WORKING PAPER

A PROTOTYPE SELECTION COMMITTEE DECISION ANALYSIS AND SUPPORT SYSTEM, SCDAS: THEORETICAL BACKGROUND AND COMPUTER IMPLEMENTATION

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Foreword

One of the important problems in decision analysis related to the situation, where the committee (group of decision makers) has to select the best alternative from a given, finite set. In the most cases, the alternatives are evaluated on the basis of several quality factors. In the paper, the authors present the new approach, based on the principle of satisfactory decision making. This approach ensures proper structuralization of the decision process and allows proper balance of opinion of the group member. The experimental decision support system SCDAS was developed to test this approach.

The research is a result of cooperative work between the System and Decision Sciences Program and the Institute of Automatic Control in Warsaw, done within the scientific agreement between IIASA and the Polish Academy of Sciences. Sarah Johnson took part in the project during her participation in the YSSP program at IIASA.

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A PROTOTYPE SELECTION COMMITTEE DECISION ANALYSIS AND SUPPORT SYSTEM, SCDAS: THEORETICAL BACKGROUND AND COMPUTER IMPLEMENTATION

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1. INTRODUCTION

Many major decisions in public and private arenas are delegated to committees. The institution of a committee, though it has many shortcomings, remains an important aspect of many decision processes; the process of committee decision-making must therefore be improved. As a result of personal experiences with committees, the authors have developed a procedural concept and an automated aid for decision-making by committee, aimed in particular at a committee charged with the task of selecting from a finite set of alternatives.

The theoretical framework for the automated system called "SCDAS" (for Selection Committee Decision Analysis and Support system) follows the concept developed by Johnson (1984). The multi-person decision support system is based on the construction of an order-consistent achievement function (Wierzbicki, 1985) which is used as a multivariable cardinal utility function and depends explicitly on the contextual information supplied by the users. The system described can be applied to a wide spectrum of decision problems and serves as a processor of information about preferences and alternatives that guides the committee. The computer implementation is non-procedural in that a menu format allows entry and re-entry into many stages of the process, thus allowing a great deal of procedural flexibility. Additionally, a rich graphic representation has proven quite user-friendly on the basis of several empirical tests.

The organization of the paper is as follows. First, the theoretical background and technical aspects of the system are discussed. A section devoted to a discussion of the procedural framework follows. A tutorial example of the selection of a candidate by a recruiting committee is used throughout for illustrative purposes. The final section presents in brief the computer implementation of SCDAS and the limitations and further extensions of the system, the primary one being the explicit inclusion of uncertainty in the evaluation of alternatives.

2. THEORETICAL BACKGROUND

The problem of selecting one alternative from a finite set of alternatives presented to a committee is one of the most basic and classical decision problems and has received much attention in the decision-theoretical literature. There are many detailed variants of such a problem; here, we consider the following abstract variant:

A ***committee*** consists of several members (denoted here by $k = 1,...,K$); each member can have either equal or different *voting power* (denoted here by a voting power coefficient $v(k)$), specified a priori by the ***committee charter***. In addition to the committee structure, the committee charter might specify the purpose of the committee's work, further procedural details, etc.

The problem faced by the committee is to jointly rank or select one or a few from a set of available *decision alternatives* (these might be candidates for a job, proposals for R&D projects, alternative transportation routes, proposed sites of an industrial facility, alternative computer systems, etc.). The list of alternatives need not be complete at the beginning of the committee's work; during the decision-making process, new alternatives may be generated and subsequently evaluated.

Evaluation of alternatives is performed by the committee by first specifying *decision attributes* (such as a candidate's age, experience, professional reputation, etc.) and then assessing each alternative with respect to each of these attributes. The list of decision attributes (denoted by $j = 1,...,J$) might be specified in the committee's charter or decided upon by the committee. In any case, decision attributes must be specified before alternatives can be evaluated and compared.

Each alternative (denoted by $i = 1,...,I$) must be evaluated by the committee or its individual members. The problem consists of proposing a *decision process* which together with assessment of various attributes of the alternatives and aggregation of evaluations across both attributes and committee members, leads to a final ranking or selection of an alternative(s) in a way that is rational, understandable and acceptable to the committee members.

