"SUPPORTING MULTICRITERIA DECISION MAKING: NEW PERSPECTIVES AND NEW SYSTEMS"

by

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Supporting Multicriteria Decision Making: New Perspectives and New Systems

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An increasing number of researchers in Information and Decision Support Systems recognize that the field of computer-based decision making is changing. Motivated by a growing recognition of the "non-rational" dimensions of human decision making, the new challenge consists of *humanizing* decision support, i.e. adopting a design approach which emphasizes the DSS capability to facilitate and stimulate learning processes (human perspective) rather than to solve problems autonomously (technical perspective). This explicitely *learning-oriented* approach has major impacts on the design process of DSS as well as on the role played by analytical techniques within these systems. Visual Interaction turns out to be a powerful means to enhance flexible human-computer collaboration, whilst Management Science methods assume the role of dynamic agents stimulating decision makers in an incremental learning and exploration process.
In this paper, the learning-oriented approach to decision support is discussed and the associated design guidelines are provided. A concrete example of a humanized DSS is presented in the specific context of supporting multiple criteria decision making.

Keywords: Decision making, DSS, Human-Computer Interaction, MCDM.

1. Supporting Multicriteria Decisions: New Perspectives

> *Multicriteria decisions pose dilemmas or even crises of judgements: ethical choices, trade-offs between cost and service, conflicts of preferences, and 'political' problems are obvious examples. The multicriteria problem is at the core of Decision Support* [Keen 1987]

As testified by the above quotation, everyday human decision making typically involves the consideration of more than one single criterion. Accordingly, multicriteria decision making (MCDM) has been widely studied in Management Science/Operations Research (see [Keeney and Raiffa 1976; Edwards and Newman 1982; Zeleny 1982; Roy 1985; Saaty 1986] as examples of the very large MCDM literature) and the resulting theories and methods have been applied in several fields, such as marketing, group decision support and computer-assisted negotiation [Bui and Jarke 1984; Jarke et al. 1987].

At the same time, these studies have stimulated the development of computer-based systems aiming at the interactive support of multicriteria decision making. These systems are generally classified as Decision Support Systems (DSS; cf. Keen and Scott Morton 1978; Sprague and Watson 1989; Turban 1988) and specifically designated as *Multicriteria Decision Support Systems* (MCDSS, cf. Jelassi et al. 1985; Eom 1989).

One of the main motivations for the work reported in this paper has been the diffuse dissatisfaction with the existing approaches to understand, model and support MCDM:
Why are the developed MCDM theories well-known, used and generally accepted almost without criticism only in the academic field? Why - if multicriteria decision situations are so common - does the number of managers/decision makers effectively using MCDSS remain practically insignificant? What is wrong with these scientific approaches to MCDM and with the resulting MCDSS?

A polemical, but very clear answer to these questions has been proposed by Zeleny [1989] in the following terms:

> Mostly, we have imposed a mathematical artifact, both simple and simple-minded in its design, on the rich, natural, self-organizing and knowledge-producing processes of individual and social decision making, without even attempting for its deeper understanding.
>
> The very triviality of this 'paradigm' makes it self-evident and thus beyond criticism. *Define a set (given, closed and/or convex) of fixed, well-defined alternatives, assign a number to each of its components according to a more or less complex (utility, preference) function or rule, then search (algorithmically) and identify the alternative(s) receiving the largest number.*
>
> Label this mechanism and search routine Decision Making and its perpetrator as The Decision Maker (DM). Base most of your economic, financial and psychological theories on this remarkable insight into the 'nature of things.'

In full agreement with the above statement, we believe that the major pitfall of traditional approaches to MCDM and MCDSS lies in the assumption that human decision making processes can be reduced to mere "problem solving" routines, whereas "problems" are perceived as *objective realities* which can be modeled by the skilled analyst and "solved" by applying or developing formal techniques reproducing/simulating what has been idealized as *rational behavior*.
In addition, we noted that the criticism applied to traditional MCDM approaches - although generating interesting "philosophical" discussions - has been almost never accompanied by new, constructive perspectives in form of concrete alternatives for approaching and supporting multicriteria decision making.

By briefly discussing the conceptual basis ("Weltanschauung") and the design principles underlying the development of a new system called *Triple C*, this paper aims at demonstrating that such a concrete alternative exists and that it effectively leads to a different type of DSSs.

Furthermore, it should be noted that the application of the principles discussed in the following sections is not limited to the MCDM domain but can be successfully employed in other contexts for supporting human decision making through interactive computer-based systems, as reported by Angehrn [1991a] and Angehrn and Lüthi [1990].

The remainder of the paper is structured into three sections presenting our approach through a discussion of the three concepts contained in the acronym DSS, i.e. :

- The adoption of an alternative perspective to *Decision* making (section 2),
- The related, alternative way of delivering *Support* (section 3), and
- The different characteristics of the resulting *Systems* (section 4).

