On the concept of decision aiding process

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Abstract

The paper presents the concept of decision aiding process as an extension of the decision process. The aim of the paper is to analyse the type of activities occurring between a "client" and an "analyst" both engaged in a decision process. The decision aiding process is analysed both under a cognitive point of view and an operational point of view: i.e. considering the "products", or cognitive artifacts the process will deliver at the end. Finally the decision aiding process is considered as a reasoning process for which the update and revision problems hold.

1 Introduction

Decision aiding is an activity occurring in the every day life of almost everybody. We all have concerns for which we have to make decisions and it is very often the case that we will ask for help in order to do so: a good friend, a lawyer, a physician, a psychotherapist, a counselor, a social worker, an expert in "something", an Operational Research consultant, are the typical persons from whom we may seek advice before making up our mind and act in some way.

However, what I am interested to is not any type of decision aiding activity. Not all decision aiding activities have been the object of scientific investigation and among the ones for which it has been the case not all of them are founded on the use of an abstract and formal model. With this term I mean the use, for decision aiding purposes, of an abstract and formal language:
- abstract because independent from the specific domain for which the decision aiding has been asked;
- formal because aimed at reducing the ambiguity inherent to human communication ([113]).

I would like to emphasise that my point of view is a choice. Other types of decision aiding exist and several among them are objects of scientific investigation (as it is the case with psychotherapy, [19]), but none of them uses formal and abstract languages. Lawyers or psychotherapists do use the ambiguity of human language in order to take full advantage of its effectiveness. For certain types of psychotherapy ([48], [49]) human language is THE vehicle of the therapy and this thanks to the multiple meanings and interpretations allowed by human ambiguous communication. My choice concerns the case where a formal and abstract language is used. From hereafter when I use the term decision aiding it will always refer to such a choice.

My first claim therefore will be that doing decision aiding is a choice (and not a natural situation). As such, both the person who asks for such a decision aiding and the one who provides it should be able to justify why this type of decision aiding and not another one is necessary. Not all decision situations fit to such an approach. Indeed the literature (see for instance [100]) is full of industrial, military, commercial, regional planning, health care, network management etc. applications, but none, to my knowledge, ever suggested to use such an approach for wedding, divorcing, drug addiction or leisure purposes.

The paper is organised as follows. In section 2, I try to clarify the concept of decision process, claiming that in the literature this is usually considered to be the decision making process (mainly of an individual). For this purpose I will try to show the differences between decision making process and decision aiding process. In order to do so I will introduce a rough classification of "decision aiding approaches" leading to the existence of different "decision theories" (for more details see [100]). In section 3, I will go through more details as far as the decision aiding process is concerned, outlining a model of such a process based on its "outcomes" (cognitive artifacts of the process). For this purpose I will adopt a more operational point of view. In section 4, I will try to show how such an analysis of the process can be useful, mainly when the conduction of the process leads to revisions and updates. The different claims done in this paper will be summarised and discussed in the conclusive section.

2 The Decision Process

The concept of decision process is essentially due to Simon [92]. It mainly concerns the cognitive activities of an individual (hereafter identified as "decision maker") facing a question for which no automatic reply pattern is available. Most of the literature around this concept is based on the hypothesis that such cognitive activities are scientifically observable (either empirically or in experimental settings) and that "patterns" of "decision behaviour" can be established (see [42], [65], [64], [98], [40], [105], [93], [94]). The use of this concept in decision theory introduced two major innovations:
- rationality is expected to refer to the process and not to the final decision; coherence is expected along the process, but such a coherence is not necessarily economically rational;
- rationality is bounded in time, space and the cognitive capacity of the decision maker, therefore it is subjectively defined and only locally valid.

Later on, the concept of decision process has been associated to organisational studies and more precisely to the study of how organisations and other collective bodies face decision situations. Although the first idea was a simple extension of the model suggested by Simon (intelligence, design and choice) to an organisational level, it soon appeared that such an approach could not account for the complexity of organisational decision making (see [63], [73], [74], [76], [75], [59], [58], [9], [23], [78]).

The observation of organisational decision processes leads to at least the following remarks:
- multiple rationalities coexist within organisational decision processes that can be associated to different individuals and/or organisations;
- such different rationalities rarely aggregate to a unique rationality characterising a process; an organised collection (a system) of rational individuals does not necessarily constitutes a rational entity.

In the following I will propose a descriptive model of a decision process. Such a model is going to be used in order to understand the differences between the concept of "decision process" and the one of "decision aiding process". Actually I will try to show that a decision aiding process is a particular type of decision process.

2.1 A descriptive model of the decision process

In the following I will make extensive use of a descriptive model of decision process introduced in [78]. This model was originally aimed at describing inter-organisational decision processes, but is sufficiently general to be used in more abstract contexts.

A decision process is characterised by the appearance of an "interaction space", an informal abstract space where actors introduce and share a set of concerns (named "objects"). The awareness of the existence of such an interaction space is due to the existence of a "meta-object" (a concern which only exists in order to allow the actors to justify their presence in the interactions space projecting their concerns on such a meta-object).

Example 2.1 *"The procurement policy issue" within a company is a meta-object where different actors (the acquisition department, the financial management, the technical division etc.) project their concerns which could be: "improve the selection of suppliers", "decrease procurement costs", "improve quality of procurement" etc.. The existence of this meta-object identifies a decision process, within the company, which could be named "establish a procurement policy".*

In other terms, what is usually considered to be the "problem" for which a "decision" is expected (thus initiating a decision process), quite often is a "label" used by different actors in order to carry within the process their own concerns, hoping this will be useful to handle them.