Several approaches to this problem have been developed; most of them are based on the classical multi-attribute utility theory (see e.g. Keeney and Raiffa, 1976), but there are also alternative approaches, such as the analytical hierarchy of Saaty (1982) or the orderings of Roy (1971). Some of these approaches have been also implemented as microcomputer-based decision support systems: an interesting implementation is that of analytical hierarchy (EXPERT CHOICE, 1983) or the non-procedural package DEMOS (1982) used for probabilistic evaluation of alternatives. Another commercially available implementation (LIGHTYEAR, 1984), based on utility theory and weighting coefficients specified by the user, employs a rather primitive decision process and is restricted to only one user, hence it is not applicable in committee decisions.

Most of these approaches rely on either user-supplied rankings of attributes and alternatives for each attribute, pairwise comparisons of alternatives, or some uncertainty equivalence principle (e.g. comparisons to a lottery). The available assembly of alternatives plays an important role when establishing the principles of the decision. Such decision processes will be called *alternative-led*. An attempt to establish decision principles independently of available alternatives is possible when specifying weighting coefficients by the user; but in addition to the problem of having to specify utility functions or explicit weighting functions for the multiple attributes, weighting coefficients can be reasonably interpreted only locally, when the available alternatives do not differ much in all of the attributes. When the available alternatives differ significantly in some attributes, the approximate linearity of the user's utility function is a questionable assumption.

An easily interpretable outline of decision principles that are independent of available alternatives is possible when requiring each member to specify aspiration and (or) reservation levels for the evaluation of each attribute. Such a process will be called *aspiration-led*. The concept of an aspiration level is essential for the *satisficing framework* of decision-making (Simon, 1958), where it is assumed that as soon as an alternative is discovered that meets aspiration levels for all attributes, the search for alternatives is terminated and the choice is made. However, we do not adhere here to the strictly satisficing framework: aspiration levels are used rather in the construction of an approximate multivariable cardinal utility function that is further averaged and maximized in the system. This approach is called *quasisatisficing* (see Wierzbicki, 1985).

The reservation level represents a minimum acceptable level for each attribute (e.g. minimum 5 years' experience for the position), whereas an aspiration level reflects a higher desired level of expertise. If an alternative is evaluated below the reservation level on even one attribute, it is considered unacceptable, and if it is evaluated at least equal to aspiration levels for all attributes, it is considered highly desirable. Nonlinear approximations of utility functions based on aspiration (reservation) levels supplied by the user are called (order-consistent, or order-preserving and representing) *achievement functions* and have been studied in detail by Wierzbicki (1982, 1985). Johnson (1984) has worked out a concept for a selection committee decision analysis and support system based on committee-supplied aspiration levels and the use of achievement functions for both alternative-led and aspiration-led variants of the decision process; however, only the latter is chosen here for implementation.

2.1. Setting and discussing aspirations

An aspiration-led decision process has several advantages. Most judgmental decision processes require a choice of (and, in a committee, agreement upon) scales of evaluation for each decision attribute . The scales are often qualitative, such as unacceptable, bad, acceptable, good, very good, excellent, though they can be transformed into quantitative scales for computational purposes. When asked to specify *anchor points* (aspiration and reservation levels) on these scales at an early stage of the decision process, the decision-maker is better prepared to make consistent evaluations across alternatives. However, we cannot expect and should not require full consistency in any judgmental decision process, since not all relevant attributes might be evaluated and the relevant information on alternatives is never completely shared by all committee members. If each committee member is asked independently to specify his or her aspiration and (or) reservation levels for each attribute, a comparison of such results across the committee and across attributes serves several purposes:

(a) the relative importance of each attribute for each committee member and across the committee, as implied by the more or less attainable levels, becomes apparent, as discussed below.

(b) the division of opinions among the committee members can be discussed: if a significant subset of the committee has high aspirations (reservations) for an attribute and another subset has low aspirations (reservations), it is a case of a clear disagreement on decision principles. The committee might then discuss this disagreement and come to a consensus; or agree to disagree by allowing the formation of coalitions that rally for the importance of various attributes (for example, when deciding on siting an industrial facility, a part of the the committee might be more concerned with environmental impacts, another more concerned with economic impacts).