In section 5, the framework described in this paper will be illustrated by a concrete example: The visual interactive MCDSS *Triple C.*

2. Learning vs. Solving: Towards alternative Decision Making Models

As discussed in the previous section, one of the main problems with the traditional approach to support human decision making is the neglecting of the "human", or cognitive aspects. Aiming at being as "scientific" as possible (cf. concepts such as *objectivity*, *rationality* and *optimality*), the traditional perspective tends to reduce the influence of human components such as subjectivity and creativity, and it approaches decision making processes as if they were identical to technical problem solving processes.

Usually, a first phase of problem identification is supposed to be followed by a deduction step in which the decision situation is reduced to a formal problem and then solved. This mainly sequential process is illustrated in Figure 1 together with the classical, widely referenced "Intelligence-Design-Choice" model proposed by Simon [1960].

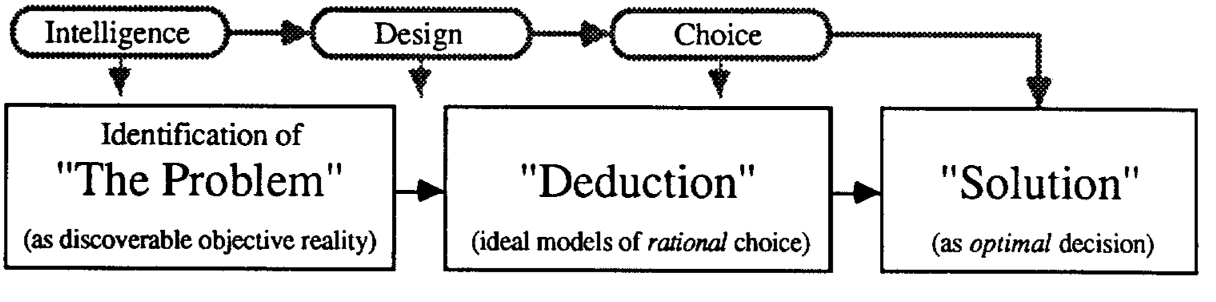

Figure 1: The traditional "solving" perspective

A similar approach is also generally adopted in the MCDSS field. First, decision makers are asked to express their preference structure in different forms, e.g. by weighting different criteria, by specifying a holistic ranking of a subset of alternatives or by answering a structured set of questions. This information serves then as an input to the model(s) which have been developed and a-priori embedded into the MCDSS and whose output will generally deliver an "optimal" ranking of the available alternatives, i.e. the "best" decision to take.

The main dimensions in which the perspective adopted in our work differs from the one described previously are:

(1) Decision situations are not viewed as *problems* (which can be objectively formulated and solved) but as *processes* (which start from a subjective perception of an unsatisfactory real-world condition).

(2) Decision making is not interpreted in terms of a procedure for deducing the *best solution*, but as a continually evolving, individual *learning* process (cf. the seminal work of Scott Morton [1971] on the impact that Management Decision Systems have on the manager's problem-solving process, Checkland's [1985] work on System Thinking, as well as the attempt of Courbon [1984] to relate decision making processes to Piaget's theories of learning).

