater consistency in individual behavior can be an advantage for aggregation at the group stage. The use of a common decision method might not only increase the internal consistency of group members but also consistency between members.

Evaluation methodology in a group context seems to be not fully developed. While developments for individual decision makers deal with several aspects of problem complexity, in the literature today most approaches to group decision support take into account only one or two aspects, mainly multiple criteria [20, 47, 65, 23, 6, 32]. In contrast, problems related to time or risk are rarely explicitly considered.

3.2.3. Bargaining Strategy. In a negotiation setting with adversaries, determining the preferences of a party is only part of the individual decision process. Another important issue is the development of an individual bargaining strategy [39, 38]. The systems presented in the literature so far are intended to be consulted before negotiation is started and to provide an optimal recommendation for strategy. They therefore offer normative guidance to the individual.

In contrast to the previous two sub-processes, where theoretical arguments for using a specific level of support can be given, normative guidance is not the only possibility for supporting individual bargaining behavior. The development of a bargaining strategy can be regarded as an ill-structured (individual) decision problem and many approaches and methodologies developed for individual decision support could be put to use for this problem.

3.3. Group Processes

The second major process to be considered is the formation of a group opinion. A group opinion can be obtained in two distinct ways: either the group as a whole goes through a new opinion formation process or the individual opinions, which were determined by a previous process, are aggregated. Group decision support systems have been proposed for both approaches and different levels of support.

3.3.1. Joint Evaluation. Similar tools as those used in individual support can be used to support joint evaluation. Therefore this approach is compatible with all levels of decision support.

Process *facilitation* for joint evaluation is not different from the individual stage and is widely used in group decision support systems. In a hierarchical framework, decision support tools are used to clarify differences in individual analyses by performing a joint attempt at solving the problem [27]. Empirical research has shown that a group using a process facilitation system will encounter similar benefits as an individual decision maker [50, 61].

Approaches to *interactive and normative guidance* at the individual stage can also be applied to the group stage if the group as a whole is to perform an evaluation of decision alternatives. In an hierarchical system, the joint analysis is based on an aggregated set of parameters (e.g. criteria weights) obtained from the individual evaluation processes.

The results achieved when a group uses a more formal decision technique depend on the parameters provided and therefore on the parameter aggregation technique used. Such an aggregation technique would, ideally, fulfill two sets of requirements:

- Consistency requirements necessary for a meaningful application of the technique used
- Requirements concerning desirable properties of group solutions

While suitable aggregation rules have been developed for utility functions [14, 36, 41], parameter aggregation remains an open research question for many other approaches.

3.3.2. Aggregation of Opinions. Aggregation of opinions is a concept different from individual decision making. For this sub-process, therefore, techniques specific for group decision support were developed. There are aggregation support methodologies corresponding to all possible levels of support.

Facilitation of group processes serving the aggregation of opinions is often attempted by reducing communication barriers. Communication is the main focus of so-called "Decision Room" systems [26, 51, 50, 53, 43] and similar systems oriented towards geographically dispersed groups [68]. These systems provide an interactive environment to support brainstorming and group discussions and facilitate other group activities like voting.

Experiments with this kind of support have shown that an electronic communications medium indeed has positive influence on the group process, especially regarding participation of all group members. Group members feel free to contribute their opinions when the system provides facilities for anonymous remarks, while authority in the organization might prevent them from doing so in face-to-face communication.

Systems that facilitate the group process are usually not concerned with the contents of information flowing between group members, e.g. about individual preferences. These items become important when guidance is to be provided on how the opinions should be aggregated. Several techniques have been suggested to provide such guidance.

An important source of concepts is game theory and its dynamic extensions. But while individual decision modules are often based on results from decision theory, theoretical models of the bargaining process e.g. [9, 10, 39]; (a survey is given in [18]) are rarely used in group decision support. Most systems based on game theory use static approaches like the Nash solution and offer normative rather then interactive guidance.