Under such a perspective a temporal instance of a decision process (a state of the process) is characterised by: the participating actors, their concerns (the objects) and the resources committed by each actor on each object. Different levels of commitment and more or less actors interested to the same object characterises the structure of such a temporal instance anticipating the dynamics under which such a state has been reached. In [78], the following characteristic states were suggested:

- controlled expansion (new actors and their concerns enter the interaction space under the control of one or more key actors able to accept or to refuse access);
- uncontrolled expansion (new actors and their concerns enter the interaction space, but nobody is able to control the access);

- controlled reduction (actors and concerns which were present in the interaction space are expelled due to the action of one or more key actors);
- stalemate (the interaction space is unable to evolve and to handle the actors concerns);
- dissolution (the interaction space is dissolved);
- institutionalisation (the interaction space becomes an "institution", a new organisation with a precise description of means and rules);

in order to show the different directions in which the state of the process can evolve. For more details the reader can see [78]. Recognising the present state and fixing a desired state to reach can help in understanding the strategy to follow within the decision process.

However, what I am interested to is decision aiding. Under such a perspective the introduction of the above model of the decision process is functional to the purpose to describe the decision aiding process. Intuitively, in decision aiding we also take decisions (what, why and how to model and support). *Decision aiding is also a decision process. However, of a particular nature*.

My claim is that in decision aiding situations appears an interaction space (for at least two actors: the client and the analyst) characterised by a meta-object which is the "consensual construction of a client's concern representation". Such a construction is based on the methodological knowledge and the technical skills of the analyst as well as the domain knowledge of the client. Such an hypothesis implies that the two actors engage in a decision process, that is the decision aiding process is a special type of decision process.

2.2 Decision Making and Decision Aiding

The difference between these two concepts has already been discussed by Roy in [85] (see also [16],[17]), although Roy considers these as two different approaches and not as different situations as I will do. In a decision making context the situation concerns a decision maker who, having a concern, might use a decision theoretic tool in order to establish potential actions to undertake (although in more general terms decision making can be decision theoretic free). In such a setting decision theory is directly used by the decision maker and if there is an analyst, his presence is justified either for tutorial purposes or because he is a "clone" of the decision maker. Theoretically there is no distinction between these two actors. It should also be clear that in such a setting we consider the decision maker as endowed with decision power and therefore also responsible for the decision to make.

On the other hand a decision aiding context implies the existence of at least two distinct actors: the client and the analyst, both playing different "roles" with respect to the concern of the client. More actors may exist in such a setting, the client not necessarily being a decision maker (he might not have decision power and be for instance himself analyst for another client). For simplicity, I shall only consider the simpler setting with only these two actors present and use indifferently the concepts of decision maker and client.

A decision aiding context only makes sense with respect to one or more decision processes, the ones where the client's concerns originate. In this paper I will focus on the set of activities occurring within such a setting. I will call such a set of activities a "decision aiding process". The ultimate objective of this process is to arrive to a consensus between the client and the analyst. On the one hand the client has a domain knowledge concerning the decision process. On the other hand the analyst has a methodological knowledge, that is domain independent. The task can be summarised to be: given the client's domain knowledge and the analyst's methodological knowledge (and the associated formal and abstract language), interpret the client's concerns and knowledge so that he can improve his perceived position with respect to the reference decision process. Such an interpretation ought be "consensual": the client should consider it as his own interpretation, while the analyst should consider it correct and meaningful. However, the coherence sought by the actors does not refer to a given situation, information or knowledge, but to the cognitive artifacts they produce when working together. From this point of view the decision aiding process is an autopoietic system (a self reference system which maintains constant its organisation, but not a closed system since the environment is part of the system's organisation, see [61]).

Using a stakeholder approach [5] decision aiding sees the emergence of a new stakeholder in the decision process, that is the pair "client-analyst". The decision aiding process represents the cognitive efforts undertaken by this pair in order to "positively" influence the decision process in which they are involved.

Example 2.2 *Consider again the "procurement policy" example. If decision aiding is requested by any of the participating actors, this will concern "an object" among the possible ones evoked by the decision process (and its meta-object: "the procurement policy issue").*

Providing some decision aiding in this context raises questions of the type:

- *who is the client and why he do need a support?*
- *what are exactly the issues concerning the client and why (money, authority, time, knowledge, power etc.)?*
- *how can we formulate such issues in a decision support language, in terms of a decision problem (do we have to convince, to justify, to choose, to analyse etc.)?*

- *what type of decision support are we expected to deliver (which alternatives, any uncertainty, several scenarios etc.)?*
- *what will be effectively done (negotiate with the other actors, impose a precise policy, expand the interaction space etc.)?*

In a decision aiding process the answers to the above questions are not unique and have to be provided by both the client and the analyst who are now perceived as a unique stakeholder within the process. However, decision aiding can be provided following different approaches, which I will briefly survey in the following section.

2.3 Decision Aiding approaches

In the literature [6, 13, 34, 45, 86, 88, 28] on decision theory and decision aiding we can find reference to four types of possible approaches (although some authors omit the last one or two): normative, descriptive, prescriptive and constructive. I next clarify what I mean by each of these terms, noting that different authors may attach different meanings to the same words.

We are concerned here with decision aiding based on formal models of the client's preferences and values. The preference models, which are going to be used to draw answers to the decision problem, contain therefore a model of rationality. The different approaches diverge in the meaning attached to the client's rationality model, the process of obtaining this model, and the interpretation of the answers that are provided to the client based on the model.