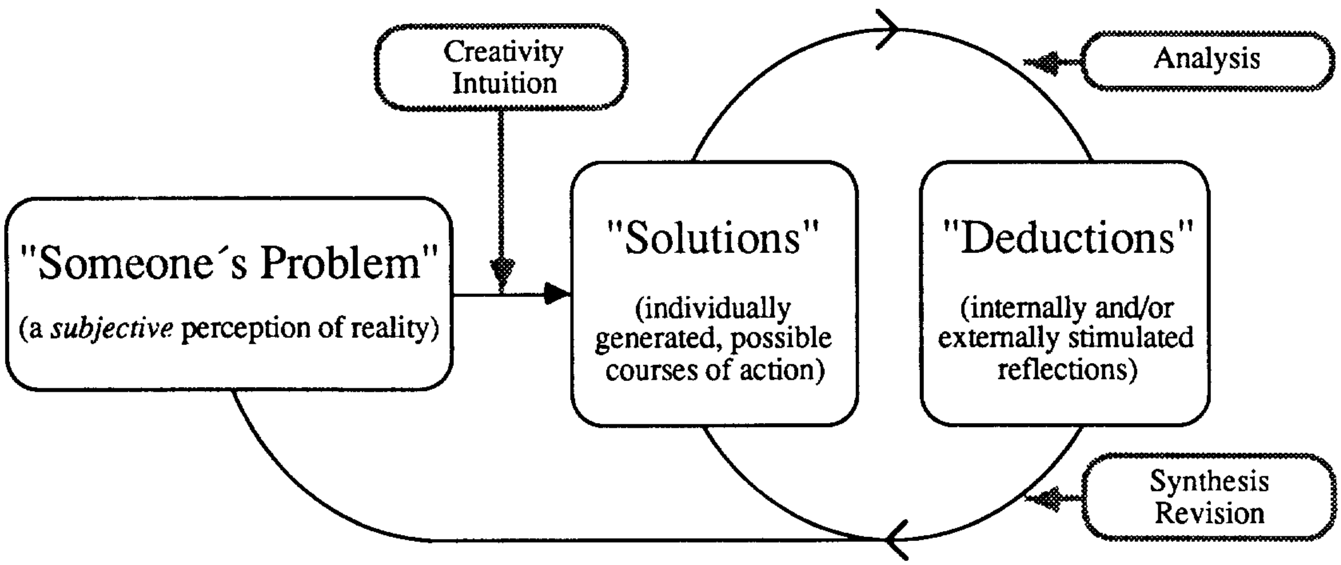

Figure 2: The alternative "learning" perspective

Accordingly, the model depicted in Figure 2 offers an alternative to the traditional one (cf. Figure 1). In this model the key elements - as opposed to the three classical phases "intelligence", "design" and "choice" - are

(a) *Creativity* and *Intuition,*

i.e. the human capabilities of formulating possible courses of action even in the absence of a well-structured, clearly and completely formulated problem statement, or - in other words - the ability to generate "solutions" starting from still vague perceptions.

(b) A *learning* cycle driven by

- *analytical* steps, in which human reflection or alternatively the need for communicating/ justifying their own choices stimulates decision makers in continuously questioning their own judgment and solutions, developing and exploring arguments for or against.

- *synthetical* steps, in which the new insights gained during the analytical phase serve for formulating new solutions and/or reinforcing existing ones. These steps can even lead to a revision of previous perceptions and to a new or more precise "problem" formulation.

3. An alternative approach to delivering "Support"

The two different perspectives described in section 2 lead to different interpretations of how a decision making process should be supported by computer-based instruments (as well as in more general terms).

According to the first, traditional perspective, supporting a decision process mainly consists in delivering to a decision maker a set of good problem solving techniques (efficient mathematical methods, fast information retrieval techniques, inference mechanisms etc.). This tendency can be observed in the majority of today's DSS (and MCDSS). In spite of the often repeated but seldom applied original paradigms *-user first-technology second, support rather than replace, deal with unstructured tasks,* etc. - these systems still remain strongly technology-driven, as attested by the still current use of terms such as "data-oriented" and "model-oriented" [Alter 1977] for classifying different DSS types.

The "learning" perspective proposed in section 2 asks for a different kind of support which will be discussed here in the specific MCDM context. In supporting incremental processes as the one displayed in Figure 2, "solving" techniques only play a secondary role. The primary support component consists in helping decision makers to progressively gain insights into the situation they are faced with by providing different tools enabling them:

(1) to *understand* better the decision situation at hand by expressing and analyzing their *own* preference structures, testing different alternatives and comparing them interactively,

(2) to *question* and *verify* their *individual* judgement by performing different types of sensitivity analysis, and

(3) to *justify* their *subjective* choices and *communicate* them easily - a crucial factor in group decisions.

As a result, a MCDSS should primarily have the characteristics of *a flexible environment in which individual learning about a decision situation can take place.*

This implies that - independently from specific, predefined solving or information processing techniques - these systems provide:

(a) a set of structured means supporting users in flexibly *modeling* their own views of the decision situation at hand (cf. [Geoffrion 1987,1989; Jones 1989], as well as the concept of "modeling primitives" in Angehrn and Lüthi [1990]),

(b) the flexibility to access different information processing techniques according to their own cognitive style in order to refine their views in an incremental process and to develop individual strategies in exploring and generating decision alternatives (cf. the concept of "Modeling by Example" described in Angehrn [1991a]).

In summary, the two main roles (or support dimensions) a (MC)DSS should play in order to support an evolutive decision making process are (Figure 3):

(1) A *Facilitator* role,

i.e. the system should supply tools enabling decision makers to easily *express/represent* their views and ideas interactively using different available information sources.

(2) A *Stimulator* role,

i.e. the system should supply a dynamic environment which enables decision makers to continuously *process* the information at hand and which stimulates an incremental reviewing / learning process.