Instead, several researchers suggested to use techniques explicitly taken from multi-criteria decision making [49, 30, 69, 42, 44] or similar to multi-criteria decision techniques e.g. [80, 81, 22] to resolve differences between group members. In other GDSS developments, special algorithms were constructed to provide group solutions or identify possible areas of bargaining [7, 57].

Of all the approaches mentioned, game theoretic models have the advantage of being axiomatically founded. Dynamic bargaining models also have been shown to be applicable to actual problems [19].

The justification of MCDM and other models is not so clear. An MCDM-based approach is often motivated by the analogy between a single decision maker, who tries to formulate his trade-offs among criteria, and a group, which tries to find trade-offs between its members' utilities. A more direct analogy can be found in hierarchical organizations, where conflicts between lower level group members are often resolved according to the preferences of decision makers at higher levels in the organization [54, 77, 79]. While using an MCDM-based technique at the group stage leads to an ostensibly symmetric treatment of the two stages, this approach ignores important differences between the subproblems. In decision support for a single user, the user's preference can be regarded as the decisive factor. Providing an interactive process in which these preferences are determined therefore is a viable approach to decision support.

At the group stage, however, there is nothing like "the group's preferences". Any notion of fairness, equity or similar properties of outcomes can only be determined from outside the group process. To support a group in reaching a better outcome in terms of these criteria introduces a stronger normative component than usually found in individual decision support. This aspect is not explicitly recognized in most approaches. Similar criticism can also be raised against most ad hoc techniques for preference aggregation that were proposed in the literature.

4. Consistency Across Hierarchical Stages

The previous section dealt with the applicability of different levels of support to different phases of the decision process. Another important issue in GDSS design is the consistency of support levels used at different hierarchical stages.

As the survey given in the next section will show, most systems provide the same level of support for both individual and group processes. This symmetry can be justified by considering problems that might arise from the use of different support levels. Complex group processes used in interactive or normative guidance usually require consistent and complex information about individual preferences, e.g. the specification of utility functions. This kind of information can hardly be provided without adequate individual support.

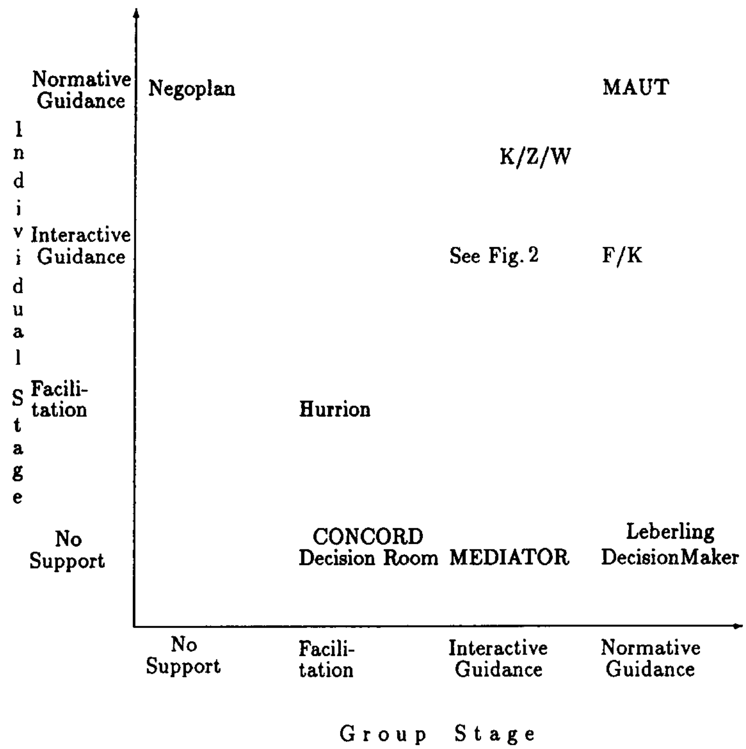

Fig. 1. Classification of Systems

As a first consistency requirement for selecting support levels, support at the individual stage should be sufficient to produce output of the complexity required by the group stage component of the GDSS. So the level of support for individual processes therefore should be at least equal to that for the group.