- **Normative approaches**

  Normative approaches derive rationality models from norms established a priori. Such norms are postulated as necessary for rational behaviour. Deviations from these norms reflect mistakes or shortcomings of the client who should be aided in learning to decide in a rational way. These models are intended to be universal, in that they should apply to all clients who want to behave rationally. As an analogy, we may consider ethical norms, laws and religious norms. For more details the reader can see the following classics: [32, 33, 109, 56, 82, 89, 112].

- **Descriptive approaches**

  Descriptive approaches derive rationality models from observing how decision makers make decisions. In particular, it may link the way decisions are made with the quality of the outcomes. Such models are general, in that they should apply to a wide range of clients facing similar decision problems. As an analogy, we may consider scientists trying to derive laws from observed phenomena. For more details the reader can see: [2, 40, 41, 42, 64, 65, 81, 98, 101, 102, 110].

- **Prescriptive approaches**

  Prescriptive approaches *discover* rationality models for a given client from his/her answers to preference-related questions. Modelling consists in discovering the model of the person being aided to decide, i.e. unveiling his/her system of values. Therefore, they do not intend to be general, but only to be suitable for the contingent client in a particular context. Indeed the client can be in difficulty trying to reply to the analyst's questions and/or unable to provide a complete description of the problem situation and his/her values. Nevertheless, a prescriptive approach aims to be able to provide an answer fitting at the best the client's information *here and now*. As an analogy, we may consider a physician asking questions to a patient, in order to discover his illness and prescribe a treatment. For more details the reader can see: [8, 44, 54, 86, 103, 104, 106, 115].

- **Constructive approaches**

  Constructive approaches are expected to help a client to *build* his/her own rationality models from his/her answers to preference-related questions. Under such a perspective the analyst only helps the client to construct the model of rationality. The "discussion" between the client and the analyst is not "neutral" in such an approach. Actually such an interaction is part of the decision aiding process since it constructs the representation of the client's problem and anticipates, to some extent, its solution.

  If, while talking on what to do tonight, we ask the question *"where to go this night?"* we implicitly do not consider all options implying staying at home. If we ask *"Who to meet?"* we implicitly do not consider all options involving staying alone.

  Structuring and formulating a problem becomes as important as trying to "solve" it in such an approach. Recent real world applications (see for instance [4, 79, 97]) do emphasise the importance of supporting the whole decision aiding process and not just the construction of the evaluation model.

  Modelling under this approach consists in constructing a model **with** the person being aided to decide, suitable for that contingent client and his/her particular context. As an analogy, we may consider a designer or an engineer tentatively developing a new product together with the client. For details the reader might see: [20, 36, 37, 51, 53, 84, 86, 90, 114].

Quite often the differences among the previously described approaches are summarised through existing decision support methods which are supposed to be "representative" of the approach. For instance methods using expected utility are supposed to be "normative", while decision heuristics are supposed to be descriptive. However, my claim (see also [28]) is that a distinction is misleading. I consider that it is possible to follow a constructive approach and use a combinatorial optimisation procedure, while being normative and use an outranking based MCDM method. What makes the difference among the approaches is how rationality is conceived and not the method used. From a practical point of view the difference concerns the way the decision aiding process is conducted, not the tools used within it.

3 A model of the Decision Aiding Process

I consider the decision aiding process as a distributed cognition process [60, 111]. With such a term I indicate any process where different agents endowed with cognitive capabilities have to share some information and knowledge in order to establish some shared representation of the process object. I call such shared representations *shared cognitive artifacts* (for a broader perspective on similar issues the reader can start with [10]). To understand the concept consider two people observing an abstract painting in an exhibition. If they try to find a shared interpretation of the painting they are engaged in a distributed cognition process aimed at producing a shared cognitive artifact which is the painting interpretation.

Indeed within a decision aiding process there are at least two such "cognitive agents"(the client and the analyst) who share information and knowledge under the perspective of producing a set of shared cognitive artifacts, replying to questions such as:
- who has which problem?
- what could be a solution to that problem?
- why such a solution could be successful?
- etc...

However, my analysis of the decision aiding process will not be cognitive (describe and analyse the mental activities of the involved actors), but operational (how to conduct the process?). Actually, I am not going to analyse how such a distributed cognition occurs and how it works (although analysing how the two agents interact can be extremely interesting). My hypothesis is that since we are looking for formal models of decision support there is a basic agreement between the client and the analyst that they are looking for such a model and that they are going to use a formal representation language (possibly, this may reduce the cognitive effort).

There is no loss of generality with such an hypothesis. If such an agreement does not exist in reality, it is always possible to consider that the analyst will spend some of its time to convince his client of the opportunity to follow a formal approach. Therefore, the operational question we have to make is the following: what are the cognitive artifacts we precisely expect from a decision aiding process?

In other terms I model the decision aiding process through its main products, the ones enabling to obtain "a consensual representation of the client's concern". At the same time we can see such products as the deliverables honouring the contract with the client.

I introduce four cognitive artifacts as products of the decision aiding process (for some applications of these concepts in the practice see: [79],[97])

- a representation of the problem situation;
- a problem formulation;
- an evaluation model;
- a final recommendation.

3.1 The problem situation

A representation of the problem situation is the result of an effort aimed at replying to questions of the type:
- who has a problem?
- why is this a problem?
- who decides on this problem?
- what is the commitment of the client on this problem?
- who is going to pay for the consequences of a decision?
The construction of such an artifact allows, on the one hand, the client to better understand his position within the decision process for which he asked the decision support and, on the other hand, the analyst to better understand his role within this decision process.

From a formal point of view a representation of the problem situation is a triplet:

$$\mathcal{P} \;=\; \langle \mathcal{A}, \mathcal{O}, \mathcal{S} \rangle$$

where:
- $\mathcal{A}$ is the set of participants to the decision process;
- $\mathcal{O}$ is the set of stakes each participant brings within the decision process;

- $\mathcal{S}$ is the set of resources the participants commit on their stakes and the other participants' stakes.