(c) if the discussion shows that the reason for disagreement stems from different perceptions by various committee members about the exact meaning of a particular attribute and its scale of evaluation, the result might be a better specification of, or at least corrections in, the list of attributes.

(d) if the committee (or a coalition inside the committee) agrees to use averaged aspiration and (or) reservation levels, each committee member has a better perception of the anchor points to be used when evaluating alternatives.

In order to support these discussions, a number of indicators can be computed. Denote the individually specified aspiration levels for attribute j by the committee member k by $p(j,k)$ and the corresponding reservation levels by $r(j,k)$. Then the committee "voting" procedure might specify an averaging of individual inputs, weighted by the voting power coefficients as follows:

$$p(j) = \sum_{k=1}^{K} v(k)p(j,k) / \sum_{k=1}^{K} v(k) \tag{1a}$$

$$r(j) = \sum_{k=1}^{K} v(k)r(j,k) / \sum_{k=1}^{K} v(k) \tag{1b}$$

Such an average is subject to manipulations by committee members who have an incentive to distort their true aspirations in order to influence the entire committee. A classical remedy, successfully used in subjective evaluations of certain sport performances (e.g. ice-skating or ski-jumping) is to exclude outlying opinions, in this case deleting the highest and the lowest $p(j,k)$ or $r(j,k)$ across all k before aggregating. This procedural option motivates committee members to state their preferences carefully since they will have no impact if they voice the outlying opinions. If the committee adopts this option (or if it is imposed by the committee charter), then an aggregation of opinions can be characterized by:

$$p(j) = \sum_{k \neq \bar{k}(p,j),\, \underline{k}(p,j)} v(k)p(j,k) / \sum_{k \neq \bar{k}(p,j),\, \underline{k}(p,j)} v(k) \tag{2}$$

where

$$\bar{k}(p,j) = \underset{1 \le k \le K}{\operatorname{argmin}}\, p(j,k); \quad \underline{k}(p,j) = \underset{1 \le k \le K}{\operatorname{argmax}}\, p(j,k)$$

denote the committee members with outlying aspiration levels who are therefore excluded from the averaging. The calculations are similar for aggregation of reservation levels $r(j)$ and $\bar{k}(r,j)$.

2.2. Assessing disagreement

The disagreement about aspiration (reservation) levels for an attribute among the committee can be measured in various ways. Clustering algorithms can be used in the case of very large numbers of committee members to identify the positional structure of the committee. Or, one could evaluate various statistical moments of the distributions of $p(j,k)$ and $r(j,k)$ across k, although moments of a distribution do not typically indicate the configuration of dissent. A good indicator of disagreement should distinguish between the case when there are two or more sizable dissenting groups of committee members, each representing a uniform opinion, and the case when the differences of opinion are distributed uniformly or attributed mainly to outlying opinions. To identify these differences, a *disagreement indicator* can be defined in the following way.

First let us consider the absolute change of aspirations:

$$\Delta P(j,K) = p(j,1) - p(j,K)$$

where committee members are renumbered such that

$$p(j,1) \geq p(j,2) \geq \ldots p(j,K-1) \geq p(j,K)$$

Now $\Delta P(j,k)$ can be split into the distribution of individual changes of opinion:

$$\Delta p(j,k) = p(j,k) - p(j,k-1), \quad k = 1,\ldots K-1 \tag{3}$$

In these equations, k can be interpreted as the index of the pairwise comparison between two ranked committee members. If large differences occur only at the ends of the range of k, corresponding to outlying opinions or small minority groups, they are not as significant as when they occur in the middle of the range. To correct for this, we introduce a coefficient $c(k)$:

$$c(k) = 16(k-1)^2(K-1-k)^2/(K-2)^4 \tag{4}$$

Other formulae can also be used for this coefficient; the above has been selected after empirical tests. The maximum value of $c(k)$ for any (K,k) is one. Also, for all $K, c(k) = 0$ for both $k = 1$ and $k = K-1$ since outlying opinions are not counted in the aggregation. It is useful to define the disagreement indicator as:

$$DI(p,j) = \sum_{k=2}^{K-2} c(k)\Delta p(j,k) \tag{5}$$

This disagreement indicator is bounded by the absolute difference of aspirations, $\Delta P(j,k)$; but $DI(p,j) = \Delta P(j,k)$ only if the committee is split into two equal fractions of equal aspirations in each fraction. Note that the disagreement indicator (5) has a peculiar property: it is always equal to zero if $K \leq 3$. Clearly this is because a committee of three always has two outlying opinions and only one will therefore be counted in the aggregation.