On the other hand, more sophisticated techniques at the group stage can also be expected to lead to better group results. It would therefore be inefficient not to use such techniques if the individual decision technique already generates the information required. A second consistency requirement therefore states that techniques used at the group stage should be able to make use of all information generated at the individual stage. This requirement precludes the use of lower levels of support for group than individual processes.

Combining the two requirements leads to identical level of support for individual and group processes.

An obvious exception to that rule are systems which do not support individual decision processes. In this case, if support at the group stage requires complex information from members, some kind of support must be provided externally to the GDSS.

5. Hierarchical Systems

Based on the hierarchical process perspective, we will now briefly review systems proposed in the literature to implement this framework. Figure 1 shows how several proposed systems provide different kinds of support at the two hierarchical stages.

5.1. No Support at the Individual Stage

Decision Room systems provide an integrated environment consisting of software, hardware and other components. The software provides capabilities similar to those of single user DSS, communication between group members and facilities for presentations to the entire group. Hardware usually consists of a network of personal computers. The environmental setting is comparable e.g. to a corporate board room, which is considered adequate for solving complex problems. Empirical research performed with such facilities is documented e.g. in [50, 51, 53, 43], surveys focused mainly on this class of systems are [26, 12] and [24].

A more structured approach to process support was taken in the CONCORD system [33]. This system advises the group in general terms on how to conduct the problem solving process but does not refer to the specific problem the group is about to solve.

There are many approaches to interactive guidance at the group stage. Most systems that provide this kind of support also support the individual decision processes. Among systems surveyed here, only MEDIATOR [32] can be considered to fall into the first row of Fig. 1.

MEDIATOR is a comprehensive database and model-oriented tool to aid a group in finding a

	Same Method	Different Methods
Aggregation	Leung (1982) Reimers (1984) Isermann (1984)	Co–oP
Group Evaluation	SCIDAS Bui/Jarke (1984)	

Fig. 2. Systems Providing Interactive Guidance at Both Stages

consensus. The underlying concept is the set of admissible alternatives accepted by all group members as a possible decision outcome. This set is expanded by concessions and/or the evolvement of new alternatives. Contractions of the set occur by increasing individual aspiration levels or by introducing axioms the solution should fulfill. This expansion and contraction process, which might also be influenced by a human mediator, is continued until the group agrees on one solution.

An example for a normative aggregation technique based on multi-criteria decision theory is the approach developed by Leberling [44], which is based on fuzzy linear programming. A fuzzy objective function is formulated for each participant and a compromise is determined via a max–min approach.

DecisionMaker [21, 11] is based on metagame theory. Its inputs are individual preference orders on actions rather than on outcomes. Through game theoretic stability analysis, equilibrium outcomes are then determined from these preferences.

5.2. Facilitation at the Individual Stage

As we have already discussed, the single user approach to decision support with its emphasis on models and database access can also facilitate group processes. For example, in the system developed by Hurrion [27], analysis tools for production planning are first used individually by departments, then jointly to develop an overall production plan.

5.3. Interactive Guidance at the Individual Stage

In accordance with the second consistency requirement formulated above, there are no systems that provide interactive guidance for members and only facilitation for the group process.

Several GDSS presented in the literature provide interactive guidance at both the individual and group stages. We can further classify these systems according to two criteria as shown in Fig. 2.

On the vertical axis, we distinguish between group evaluation and aggregation approaches. On the horizontal axis we indicate if the formal technique is the same at individual and group stages or if different techniques are used. In group evaluation, the same technique must be used by the group to make parameter aggregation possible. The second distinction is therefore only applicable to aggregation systems.

Aggregation systems using one methodology are often based on a multi-criteria decision technique, which is also used to determine a possible compromise between group members. An example is the method of displaced fuzzy ideal proposed by Leung [46]. This approach extends Zeleny's [82] theory of displaced ideals to find a compromise between different criteria at the individual stage and the opinions of different members at the group stage.