Such a representation is not fixed once for all within the decision aiding process, but usually will evolve. Actually, one of the reasons for which such a representation is constructed is to help clarify the misunderstandings during the client - analyst interaction and therefore improve the communication between these two actors. It can also turn useful when both the two actors have to establish whether their efforts are legitimated with respect to the decision process (see also further on sections 3.5 and 4.1.4).

3.2 The problem formulation

For a given representation of the problem situation the analyst might propose to the client one or more "problem formulations". This is a crucial point of the decision aiding process. The representation of the problem situation has a descriptive (at the best explicative) objective. The construction of the problem formulation introduces what I have called a model of rationality. A problem formulation reduces the reality of the decision process, within which the client is involved, to a formal and abstract problem. The result is that one or more of the client's concerns are transformed into formal problems on which we can apply a method (already existing, adapted from an existing one or created ad-hoc) of the type studied in decision theory.

Example 3.1 *Consider the case of a client having the problem "to buy new buses in order to improve the service offered to its clients". Different problem formulations are possible:*
- choose one among the potential suppliers;
- choose one among the offers received (a supplier may have done more than one offer);
- choose combinations of offers;
The choice of one among the above formulations is not neutral. The first is focussed on the suppliers rather than to the offers and allows to think about the will to establish a more strategic relation with one of them. The second one is a more contingent formulation and introduces the implicit hypothesis that all buses will be bought from the same supplier. The third is also a contingent problem formulation, but considers also the possibility to buy from different suppliers. Obviously choosing one of the above formulations will strongly influence the outcome of the decision aiding process and the final decision.

From a formal point of view a problem formulation is a triplet:

$$\Gamma = \langle \mathbb{A}, V, \Pi \rangle$$

where:
- $\mathbb{A}$: is the set of potential actions the client may undertake within the problem situation as represented in $\mathcal{P}$;
- V: is the set of points of view under which the potential actions are expected to be observed, analysed, evaluated, compared, including different scenarios for the future;
- Π: is the problem statement, the type of application to perform on the set A, an anticipation of what the client expects (the reader can see more details on this point in [3],[76],[88], for a detailed example see [97]).

Obtaining the client's consensus on a problem formulation has, as a consequence, the gain of insight, since instead of having an "ambiguous" description of the problem we have an abstract and formal problem. Several decision aiding approaches will stop here, considering that formulating (and understanding) a problem is equivalent to solve it, thus limiting decision aiding to helping to formulate problems, the solution being a personal issue of the client. Other approaches instead will consider the problem formulation as given. Within a constructive approach the problem formulation is one among the artifacts of the decision aiding process, the one used in order to construct the evaluation model.

3.3 The evaluation model

With this term I indicate what the decision aiding models traditionally are as conceived through any operational research, decision theory or artificial intelligence method. Classic decision theoretic approaches will focus their attention on the construction of this model and consider the problem formulation as given.

An evaluation model is an n-uplet:

$$\mathcal{M} = \langle A, \{D, \mathcal{E}\}, H, \mathcal{U}, \mathcal{R} \rangle$$

where:

- A is the set of alternatives on which the model applies. Formally it establishes the universe of discourse (including the domain) of all relations and functions which are going to be used in order to describe the client's problem.

- D is the set of dimensions (attributes) under which the elements of A are observed, described, measured etc. The set D might be endowed with different structuring properties. Formally D is a set of functions such that each element of A is mapped to a co-domain which we call a "scale".

- $\mathcal{E}$ is the set of scales associated to each element of D. Formally each element of $\mathcal{E}$ is the co-domain of some element within D ($\forall i\ \forall d \in D,\ d_i : A \rightarrow E_i \in \mathcal{E}$).

- H is the set of criteria under which each element of A is evaluated in order to take in account the client's preferences. Formally a criterion is a preference relation, that is a binary relation on A (a subset of $A \times A$) or a function representing the criterion.

- $\mathcal{U}$ is a set of uncertainty structures and/or epistemic states applied on D and/or H. Depending on the language adopted, $\mathcal{U}$ collects all uncertainty distributions or the beliefs expressed by the client which can be associated to the relations and functions applied on A, besides possible scenarios to which uncertainty can be related.

- $\mathcal{R}$ is a set of operators such that the information available on A, through D and H can be synthesised to a more concise evaluation. Formally $\mathcal{R}$ is a set of operators such that it is possible to obtain a global relation and/or function on A, possibly allowing to infer a final recommendation.

The reader can observe that a large part of the existing decision aiding models and methods (see e.g. [8]) can be represented trough the above description (from traditional optimisation procedures to multiple criteria decision making methods and artificial intelligence tools). Besides, such a description allows to draw the attention of the reader to a number of important remarks:
1. It is easy to understand why the differences among the approaches do not depend on the adopted method. The fact that we work with only one evaluation dimension, a single criterion or a combinatorial optimisation algorithm can be the result of applying a constructive approach. What is important is not to choose the method before the problem has been formulated and the evaluation model constructed, but to show that this is the natural consequence of the decision aiding process as conducted up to that moment.
2. The technical choices (typology of the measurement scales, different preference models, different aggregation operators) are not neutral. Even in the case where the client has been able to formulate his problem clearly and he is convinced about it (possibly using one of the techniques aiding in formulating problems), the choice of a certain technique, procedure, operator can have important consequences which are not discussed at the moment where the problem has been formulated (for a critical discussion see [13]). Characterising such techniques, procedures and operators is therefore crucial since it allows to control their applicability to the problem as has been formulated during the decision aiding process.