Similarly, disagreement indicators $DI(r,j)$ for the distribution of reservation levels $\Delta r(j,k)$ can be computed. If both aspiration and reservation levels are used, the committee might be interested in disagreement indicators for averages, $DI(pr,j)$, computed for the distribution of $pr(j,k)$, defined as:

$$\Delta pr(j,k) = 0.5(\Delta p(j,k) + \Delta r(j,k)) \tag{6}$$

It should be stressed that the above indicators serve only to draw the attention of the committee to the attributes and aspirations that cause dissent, for which a discussion of differences of opinion might be useful. Similar disagreement indicators can be used when comparing the differences between individual assessments of specific alternatives.

Another type of indicator relates to the relative importance of various attributes as implied by specified aspirations (reservations). Various types of indicators can also be used here. We choose ***dominant weighting factors implied by aspirations*** as relevant indicators because they are consistent with the function used later for the evaluation of alternatives.

To be consistent with our theoretical decision model, the weighting factors for attributes are constructed as follows: If a committee member specifies aspirations for one attribute that are "closer" to the upper end of its evaluation scale than another, then this implies that this attribute is more important to him or her than the other. More specifically, an indicator should be inversely proportional to such a distance and, if the indicators are interpreted as weighting coefficients, they should be normalized so that they sum up to one across all attributes. To avoid computational errors, the indicators should be calculable even in such an unreasonable case that a committee member specifies aspirations equal to the upper end of the scale. Hence, we extend the upper bound slightly, denoting it by $ub(j)$, and for simplicity normalize all scales so that the lower bounds of the scales of all attributes are zero. Then the dominant weighting factors implied by aspiration levels p of attributes j for committee member k are computed as follows:

$$w(p,j,k) = (ub(j)/(ub(j) - p(j,k)))/ \sum_{\bar{j}=1}^{J} (ub(\bar{j})/(ub(\bar{j}) - p(j,k))) \quad (7)$$

Weighting factors implied by stated reservation levels $w(r,j,k)$ are calculated similarly.

These weighting factors can also be calculated for the committee's aggregated preferences. In all cases, the indicators serve only as feedback signals to individuals or to the committee to check whether their aspirations correctly reflect their perception of the relative importance of various attributes. If there are inconsistencies, they can easily be corrected.

2.3. Evaluating alternatives by individual committee members

An essential part of the decision process is an individual assessment and analysis of all alternatives by each committee member. In the approach followed in this paper, it is assumed that the assessment is performed not by rankings or pairwise comparisons but simply by assigning scores for each attribute to each alternative (as a teacher would assign grades for each subject of learning to each pupil). Uncertainty in each assessment could be expressed by supplying a range of scores or a probability distribution for the scores; however, we consider only the simpler case without individual assessment of uncertainty. The scores of the k-th committee member for the j-th attribute of the i-th alternative are denoted here by $q(i,j,k)$.

In order for each committee member to see what the scores imply and check for any scoring errors, rankings of alternatives by various attributes can be produced in the system by listing the alternatives, starting with the best score on a given attribute and ending with the worst score. However, the committee member is also interested in an aggregate ranking which takes into account scores on all attributes to test whether his or her intuitive opinion about which alternatives are best is consistent with the results of the scoring procedure.

A special approximation of a utility function implied by aspiration levels is applied in order to produce such an aggregate ranking; this approximation is called an (order-consistent) achievement function.