Reimers [54] proposed a hierarchical extension to the STEM method [4], in which conflicts are resolved by a higher authority. The higher authority uses the STEM method to determine trade-offs between the lower levels' demands according to its own preferences. The STEM method is also used by Isermann [28] at both the individual and group stages, taking also into account the possibility of coalitions [29].

An example for a system in which different techniques are used is Co–oP [8]. Co–oP deals with discrete sets of alternatives and provides the ELECTRE method [55] and Saaty's Analytic Hierarchy Process [56] as decision techniques for the individual stage. At the group stage, Co–oP contains an algorithm [7] to identify alternatives about which bargaining should take place. This algorithm provides three sets of alternatives: one set that is acceptable to all members, one of alternatives not acceptable and one in between. Bargaining among group members is then required for the final choice.

SCIDAS [47] uses the reference point approach [78] for individual opinion formation. Aspiration and reservation levels are then averaged over group members to generate a group choice. A similar approach is taken in a system by Bui and Jarke [6], which is based on the ELECTRE method. Both the individual and the group selection are performed via ELECTRE, the process parameters (thresholds) for the group stage are derived from the individual parameters via a min–max approach.

Since the information requirements of interactive and normative guidance are quite similar, information generated through interactive guidance at the individual stage can also be used for normative guidance at the group stage without violating the first consistency requirement. This is the case in the method proposed by Fortuna and Krus [20] (labeled F/K in Fig. 1). They use an interactive technique based on reference point optimization at the individual stage, but provide a normative solution (the game theoretic Nash solution) to the group problem.

5.4. Normative Guidance at the Individual Stage

A system providing strategic advice to a group member cannot support the group stage processes. An example for this class of systems is Negoplan [38], which is based on AI techniques operating on a hierarchical tree of goals. Another strategic support system based on a utility-oriented approach to the bargaining problem was developed by Kersten and Shapiro [40].

A GDSS might also provide normative solutions at both the individual and group stages. However, the distinction between interactive guidance and a normative solution is not as clear at the individual stage as it is at the group stage. Any individual decision aid must in some way determine the user's preferences. Thus, any system which then uses these preferences in a theoretically founded way might also be called "normative". For our purpose, we will consider a system to fall into the normative category if it constructs, at least partially, a utility function.

This definition encompasses the area of multi-attribute utility theory [37] and its application to group decision problems [36, 14, 60]. At least a partial construction of utility functions is performed in the technique developed by Korhonen et al. [42] (K/Z/W in Fig. 1), which is based on the Zionts/Wallenius multicriteria method [83].

6. Integrated Approaches

While the dichotomy between individual and group stages provides a convenient framework for the development of group decision support systems, some important features of the process cannot be captured in hierarchically structured systems. As it is usually interpreted, a hierarchical structure also implies a temporal sequence in which first the individual and then the group problems are solved. In reality, group processes are feedback processes in which information flows take place in both directions.

These feedback effects need not be of concern for a normatively oriented theory developing axiomatically founded solution concepts. For developing group decision *support* systems, however, it is important to adapt to the decision making style of the group. Even for practical application of normative theories, influences of group results on individual behavior might be of importance if motivational aspect of group members in the implementation phase of the decision are taken into account.

While many authors proposing hierarchically structured systems explicitly recognize the importance of such feedbacks (e.g. [32], p.92, [47], pp.9–12), they are rarely explicitly incorporated into hierarchical systems.

There are two basic possibilities to incorporate feedbacks into a group decision support system. The first is to drop the hierarchical structure and develop a system that treats the entire process as an entity. The second possibility is to consider feedbacks explicitly within a hierarchical framework.

6.1. Single Stage Approaches

In a single stage approach, the group as a whole uses a decision support system much like an individual decision maker would do. The system used can be based on different levels of support.

At the *facilitation* level, an integrated system provides access to database and modeling techniques similar to single user DSS [1, 64]. Sometimes even a DSS originally built for a single decision maker is used by the group [59]. The approach is not very different from process facilitation for joint evaluation in a hierarchical system. In the latter case, however, group members perform individual evaluations before the group convenes. In an integrated approach, the entire group starts from scratch.