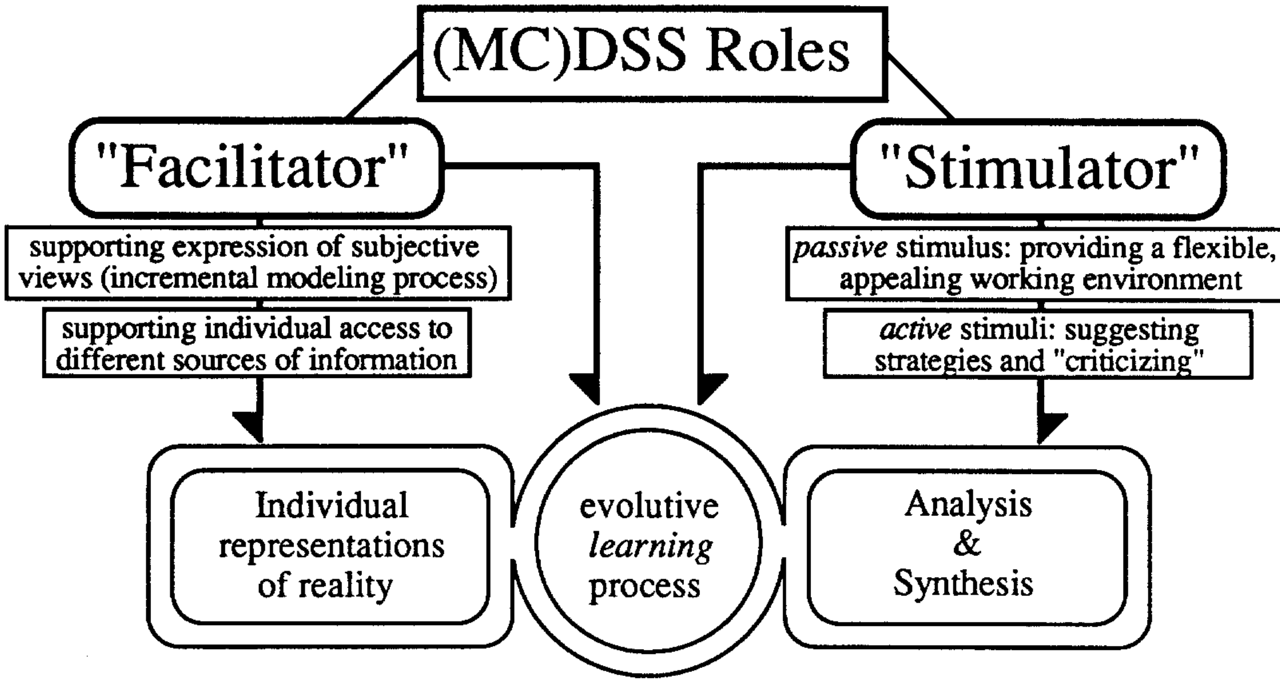

Figure 3: DSS support dimensions

4. Guidelines for "System" design

The two different perspectives described in section 2 not only influence the kind of "support" to be given to a decision maker, but also the methodology followed in designing and developing computer-based systems for this purpose.

The design methodology adopted in the traditional "solving" perspective is generally focussed on pre-determining the functionality (models, mathematical or rule-based methods, and data) which is presumably needed for solving a specific problem. Although disguised by so-called *user-friendly* interfaces, the kernel of the resulting systems consists in one or more specific problem-solving techniques (e.g. a combination of linear programming and database access).

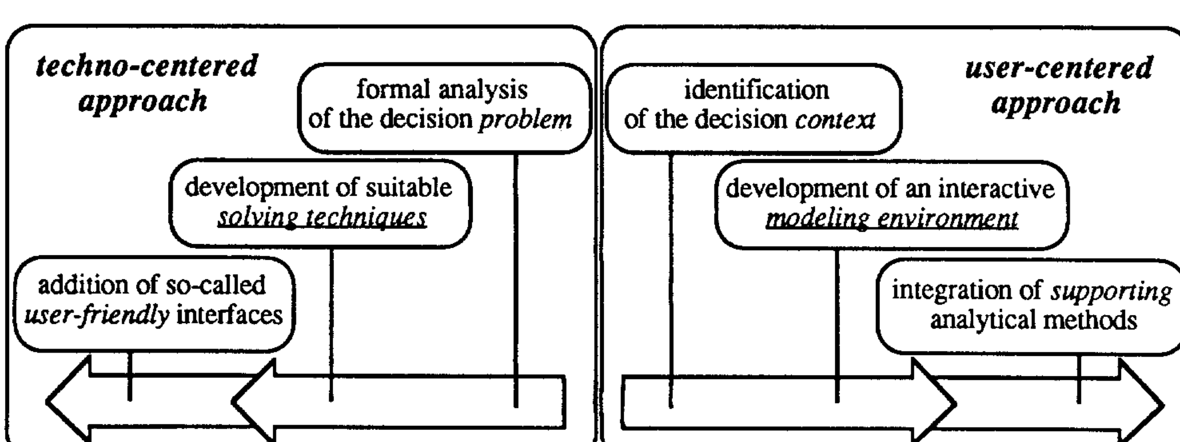

Figure 4: Techno-centered vs. user-centered DSS design

As illustrated in Figure 4 [Angehrn and Lüthi 1990], adopting the alternative "learning" perspective of decision support requires a different - *user-centered* rather than *techno-centered* - design approach. The methodology sketched on the right-hand side of Figure 4 differs from the traditional one in that it aims primarily at giving back to the decision maker two main degrees of freedom (flexibility dimensions):