3. The evaluation models are subject to validation processes, namely (see [52]):
- conceptual validation (verify the suitability of the concepts used);
- logical validation (verify the logical consistency of the model);
- experimental validation (verify the results using experimental data);
- operational validation (verify the implementation and use of the model in everyday life).

3.4 The final recommendation

The final recommendation represents the return to reality for the decision aiding process. Usually the evaluation model will produce a result, let's call it Φ. The final recommendation should translate such a result from the abstract and formal language in which Φ is formulated to the current language of the client and the decision process in which he is involved. Some elements are very important in constructing this artifact:
- the analyst has to be sure that the model is formally correct;
- the client has to be sure that the model represents his preferences, that he understands it and that he should be able to use its conclusions (the client should feel as the "owner"'of the results, besides being satisfied of them);
- the recommendation should be "legitimated" with respect to the decision process for which the decision aiding has been asked ([51]).

We should pay some attention to this last observation. The decision aiding process is an activity which introduces a certain distance between the participants on the one hand and the reality of the decision process and its organisational dimension on the other hand. Returning back to reality requires to check whether the results are legitimated. We should check whether such results are accepted or not by the participants to the decision process and understand the reasons for their position (such reasons can be completely independent from the decision process itself). Being able to put in practice the final recommendation definitely depends on such legitimation. No legitimation means no implementation.

4 How to use the model?

We can distinguish two different ways of using the decision aiding process previously introduced. The first one is basically operational and is mostly oriented to problem structuring and formulation: how to conduct the process in order to obtain useful, robust and meaningful conclusions? The second one concerns an open theoretical and operational problem: how to manage the revision and update of the process partial and/or general conclusions?

4.1 Problem structuring

There is a large literature on problem structuring ([1], [8], [11], [18], [24], [25], [30], [29], [31], [46], [50], [55], [57], [60], [62], [72], [80], [95], [96], [99], [118]). A common characteristic of such a literature is the emphasis on the claim that supporting decisions should not be limited to solving well established decision models, but should help facing more "soft", "ill-structured" decision situations which require to be "structured". The idea is that trying to fit a decision situation to a given decision model may result in solving correctly the wrong problem.

Problem structuring methodologies aim at helping decision makers to better understand their concerns ([84], [50], [20], [53]), better justify and legitimate their conclusions [51] and ease the validation process ([52], [77]).

Several among the problem structuring methodologies consider that decision aiding IS problem structuring (see for instance [20], [84], [35]). In other terms the quantitative aspects on which evaluation models usually rely are considered irrelevant, neglected or not at all considered under the non unrealistic claim that once the decision maker has a definitely clear idea of what the problem is he also knows how to solve it.

Other approaches (see [44], [7], [8]) limit their problem structuring methodology by adopting a precise shape for the evaluation model (using value functions, again under the non unrealistic claim that value functions represent the most common and easier to understand decision support tool). Multi-methodological approaches have also been considered in the literature (see [71], [72], chapter 13 within [84], [4]).

All the above introduced approaches are basically prescriptive in nature. They suggest how an analyst should conduct the interaction with his/her client in order to lead him (the client) to a reasonably structured representation of his problem. However, they are either based on empirical grounds (we tried it several times and it works) or they represent a consistent theoretical conjecture. In all cases they have never been based on a model of the decision aiding activities, fixing the cognitive artifacts of the process, thus allowing the client and the analyst to control the process in a formal way. The result is that either they have to neglect the evaluation model aspect (ignoring situations when the problem formulated still does not allow to find intuitively dominant solutions or the cognitive biases that affect the decision maker's behaviour) or they have to fix a-priori some of the artifacts (thus limiting the applicability of the approach) or they underestimate the influence that the analyst can have on his client, biasing his behaviour.

The model of the decision aiding process previously suggested aims at filling such a gap. It shows how the decision aiding process gets structured and at the same time it suggests a path for the process concerning both the client and the analyst. Moreover it allows to control the conduction of the process since it fixes the cognitive artifacts that are expected to be constructed during the process. This allows to control the process itself since each such artifact is precisely defined. In the following, I am going to present with more details how such artifacts can be constructed suggesting empirical procedures for conducting of the interaction with the client.

4.1.1 Representing the problem situation

We consider as given the interest of the client to work with the analyst. Such an interest is expected to be due to one or more concerns for which the client seeks advice under his (possibly justifiable) conviction that he is unable to do that alone.

The construction of such a representation begins establishing a list of actors potentially affected by the interaction between the client and the analyst (see also the so-called stakeholders approaches in decision aiding ([5], [27], [91]). "Who else could be concerned by the client's concern?" A particular issue to explore here is whether the client is the (only) "owner" of this particular concern. It is often the case that the client on his turn is involved in a decision aiding process as an analyst or that this concern originates within a particular organisational structure. The advice could be asked:

- for a (a priori or a posteriori) justification purpose;
- in order to understand a problem, in which, however, no immediate action is expected to be undertaken;
- because the client has to report to somebody within the organisational structure.

This leads to the questions: why could the other actors be concerned and what other concerns could they associate to the client's concerns? Intuitively we trace a map associating actors to concerns. Two questions arise at this point:

- are there any links among the concerns?
- how important are such concerns for the different actors?

In order to reply to the first question, we can make use of a relation of "projection" (see [78]) showing how a concern projects onto another one (usually from simple very specific concerns to more general and abstract ones). Usually such a relation results in a tree the leaves of which represent the simple (not further "decomposable") concerns and the root represents the meta-object characterising the decision process for which the decision aiding has been requested.