Consider the following question (Wierzbicki, 1986). Suppose the user knows the upper and lower bounds of an assessment scale and has specified a reservation and an aspiration level for each decision attribute; these four points we denote respectively by $lb(j)$, $ub(j)$, $r(j)$ and $p(j)$, where $lb(j) < r(j) < p(j) < ub(j)$. Suppose a satisfaction (utility) value of zero is assigned to an alternative whose attribute assignments are all equal to reservation levels, and a satisfaction (utility) value of one to an alternative whose attributes are all equal to aspiration levels. We assume further that alternatives which have scores satisfying all their reservation levels are preferred to any alternative which has at least one score not satisfying the corresponding reservation level. And similarly, alternatives which have scores satisfying all their aspiration levels are preferred to any alternative which has at least one score not satisfying the corresponding aspiration level. Finally, let an (unlikely) alternative with scores all equal to the lower bounds of the scales have the value of $-b$ (a negative number) and an (unlikely) alternative with scores all equal to the upper bounds have the value of $1 + a$ (a number greater than one). What is the simplest cardinal utility function (i.e. a function that is independent of all linear transformations of the assessment scales) that is consistent with all of these assumptions?

The simplest function that meets these requirements can be constructed by using linear approximations between the points for which its values are known ($-b$, 0, 1 and $1 + a$). Such a function, called also an order-representing achievement function, has the following form:

$$s(q(i,k),p,r) = \min_{1 \le j \le J} u_j(q(i,j,k),p(j),r(j)) \tag{8}$$

where

$$u_j(q(i,j,k),p(j),r(j)) =$$

$$= \begin{cases} b((q(i,j,k) - lb(j))/(r(j) - lb(j)-1) & \text{if } lb(j) \le q(i,j,k) < r(j) \\ (q(i,j,k) - r(j))/(p(j) - r(j)) & \text{if } r(j) \le q(i,j,k) \le p(j) \\ a(q(i,j,k) - p(j))/(ub(j)-p(j))+1 & \text{if } p(j) < q(i,j,k) \le ub(j) \end{cases} \tag{9}$$

and $q(i,k) = (q(i,1,k),\ldots,q(i,j,k),\ldots,q(i,J,k))$ is the vector of scores given by the k-th committee member to the i-th alternative. Thus the achievement function maps a vector of attributes into a scalar value for each alternative. Additionally, $p = (p(1),\ldots,p(j),\ldots,p(J))$ and $r = (r(1),\ldots,r(j),\ldots,r(J))$ are vectors of aspiration and reservation levels aggregated across the committee in a way that is acceptable to all members. In its middle range, the function (8) can also be interpreted by the difference between aspiration and reservation levels for each attribute.

However, the above achievement function has some disadvantages. Suppose the scales of assessments for all attributes are from 0 to 10, and the reservation levels are all 3 while the aspiration levels are all 7. Compare two alternatives: one with all scores equal to 5 so that the value of the achievement function (8) equals 0.5, while the second alternative has scores of 7 for all attributes but one, which has the score 4 so that $s(q,p,r) = 0.25$. But the second alternative might be considered better: the better achievements on many attributes could compensate for a worse achievement on one attribute. In order to correct for this consideration, we propose a modified form of the function (8), called an order-approximating achievement function:

$$s(q(i,k),p,r) = \tag{10}$$

$$= \left[\min_{1 \le j \le J} u_j(q(i,j,k),p(j),r(j)) + (\varepsilon/J) \sum_{j=1}^{J} u_j(q(i,j,k),p(j),r(j)) \right] / (1 + \varepsilon)$$

where $u_j(q(i,j,k),p(j),r(j))$ are defined as in (9). The parameter ε in this function represents the intensity of correction of the worst (under-)achievement by the average (over-)achievement. In the example considered above, if $\varepsilon = 1$ and there are 5 attributes, then the first alternative has a value of the achievement function (10) equal to 0.5 (due to the subdivision by $1 + \varepsilon$ in (10), this does not depend on ε if all u_j are equal) but the second alternative has the corresponding value of 0.55. So the second alternative is preferred. If, however, $\varepsilon = 0.5$, then the first alternative has an achievement value equal to 0.5 but the second alternative has an achievement value of 0.45, so the first alternative is now preferred.

The choice of the parameter ε is left to the committee: if its members feel that the worst achievement matters most, they should choose slight correction (say, $\varepsilon = 0.1$); if they feel that the average achievement matters most, they should choose very strong correction (say, $\varepsilon = 2$), indicating that average achievement is twice as important as worst achievement. A good interpretability of the values of the achievement function (10) by the users is obtained if $a = b = 1$ and the values of $s(q(i,k),p,r)$ are multiplied by 10. Then the achievement range is from -10 (corresponding to all scores equal to 0) through 0 (all scores on reservation levels), through 10 (all scores on aspiration levels) to 20 (all scores maximal, equal to 10).