When a group as a whole uses an *interactive* or *normative guidance* system, it cannot be expected to provide consistent statements about preferences like a single decision maker. An integrated group decision support technique must therefore either eliminate differences before information is processed by the decision method or the decision method used must be able to deal with inconsistent information.

The first possibility still requires an individual evaluation process and thus leads to a hierarchical system design. A method that deals explicitly with inconsistent inputs is Saaty's [56] Analytic Hierarchy Process. It is therefore especially well suited for direct application in a group context [25] and has been applied experimentally [48] as well as practically [13, 23].

Within a utility based framework, it is possible to apply estimation techniques for utility functions based on incomplete information. These techniques make it possible to derive a utility function using only responses upon which all group members agree [74, 75].

6.2. Explicit Feedback

While an integrated approach allows feedbacks from the group stage to individual evaluations to take place, it does not explicitly support them. Explicit modeling of feedbacks allows the system to further structure the group decision process.

One approach that comes close to an explicit consideration of feedbacks is the two-party negotiation support method proposed by Saaty [57, 58]. The opponents perform an evaluation of alternative moves both in terms of their own preferences and in terms of their *perception* of the opponent's preferences. A bargaining move (e.g. an exchange of concessions) is made if each party believes to be gaining more from that move than the opponent. In addition, an algorithm is provided that helps the parties or a mediator to determine packages of concessions attractive to both parties.

This method provides two important extensions to the traditional hierarchical approach to group decision support: First, it explicitly considers the importance of perceptions of the other party's view in individual evaluations. While this is an important aspect, especially in a two-party negotiation situation, it is hard to be generalized to larger group sizes. A second important aspect is the construction of concession proposals. This algorithm explicitly introduces feedbacks by proposing individual actions based on group results.

This author recently proposed a method [70, 71] to determine minimal changes in individual evaluations to match individual and group preference orders. These changes can aid individual group members in evaluating group proposals and indicate the direction of changes necessary to achieve consensus.

7. Topics for Further Research

From the preceding sections, several issues emerge that up to now have received little attention in the group decision support literature. Returning for the moment to the hierarchical point of view, we can identify such issues at both the individual and the group stages.

At the individual stage, research in group decision support mainly regards individual decision processes as multi-criteria problems. Other important factors, like risk or the time perspective, are recognized but given less attention. This might be due to the lack of integration of all these aspects in the individual decision area, too. While all three aspects of time, risk and multiple criteria are often viewed together in utility based approaches, interactive decision techniques in the multi-criteria area tend to ignore the other two aspects. For these techniques, a broader perspective incorporating all sources of complexity is necessary to apply group decision support techniques to real world problems.

Also at the individual stage, strategic behavior of group members deserves more attention in group decision support systems. Even in a cooperative setting, group members have different values and opinions and will try to let their point of view prevail. Unless a group decision support system takes strategic behavior explicitly into account, it might itself be subject to purposeful misrepresentation in the inputs provided by users.

Fig. 1 also offers some insight into possible areas where further research in group decision support is required. One conspicuously empty area in this figure concerns normative guidance at the group stage. Most systems are located at the intersection of interactive guidance at the individual as well as the group stage. As we already noted, even interactive approaches at the group stage need some axiomatic foundation, which is lacking in most current approaches.

The hierarchical model of group decision support tends to ignore the importance of feedbacks from the group to its members. With increased practical applications of group decision support systems, these issues will probably be recognized and introduced in future systems.

This brings us to the probably most important direction for future research, practical application. Most approaches discussed have only reached the status of formal models and sometimes computer implementations of a method. Only few have been tested empirically and even fewer applied in real organizations to solve actual problems. The applicability of such systems in organizations was only recently studied [66]. While any newly emerging field needs some theoretical groundwork before it can be applied, once the theoretical foundations are laid out, the ultimate test of their validity lies in their use. Given the momentum group decision support has gained on the theoretical side, it seems that the time for practical use has come.

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