Example 4.1 *Imagine an artificial lake, created due to a dam constructed in order to build an hydroelectric power station, used also for recreational activities (fishing, sailing etc.). The concern of "fish availability" (associated to the local fishermen) as well as the concern of "hydrogeological stability" (associated to* *the local electricity company) both project onto the concern "lake management" (associated to the local authority: the local province).*

In order to reply to the second question, we can associate to each object the resources committed to or requested by each actor for each of his concerns. The client's commitment in particular is a key issue for two reasons:
- it will influence the contents of the problem formulation and the evaluation model;
- it will play a particular role as far as the timing of the decision aiding process is concerned.

4.1.2 Formulating a problem

As already introduced, formulating a problem is the first effort to translate the client's concern in a formal problem. The first question to ask here is: "what are we going to decide about"? We might call this a set of potential decisions. What is important to establish with sufficient clarity at this stage is what the set $\mathbb{A}$ do represent (for instance: suppliers or bids or combinations of bids etc.) and how (are they quantities, alternatives, combination of actions etc.).

Where do such information come from? A source is of course the client who might be able to provide directly at least part of the set $\mathbb{A}$ (for the cognitive problems associated to this activity see [70]). The actors and their concerns as identified in the problem situation representation can also be sources. However, quite often, the elements of the set $\mathbb{A}$ have to be "designed" (see [38]), in the sense that such a set does not already exist somewhere (and we just have to find it), but has to be constructed from existing or yet to be expressed information (the reader can see examples of such a process in [44]: a couple starting comparing one week holiday packages in national tourist resorts and finishing by considering a one month holiday in the Pacific islands). A way to do that can be to work on the structure of values and expectations of the client (as suggested in [44]) or using an "expandable rationality" (see [38]) allowing to make the set of potential decisions evolve. Another way is through an analysis of the structure of concerns in the problem situation. The client typically presents himself with a concern which remains somewhere in an intermediate level of the tree of concerns. Going up and down on such a tree enables to identify different sets of potential actions (considering the resources the client may commit for each such concern).

Example 4.2 *Using the holiday example, the concern of an ordinary holiday may project on a more general one which is the well being of the couple, for which further resources could be committed and thus allow to consider a concern of a special holiday.*

The final shape of the set $\mathbb{A}$ will only be defined when the evaluation model will be established, but the effort of constructing the set $\mathbb{A}$ during the problem formulation will pay during the whole decision aiding process: *half of a problem is deciding what to decide*.

The analysis of the different concerns (and how and why these associate to the different actors) leads to the establishment of the points of view to be considered in the decision aiding process. These represent the different dimensions under which we observe, analyse, describe, evaluate, compare the objects in $\mathbb{A}$. At this stage the elements of V do not have any formal properties and do not necessarily define a structure (such as an hierarchy). They simply represent what the client knows or wishes to know about the set $\mathbb{A}$. The key question here is: "what among all this knowledge is relevant for the decision situation under analysis?" Again the representation of the problem situation can be useful here, since certain concerns can be of descriptive nature (thus resulting in points of view), while the identification of the different resources to be committed to the concern may reveal other points of view. A more structured approach for this particular problem can be the use of cognitive maps ([29], [30]) or Checkland's soft systems methodology ([21]).

Last, but not least we have to establish a problem statement Π. Do we optimise or do we look for a compromise? Do we just try to provide a formal description of the problem? Do we evaluate or do we design alternatives? Establishing a problem formulation implies announcing what we expect to do with the set $\mathbb{A}$. We can first distinguish three basic attitudes:
- the first being constructing a set of feasible and realistic alternative actions without any necessary further evaluation purpose (as for instance in the "constraint satisfaction" case, see [15]);
- the second being describing a set of actions under a set of precise instances of the points of view established in V;
- the third one, which we call also "operational" (see [86]), consisting in partitioning the set $\mathbb{A}$.

Let us focus on this third attitude. Partitioning the set $\mathbb{A}$ implies to establish a set of categories to which each element of $\mathbb{A}$ are univocally associated (the "good" elements and the "rest", the "better", the "second better" etc., the "type X", the "type Y", the "type Z" etc.). In all cases and under all approaches an operational problem statement results from the replies to the following answers:
- are the categories predefined or do they result from the comparison of the elements of $\mathbb{A}$ among them?
- are the categories ordered (at least partially) or not?
- how many such categories can exist (if they are not predefined)? Just two complementary or more than two?

An operational problem statement is a combination of answers to the above

questions and establishes a precise form of partition of the set $\mathbb{A}$:
1) in predefined, not ordered categories (a typical example being the assignment problem);
2) in predefined, ordered categories (as in the "sorting" procedures);
3) in two, not predefined, not ordered categories (as when we partition the elements of $\mathbb{A}$ in similar or analog objects and not);
4) in more than two, not predefined, not ordered categories (as in the clustering and more generally classification case);
5) in two, not predefined, ordered categories (for instance the chosen or rejected objects and the rest);
6) in more than two, not predefined, ordered categories (as in the ranking procedures).

Up to now we have presented eight possible problem statements, the six operational ones previously described, and the two "non operational" ones which we may call "design" and "description". All such statements can be further characterised by the possibility of looking at "robust" decision aiding. I will not further discuss this issue which already attracted the interest of several researchers (see [117], [107], [108], [47], [83], [22], [87]).

Operational Research and Decision Theory usually focus their attention in optimisation and more generally on "choice" problem statements where one alternative or vector of decision variables is expected to be established as a solution (thus introducing the use of only two categories of solutions: the chosen ones and the rest). However, decision aiding is also provided when we rank-order the alternatives, when we classify them in categories (ordered or not, pre-existing or not) under internal (relative) or external (absolute) comparison. Establishing the problem statement with the client enables to focus on the appropriate methods and procedures to be used and avoids to waste time in trying to force the information in irrelevant ones. Nevertheless the establishment of problem statement Π is an anticipation of the final solution and as such it is rare that the client is able to provide it by simple questioning. The work of the analyst here is to show (through examples) the different possible problem statements and the different outcomes to which they lead.