(i) The flexibility to *express* dynamically his/her own problem perception;

(ii) The flexibility to incrementally *process* the available information - and explore solution alternatives - following his/her individual strategy (Note that this strategy could also consist in justifying a preconceived solution rather than in trying to identify new ones).

For attaining these goals, system design can no longer be driven by the traditional questions "What is the problem?" and "Which are the most efficient techniques for solving it?", but rather by the questions "Which are the tools a decision maker needs in the dynamic process of expressing and exploring a particular class of problems?" (the facilitator component), and "Through which techniques can he/she be supported and stimulated along this process?" (the stimulator component). The kind of systems resulting from this design approach and the new role that classical analytical techniques assume in this different framework are illustrated in the next section through a DSS supporting multicriteria decision making.

5. Putting Theory into Practice: The *Triple C* system

Triple C is a visual interactive system supporting multicriteria decision making processes. Based on the conceptual framework described in section 2 (individual learning vs. generic problem solving), *Triple* C aims at delivering the type of decision support illustrated in section 3 by facilitating and stimulating incremental problem structuring, individual exploration of the space of alternatives and easy communication/justification of the results of a decision making process.

According to the guidelines illustrated in section 4, the first step in system design consists in identifying a set of basic information processing activities which are performed by decision makers in the context of multicriteria decision making. An overview of these highly related activities (*potential scope of action* supported by the system) is represented in Figure 5.

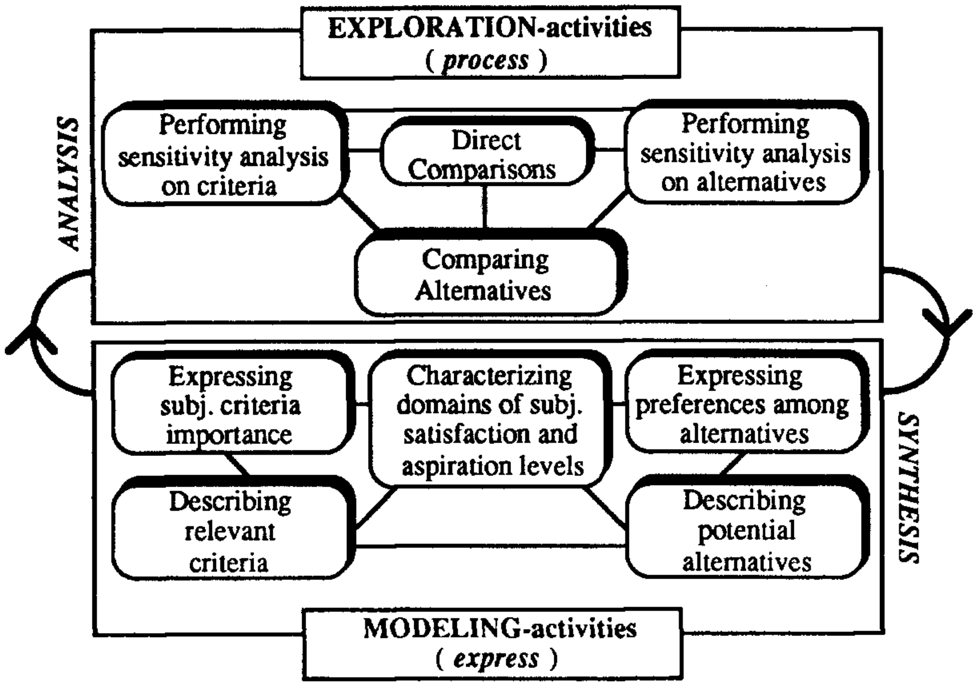

Figure 5: Main information processing activities

In the second step the focus lies on the design of an interactive environment supporting the decision maker in flexibly performing the activities identified in the previous step. A crucial element in this phase consists in taking into account the cognitive aspects of human information processing as well as existing/accepted ways of performing the task, trying to recreate on the screen a context matching as much as possible the mental models of the decision maker (cf. [Winograd and Flores 1986; Norman and Draper 1986] and note the difference between *user-centered* system design and the widely used, but superficial concept of *user-friendliness*).

Designing the *facilitator* component

In the concrete case of the *Triple C* system, this second step was guided by the experimental objective to design a purely *visual interactive* modeling environment in which human-computer communication takes place through a *visual* language [Chang 1986]. Although a detailed discussion of this specific topic goes beyond the scope of this paper, the choice of using Visual Interaction (VI) is shortly motivated in the following paragraphs.