We should also mention here some mathematical interpretations of the dominant weighting factors implied by aspiration or reservation levels in connection with achievement functions in the forms (8) and (10). These achievement functions are nonlinear, hence their derivatives (corresponding to the classical concept of a weighting factor in a linear utility function) depend on $q(i,k)$. In fact, these achievement functions are nondifferentiable, hence they do not possess derivatives in the classical sense at some points - and, in particular, at the anchor points, that is, if $q(i,k) = r$ or $q(i,k) = p$. The dominant weighting factors indicate directions in the J-dimensional space of the assessment vectors $q(i,k)$, on which the points of nondifferentiability are located. While these properties of the dominant weighting factors are important mathematically, the reader should remember two points: the dominant weighting factors are not specified a priori or supplied explicitly, rather they are *implied* by the choice of aspiration and/or of various attributes as implied by aspiration and/or reservation levels.

The achievement function (10) is used to aggregate scores given by a committee member to various attributes of an alternative and then to rank various alternatives according to their achievement values. This can be done when using either individual aspirations (reservations) of a committee member or aggregated aspirations (reservations). In the former case, the ranking proposed by the system serves as a feedback to the committee member: he or she should compare it with his or her intuitive perception of ranking of alternatives. If the ranking does not match his or her intuitive perception, he or she should check whether he did not make any errors in scoring; another reason for such mismatch might be his disagreement with the correction coefficient ε adopted by the committee. If the ranking does match his or her intuitive perception, he or she should be prepared to accept the fact that the ranking based on aggregated aspirations (reservations) might be different; but the committee member cannot protest if he or she accepts the right of the committee to impose aggregated decision principles on the collective group.

2.4. Aggregating individual assessments across the committee

There are various interpretations of the process of aggregating preferences across a group of decision-makers. Typically, the interpretation is related to the concept of fairness; however, various paradoxes in decision theory (Saari, 1982) show that there is no absolute meaning in this concept. In this paper, we simply require that the committee specify a set of procedures that is accepted as fair by the group. For example, if the charter of the committee specifies the voting power of each member, the procedurally "fair" aggregation is to take the weighted average of evaluations. The members with greater voting power are supposedly either more responsible (consider, say, the role of the chairman of the committee), more concerned with the outcome of the decision process, or more knowledgeable in a certain substantive area.

Hence, a final ranking of alternatives for the entire committee can be proposed by the decision support system by computing the (weighted) averaged achievement values for each alternative:

$$S(i) = \sum_{k=1}^{K} v(k) s(q(i,k),p,r) / \sum_{k=1}^{K} v(k) \tag{11}$$

with $s(q(i,k),p,r)$ defined as in (8) or (10).

This aggregation procedure gives reliable results under certain assumptions, of which two are most important. First, we assume that committee members do not bias their opinions in order to manipulate the outcome of the decision process. In order to discourage such manipulations, it is advisable to exclude outlying opinions from the averaging process, as was done in (2) for the aggregation of aspiration levels:

$$S(i) = \sum_{k \neq \underline{k}(i), \bar{k}(i)} v(k) s(q(i,k),p,r) / \sum_{k \neq \underline{k}(i), \bar{k}(i)} v(k) \tag{12a}$$

where

$$\underline{k}(i) = \operatorname*{argmin}_{1 \le k \le K} s(q(i,k),p,r); \quad \bar{k}(i) = \operatorname*{argmax}_{1 \le k \le K} s(q(i,k),p,r) \tag{12b}$$

Second, we assume that committee members possess the same information about alternatives. This very demanding assumption is never fully satisfied in practice. The decision process encourages discussion and exchange of information about alternatives between committee members in part by including concise descriptions of alternatives and requiring agreement at certain stages. When disagreement is indicated by major differences in individual rankings of alternatives or by large values of the disagreement indicators, this should tell the committee to stop and search for sources of disagreement. If the disagreement is due to a difference in the information base between individuals, then the problem can be resolved by sharing and exchanging information. A graphic representation of the diverging scores for an attribute of an alternative helps greatly in such discussions; a committee member with a dissenting opinion can either convince the committee that he or she has specific valuable information to share, or be convinced that his or her opinion cannot be substantiated. This serves as an additional disincentive for attempting to manipulate the outcome of the decision process by biasing assessments. The interested reader should also consult Tversky et al. (1983) for discussions about biases in decision-making.