4.1.3 Constructing the Evaluation Model

This is the typical task of the analyst where his methodological knowledge applies to the information provided by the client in order to produce a model which can be elaborated by a formal method.

Again the first step is to fix the set of potential decisions or alternatives A. At this stage the set A should have precise formal properties such as:

- being a compact or discrete subset of an n-dimensional space;
- being a list of objects;
- having a combinatorial structure.

The existence of feasibility (or acceptability) constraints should apply here either directly (limiting the enumeration of A) or indirectly (limiting the space where A can be defined). The set A, established in the problem formulation, is the starting point of this process, but new elements may be added (such as dump alternatives or ideal solutions) or eliminated. Within an evaluation model we consider the set A as stable along the time and in the case it has a combinatorial structure we have to fix whether we are going to focus on the elementary components or on a list of combinations.

The set A is described through a set of dimensions D. These represent the relevant knowledge we have about A. Some of the dimensions might already be introduced as constraints (used in order to fix the set A), but other dimensions might be necessary for evaluation purposes, that is, they should allow to show the performance of each element of A under certain characteristics. Again the establishment of D requires to fix some formal properties. Each element of D is considered a measurement, therefore the precise scale type (E) of such a measure should be established. Several types of measurement scales are possible and might co-exist within an evaluation model such as nominal, ordinal etc.. Further on, the set D may have a structure such as an hierarchy. The set D cannot be empty. At least one dimension and its associated scale exists. Usually the set D is constructed using the set V as a starting point. Typically the construction of D involves structuring V (if necessary) and associating to each element thus defined a measurement structure.

In the case where an operational problem statement has been adopted (such as an optimisation or a ranking one) then we have to construct the set of criteria H to be used for such a purpose. The key issue here are the client's preferences. We define as a criterion any dimension to which it is possible to associate a preference model, even a partial one. The construction of the set of criteria is a central activity in the decision aiding process. Dimensions expressed under nominal measurement definitely require the establishment of a preference model. Dimensions expressed under measurements which allow an ordering may use such an ordering also as a preference structure, but this is rather exceptional. Usually the preference model is an interpretation of the available ordering (consider for example the use of a semi-order as a preference structure for a dimension endowed with a ratio scale). As such it requires a careful elaboration. Further on, it should be clear that if we are looking for a final result "rich" in information (such as an optimal solution) then the preference structures of the criteria ought to be "rich" themselves.

Last, but not least, the set H has to fulfil a number of conditions depending on the type of procedure which is foreseen to be used in order to elaborate the solution.

A basic requirement is separability of the criteria: each criterion alone should be able to discriminate the alternatives regardless on how these behave on the other criteria. A more complex requirement is the establishment of a coherent family of criteria: a set which contains the strictly necessary criteria and only these ones. Further conditions can apply such as independence in the sense of the preferences (when an additive composition of the criteria is foreseen) etc.. For more details the reader can see [45], [106], [88].

At this point an element which has to be added to the model is the presence of any uncertainty structure $\mathcal{U}$. Uncertainty can be exogenous or endogenous with respect to the model. Typical cases of exogenous uncertainty include the presence of different scenarios or states of the nature under which the evaluation has to be pursued, poor or missing information as far as certain dimensions or criteria are concerned, hesitation or inconsistency of the client in establishing his preference on one or more criteria. Typical cases of endogenous uncertainty include the difficulty to discriminate alternatives on a dimension or criterion due to its ambiguous definition or linguistic nature, the appearance of inconsistencies due to conflicting information in different parts of the model, the impoverishment of the information due to the aggregation of dimensions or criteria. In all such cases the model has to contain the appropriate structure for each particular type of uncertainty (if any). It should be noted that choosing a particular representation for a certain uncertainty is not neutral with respect to the final result and that the client should be aware of which type of result is associated to each type of representation chosen.

The last element to be established within the evaluation model is the precise method $\mathcal{R}$ to be used in order to elaborate a solution to the model. Such a choice is not neutral, since different methods can result in completely different conclusions. Classic decision theory usually neglects this issue since it always considers as given the method (an optimisation procedure). However, this is not generally the case. The choice of $\mathcal{R}$ depends on the problem statement Π adopted in the problem formulation and should be fixed using two criteria:

- theoretical meaningfulness (in the sense of measurement theory): the method should be sound with respect to the information used. Typical errors in this case include the use of averaging operators on ordinal information, the use of a conventional optimisation algorithm when the cost coefficients are only ordinal, the underestimation of verifying the independence of criteria when an additive value function is used.

- operational meaningfulness (in the sense that the client should be able to understand and use the result within the decision process). It should be noted that theoretical meaningfulness does not prevent the problem of establishing a useless result: an arithmetic mean of lengths is theoretically sound, but useless if the client is looking for a volume. Typical errors here include the underestimation of the quantity of information required by the client (a simple order among the alternatives can be useless) or the aggregation of criteria without verifying their coherence.

A critical aspect in establishing $\mathcal{R}$ are the properties each such method fulfils. Each method satisfies some nice properties, but also does not satisfy other ones and may present undesired side effects (see [13]) such as, for ranking procedures, non monotonicity, dependence on circuits, different forms of manipulability etc.. The analyst should establish a set of properties that the method should fulfil (not necessarily of normative nature, but simply prescriptive ones) and make the client aware of the possible side-effects of the methods that could be used. Under such a perspective, the axiomatic study of the methods is a key knowledge for the analyst since it allows him to have a precise map of the properties each method satisfies.