Even if sufficient empirical evidence for definitively proving the effectiveness of computer graphics is still lacked [Jarvenpaa 1989; Benbasat and Dexter 1985; DeSanctis 1984], VI has been recognized in the DSS field as a powerful concept for supporting decision makers in modeling their problems and gradually gaining insights into poorly structured problems [Turban 1989; Angehrn and Lüthi 1990; Bell et al. 1984; Belton and Vickers 1990]. This is primarily due to the two foolowing facts:

(i) Visual Interaction adds a *concrete dimension* to information.
Associating symbolic, visual representations to data and data processing mechanisms supports decision makers (and human beings generally) in describing, analyzing and explaining data sets and complex concepts in a concrete way.

(ii) Visual Interaction relies on a *familiar mental model.*
VI enables human-computer communication to take place following the well-known rules of physical interaction with real-world objects and hence contributes in giving to the user a feeling of directness (c.f. the concepts of *direct manipulation* and *wysiwyg* in [Shneiderman 1987] and the concept of *transparency* in [Norman and Draper 1986]).

In the *Triple* C system there are two distinct levels at which VI contributes in order to *facilitate* individual modeling. At a first level, the adoption of a generic *desktop metaphor* [Smith et al. 1982] enables the user to dynamically manipulate and organize different information sources on the screen as if they were physical objects lying on his or her desk (sheets of paper, folders, graphics, etc.). At a second level, different task-specific visual representations based on the so-called *Triple* C (Circular Criteria Comparison) *model* have been designed in order to encourage the user to express and incrementally explore the components of a multicriteria decision.

Figure 6 illustrates two of these visual aids. The concrete example refers to the application of *Triple C* to a recruitment problem in which various candidates are scanned by a decision maker who attaches importance to criteria such as experience, salary expectation, a test score, the subjective evaluation of a personal meeting (interview), etc.

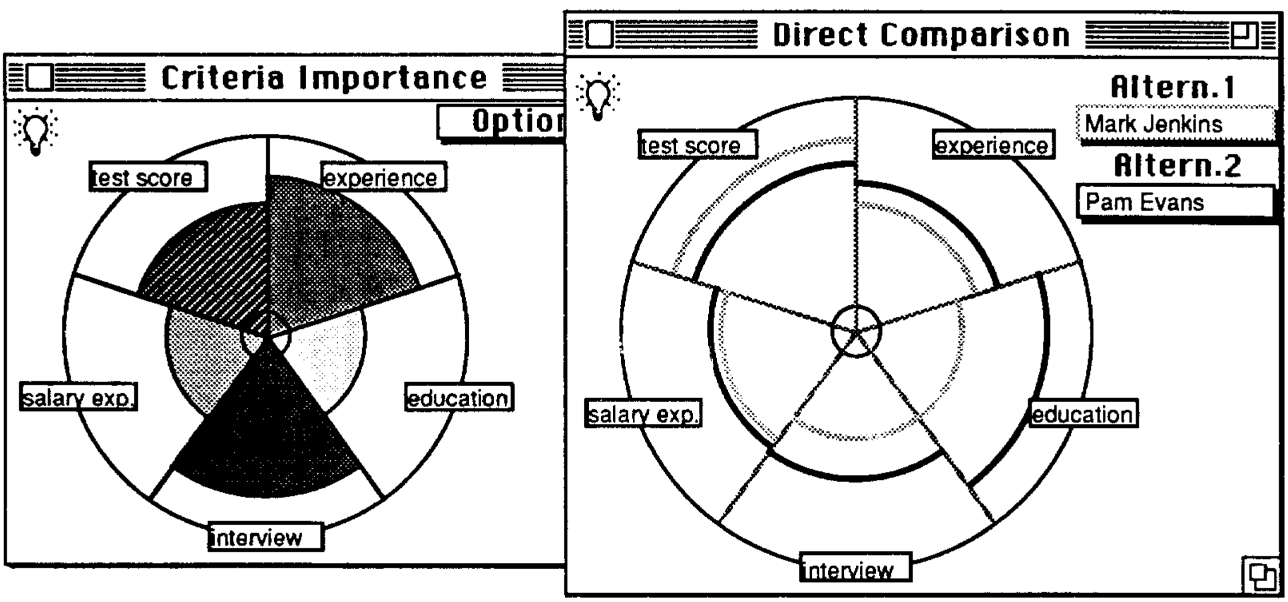

Figure 6: Example of Visual Tools in Triple C

The two visual tools displayed in Figure 6 specifically support the decision maker in dynamically defining and monitoring relevant criteria, assigning weights to them and visually comparing different alternatives (in this case: candidates). In *Triple C*, criteria are represented as sectors of a circle. The size of each sector visually indicates the importance of a criterion in respect to the others. By interactively modifying the sectors' size (radius), decision makers can easily adapt the criteria's importance to their own subjective view, creating a visual "map" of their preference structure.