After such discussion, the committee can either decide to return to some earlier stage of the decision process (for example, to correct the scores) or conclude the process. When adopting the final decision (a ranking or a selection of alternatives) the committee is by no means constrained by the aggregate ranking proposed by the decision support system, but merely guided by the results.

3. PROCEDURAL FRAMEWORK

The above theoretical background of an aspiration-led decision process suggests a general procedural framework for the committee; however, this framework is rather elastic and can be modified variously for any specific application.

The first point on the agenda is to define the procedures by which the committee will operate. The questions addressed here should include the following:

(a) What is the expected product of the committee's work and how does it influence the appropriate procedure? The answer to this question depends on the committee's charter and its perceived role. For example, if the expected product is a short list of significantly different alternatives, procedural rules will be different from the case when the expected product is a consensus opinion on the "best" alternative.

(b) What aggregation rules should be adopted, and in particular, should outlying opinions be included in or excluded from aggregation?

(c) Should the committee be allowed to divide and form coalitions that might present separate assessments of aspirations, attribute scores and thus final rankings of alternatives?

The committee should also become familiar with basic concepts concerning the use of the decision support system. A secretary or a designated committee member whose duties include working with the decision support system should study thoroughly the description of the system in the user's manual (1985), and present the basic concepts to the entire committee in the first meeting.

The second point on the agenda is problem specification. Neither the list of alternatives, nor their descriptions need be complete at this stage. The most important part of this process that requires discussion and specification by the entire committee is the definition of the attributes of the decision and their scales of assessment.

Various studies in decision theory suggest that a reasonable number of attributes should not exceed seven to nine (see e.g. Dinkelbach, 1982); if more attributes are suggested, they should be aggregated. For example, there might be a large number of qualitative indicators that are all related to professional reputation; instead of using all these indicators, it is better to ask committee members to evaluate subjectively the attribute "reputation", that is, to translate the information about all these indicators into one assessment, given originally on a verbal scale from "unacceptable" to "excellent", into a quantitative scale, say from 0 to 10.

A clear definition of relevant attributes is a very important part of the decision process. One possible approach is to first list a large number of attributes, then order them into groups in a hierarchical structure, and finally decide on a short list of aggregated attributes satisfying two requirements:

(a) they should have the same hierarchical importance - which does not mean that they should be equally important, but they should not obviously differ in importance nor be hierarchically dependent;

(b) they should not be highly correlated - that is, two different attributes should not express, under different names, the same essential aspect of the decision.

Aggregated attributes that satisfy these requirements often have a qualitative character. A committee should avoid the trap of selecting some attributes only because they might be quantitatively measurable (such as the number of publications of candidates for a scientific position). Typically, such attributes are inadequate and are more relevant when expressed in aggregate terms.

During *the third point* on the agenda, aspiration and/or reservation levels for all attributes are determined separately by each committee member. After these values are entered into the system, all necessary averages and other indicators (disagreement indicators, dominant weighting factors) can be computed.

The fourth point is the analysis and discussion of aspirations by the entire committee. These discussions are supported by the computed indicators and their graphic interpretations.

In these discussions, the committee might address the following questions:

(a) Do the dominant weighting factors accurately reflect the perceptions of individual committee members about the relative importance of various attributes (if not, should the aspirations or reservations be corrected)?

(b) What are the relevant differences and do they represent an essential disagreement about decision principles?

(c) Does the entire committee agree to use joint, aggregated aspirations (reservations), or will there be several separate sub-group aggregations?

The fifth point on the agenda is a survey of alternatives. Discussions might center on the following:

(a) Are the available descriptions of alternatives adequate for judging them according to the accepted list of attributes? If the answer is negative, additional information should be gathered by sending out questionnaires, consulting reviewers, etc.