Aiming at facilitating problem specification and exploration rather than constraining decision makers with predefined, fixed structures, the system supplies a variety of other tools which can be flexibly used for expressing and analyzing the different components of a decision situation [Angehrn 1991b]. For instance, decision makers might decide to specify *feasibility intervals* and/or *ideal values* for each criterion. According to the decision maker's point of view, a candidate in the example above could be considered as *feasible* only if he or she fulfils specific characteristics such as a work experience of at least 2 years, a salary expectation between $60,000 and $80,000, and several other conditions which can be associated with each single criterion. On the other hand, *ideal values* allows the decision maker to specify - and visualize - the *profile* of an ideal candidate - for instance, one with 4 years experience, a high test score, a salary expectation of $75,000, etc. - and to visually compare it with the profiles of the available candidates (e.g. using the tool displayed in the right-hand side of Figure 6).

By providing a visual dimension to all the data and subjective parameters involved in the decision situation, the numerous *Triple C* tools make information easier to express, to handle, to interpret and to communicate in a group (cf. the concept of "wysiwis" - What You See Is What I See - as an approach for supporting computer-based collaborative work [Stefik et al. 1987]).

Designing the *stimulator* component

The *stimulator* component of a DSS differs from the *facilitator* component in two main dimensions: its objective and the nature of the tools employed for its realization within a DSS.
With respect to their objectives, the difference between the two components can be described in terms of *enabling* (passively facilitating) versus *enhancing* (actively stimulating) a learning process. The first objective is attained by setting up a non-restrictive environment in which decision makers can explicitly model their individual perceptions and explore them using deductive logics (focussing on *problems looking for solutions*) or adopting a more inductive strategy (focussing on *solutions looking for problems* and *justifications*). On the other hand, the design of the *stimulator* component requires the identification of tools

which *actively* enhance the decision makers' understanding of the modeled situation preventing interruptions in the learning process (cf. the analysis-synthesis cycle of Figure 3) due to a premature feeling of satisfaction.

In more concrete terms, the design of the ***stimulator*** component of a DSS consists in extending the modeling environment with a set of dynamic tools (agents) whose main role is to provide relevant information the decision maker would or could not generate and consider otherwise.
This redimensioned, but nevertheless crucial function offers a different perspective for integrating the traditional (normative) approaches to decision making and their related problem-solving techniques into the "learning"-oriented DSS framework described in the first sections of this paper.

First (conceptual argument), rather than playing a prescriptive role - substituting and replacing human judgment - such methodologies and techniques would unequivocally fulfil their original function within a DSS, i.e. support and stimulate individual learning (cf. the concept of "rational myths" in [Hatchuel and Molet 1986; Landry et al. 1985]).
Second (technical argument), an approach in which normative support elements are confined to the last stage of the design process (see Figure 4) and are embedded in an independent system module (the *stimulator* component) prevents system designer from developing *techno-centered* instead of *user-centered,* humanized systems.

One of the main tools embedded in the stimulator component of the *Triple C* system is illustrated in Figure 7.

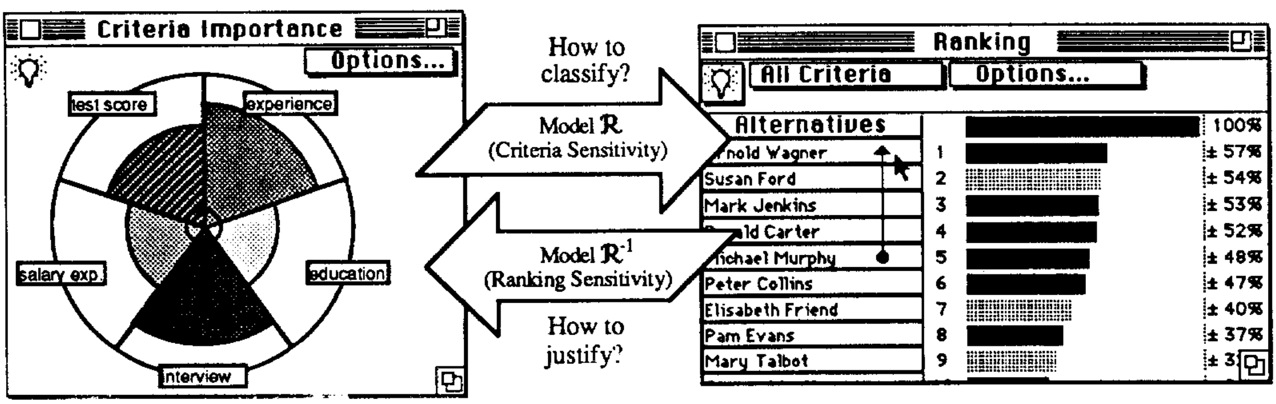

Figure 7: Rankings: A Visual Stimulation Component in Triple C

Every time the decision maker modifies the set of alternatives, the criteria, their weights or one of the other components of the modeled problem, the system automatically displays a ranking of the alternatives based on the weighted-additive model $\mathfrak{R}$ described below. The main function of these system-suggested rankings is not to indicate *optimal* solutions, but to allow the user to make a sensitivity analysis using the mathematical model $\mathcal{R}$ as an "ideal" reference.

The perception of the ranking tool as a dynamic reference point rather than as an *oracle* generating optimal solutions has been strengthened in *Triple C* by the addition of a second mechanism supporting the inverse operation: Instead of changing, for instance, the weight of a criterion and observing the immediate consequences on the system-suggested ranking, the decision maker can quite as easily modify the displayed ranking (by shifting alternatives from one position to another) and adapt it to his or her subjective perception. In this case, a second mathematical model (called $\mathcal{R}^{-1}$ in Figure 7) intervenes in the process and automatically proposes and visualizes on the screen a new, appropriate set of criteria weights reflecting (and hence supporting a *justification* of) the ranking determined by the decision maker.

In order to seek of a more detailed description of the stimulator component described above, let us mention that the model R used for deriving the system-suggested ranking is based on the computation of a classical, wheighted-additive *loss* function $\mathcal{L}$ defined on the alternatives a_i (i=1,..,m). This function takes into consideration the weights w_j of the n user-defined criteria , the n magnitudes $|S_j| = |\max\{y \mid y \in S_j\} - \min\{y \mid y \in S_j\}|$, (j=1..n) of their *feasibility intervals* (see an example in the last section), the attribute values x_{ij} for every alternative a_i and criterion j, and the *ideal values* x_j^* for each single criterion (such values exist whenever they have been explicitly indicated by the user or can be derived from preferences such as "the criterion *test score* should be as high as possible").

$$\mathcal{L}(a_i) = \sum_{j=1}^{n} w_j \ell_{ij}; \qquad \ell_{ij} = \begin{cases} \dfrac{|x_{ij} - x_j^*|}{|S_j|} & \text{if } \exists x_j^* \\ 0 & \text{otherwise} \end{cases}$$

On the other hand, the inverse mechanism, $\mathcal{R}^{-1}$ is computed interactively by solving the quadratic optimization model :

$$\left| \begin{array}{lll} \text{Minimize} & \sum_{j=1}^{n} (w_j^* - w_j)^2 & \\ \text{Subject to} & \sum_{j=1}^{n} a_{ij} w_j^* \le b_i & i = 1..m \\ & w_j^* \ge 0 & j = 1..n \end{array} \right|$$

in which the *distance* between the previous weights w_j and the new weights w_j^* is minimized under m-1 linear constraints reflecting the new ranking and the additional constraint $\sum_{j=1}^{n} w_j^* = 1$.

(6) Conclusions

Adopting an alternative perspective when considering the three key concepts *Decision, Support* and *System* leads to the design of a different kind of DSS, the paramount characteristics of which are:

(i) the high level of human-computer interaction achieved during the decision making process (cf. the concepts of *symbiotic systems* and *conviviality* in Illich [1973] and Fischer [1987]), and

(ii) their explicit objective to help users to *understand* and *communicate* better their decisions rather than to *solve* them.

Such humanized DSS have been defined here primarily as flexible environments in which individual learning about a decision situation can take place. A framework underlying their design process and a system architecture consisting of two basic parts - a facilitator and a stimulator component - have been proposed and illustrated in the specific context of supporting multiple criteria decision making.

Thinking in terms of learning-related concepts such as facilitation and stimulus (rather than in terms of technical components such as data, models or knowledge processing tools) has been recognized as a first step towards the design of humanized DSS. Furthermore, the learning-oriented approach discussed in this paper indicates broad areas for further research. On the one hand, designing effective facilitator components emphasizes the importance of human-computer interaction studies for the DSS field. On the other hand, the concept of a stimulator component provides an alternative design framework for integrating Management Science or Artificial Intelligence techniques in DSS without overlooking that decisions are always "someone's decisions".

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91/02 TM/SM	Luk VAN WASSENHOVE, Leonard FORTUIN and Paul VAN BEEK	"Operational Research and Environment," January 1991
91/03 FIN	Pekka HIETALA and Timo LÖYTTYNIEMI	"An Implicit Dividend Increase in Rights Issues: Theory and Evidence," January 1991
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