(b) Which of the available alternatives are irrelevant and should be deleted from the list? This kind of cursory screening can be done in various ways. The committee might define some screening attributes and reservation levels for them (of a quantitative or simple logical structure): for example, we do not accept candidates that do not have at least four years of teaching experience. The secretary can be empowered to prepare the list of irrelevant alternatives to be deleted; this list should be presented to the entire committee for approval. It is easy to overlook special opportunities related to seemingly irrelevant alternatives.

(c) Is the list of relevant alternatives promising for a reasonable choice? Or should the committee look for new alternatives? What are the attributes that have not been sufficiently well addressed by the existing set of alternatives?

Most of these questions are analyzed subjectively without much support from the system. However, the list of relevant alternatives must be sufficiently short before going to the next point on the agenda.

The sixth point on the agenda is the individual assessment of alternatives. The assignment of scores for each attribute to each alternative is the main input of committee members into the system. Each member specifies scores; the system supports this by displaying those assignments already made and those still to be entered.

The seventh point on the agenda is individual analysis of alternatives, based on calculations of the achievement function which lead to a ranking of all alternatives for each committee member. This ranking is the main source of learning about the distribution of alternatives relative to aspirations.

The questions addressed by each member at this point might be as follows:

(a) Do the rankings along each attribute correctly represent the individual's evaluations of alternatives; does the achievement ranking, based on individual aspirations, correctly represent the aggregate evaluation (if not, should the scores be modified)?

(b) If there remains disagreement about the member's individual achievement ranking of alternatives suggested by the system, should he or she propose at the next committee meeting to modify the parameter ε that expresses the importance of average achievements as compared to the worst achievement?

(c) If he or she agrees with the individual achievement ranking proposed by the system, what are the differences between this ranking and that based on individual scores but related to committee-aggregated aspirations? Are these differencies significant, or can he or she accept them as the result of agreement on joint decision principles?

The eighth point on the agenda is a committee discussion of the essential differences in scoring and disagreements about the preliminary ranking of alternatives aggregated across the committee. These discussions are supported by the system; the system computes indicators of differences of opinion and prepares a preliminary aggregated ranking.

The questions addressed by the committee at this point might be the following:

(a) On which attributes are the largest differences in scoring between committee members observed? Do these differences represent essential differences in information about the same alternative?

(b) What is the essential information (or uncertainty about such information) that causes these differences? Should additional information be gathered, or can certain committee members supply this information?

(c) Would the results of these discussions and possible changes of scoring influence the preliminary aggregated ranking list proposed by the system? This can be tested by applying simple sensitivity analyses.

(d) Does the preliminary ranking proposed by the system correctly represent prevalent committee preferences? If not, should the parameter ε be modified?

After these discussions, a return to any previous points on the agenda is possible. If the committee decides that the decision problem has been sufficiently clarified, it can proceed to the final, *ninth point* on the agenda: agreement on the aggregated ranking or selection of one or more alternatives. It is important to stress again that the committee need not stick to the ranking proposed by the system, since the purpose of this ranking - as well as of all information presented by the system - is to clarify the decision situation rather than to prescribe the action that should be taken by the committee.

4. IMPLEMENTATION ASSUMPTIONS AND EXTENSIONS

A prototype implementation of SCDAS on the IBM-PC (or compatible computer) illustrates the possibilities of the system and stresses graphic presentations to ensure user-friendliness.

This implementation in BASIC serves actually only as an illustration but contains a well-documented tutorial example (of scientific recruitment committee work) and has a user's manual that allows an average user to work with the system on his or her own problems. The implementation is limited in several aspects:

- only aspiration levels, not aspiration and reservation levels, are used in the decision process and in the aggregating achievement function;
- disagreement indicators are computed only for aspirations, not for scores;
- graphic illustrations, though quite rich, do not yet completely represent information that might be useful at various stages of the decision process.

This implementation is available from A. Lewandowski at IIASA. Work on the next implementation - with much more professionally treated system details - is in progress. The new implementation is designed not only to overcome the shortcomings listed above, but will also address some new issues, such as representations of uncertainty in scoring, a joint data base of information relevant to the decision process and reserved fields of the data base for use by individual members.

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