Further on, each method $\mathcal{R}$ requires the use of a number of parameters: some of these directly representing preferential information to be obtained from the client and his/her knowledge, others more or less arbitrary interpretations of such a knowledge and depending on $\mathcal{R}$ itself.

The best known example concerns the use of coefficients of importance when several criteria have to be considered simultaneously. Here the client can have an "intuition" on "how important" certain criteria are with respect to others, but the precise formalisation of this concept strictly depends on how $\mathcal{R}$ works (see [68], [12]). If for instance $\mathcal{R}$ is based on the construction of a global value function then such parameters are trade-offs among the criteria and have to be established together with the value function associated to each criterion. If on the other hand $\mathcal{R}$ is a majority procedure then these parameters are "power indexes" to be associated to potential coalitions of criteria. It is clear that, depending on what $\mathcal{R}$ is and what the available information is, the establishment of these parameters requires precise procedures and interaction protocols with the client (see [69], [67], [116], [110]).

The same reasoning applies to other parameters which could be necessary for a given $\mathcal{R}$ such as discrimination thresholds, cutting levels for valued preference relations, cost coefficients and righthand side terms in mathematical programmes, boundaries of categories in classification procedures etc.. Most of such parameters are an interpretation of what the client considers relevant for the problem and such an interpretation depends on how $\mathcal{R}$ is defined. Not all interpretations might be consistent with the client's information and knowledge and different consistent interpretations might lead to completely different results.

4.1.4 Constructing the final recommendation

The output of the evaluation model is essentially a result consistent with the model itself. This does not guarantee that this result is consistent with the client's concern and even less with the decision process for which the aid has been asked . As the client and the analyst return to the reality they should take at least three precautions before they formulate the final recommendation (to be noted that due to the expected consensus between client and analyst I consider that the outcome is considered as "owned" also by the client).

1. Sensitivity analysis. How the suggested solution will vary when the parameters of the model might be perturbed? What is the range of values of such parameters for which the solution will remain, at least qualitatively, the same? A solution which appears to be sensible to very small perturbations of the parameters implies that the solution strongly depends on this particular instance of the method and less on the preferential information. Since such an instance can be quite an arbitrary interpretation a thorough investigation on the model should be conducted.

2. Robustness analysis. We have already seen that robustness can be seen as a dimension of the problem statement within a problem formulation. How good the solution (or the method) will be under different scenarios and combinations of the parameters? Being able to show that a particular solution will remain "good" (although perhaps not the best one) under the worst conditions that may occur should be considered an advantage. Depending on the particular type of robustness considered it is reasonable to verify whether such a feature holds or not. On the other hand a typical error in robustness analysis consists in testing different methods in order to find if a certain solution will remain "the best". This is meaningless, since each method provides qualitatively different results which cannot be compared.

3. Legitimation. How legitimated is the foreseeable recommendation with respect to the organisational context of the decision process ([26], [39], [51])? As already mentioned each decision aiding process refers to a decision process which usually occurs within a certain organisation (possibly of informal nature). Coming with a recommendation that could conflict with such an organisation implies incurring risks. Either the client and the analyst pursue explicitly this conflict or they risk to waste time and resources. It should be noted that in considering legitimation we have to take in account how a recommendation is presented, implemented and perceived by the other actors

besides its precise contents. Under such a perspective a valid representation of the problem situation helps in verifying the legitimation.

4.2 Update and Revision

Conducting a decision aiding process is not a linear process where we establish the four cognitive artifacts one after the other. Since a decision aiding process always refers to a decision process which has a time and space extension it is natural that the outcomes of the decision aiding process remain *defeasible cognitive artifacts* in the sense that new information, beliefs and values may invalidate them and require an update or a revision. Usually the process will encounter situations where any of the above artifacts:
- may conflict with the evolution of the client's expectations, preferences and knowledge;
- may conflict with the updated state of the decision process and the new information available.
It is therefore necessary to adapt the contents of such artifacts as the decision aiding process evolves in time and space. Consider the following decision aiding process.

Example 4.3 *A client is planning to open a number of shops in a town structured in districts. He might start formulating a problem of "covering" the whole town with the minimum number of shops (under the hypothesis that shops opened in a district "cover" also the adjacent ones). This is a typical combinatorial optimisation problem. A solution of this "problem" (let's say minimum 3 shops necessary) could lead the client to think that this is too expensive. The "problem" will be now reformulated as maximising coverage under a budget constraint (a new issue for the client). Again this is a well known combinatorial optimisation problem. The new results, which do not cover the whole town, could allow to consider that coverage could be "weighted" (the districts having different commercial importance), thus slightly modifying the previous evaluation model. At this point the client and the analyst could go one step further and consider a bi-objective combinatorial optimisation problem: maximising weighted coverage and minimising costs.*

In the above example the reader will recognise three different problem formulations:

- Γ_1: optimise openings
  where $\mathbb{A}_1$ are the districts, V_1 contains only geographical information and Π_1 is an "optimal" choice problem statement;

- Γ_2: optimise coverage
  where $\mathbb{A}_2$ are the districts, V_2 contains geographical and economical information and Π_2 is an "optimal" choice problem statement;

- Γ_3: compromise openings and coverage
  where $\mathbb{A}_3$ are the districts, V_3 contains geographical and economical information and Π_3 is a "compromise" choice problem statement;

and four different evaluation models:

$$\mathcal{M}_{11} \quad \begin{array}{l} \min \sum_i^n x_i \\ Gx \geq 1 \\ x \in \{0,1\}^n \end{array}$$

$$\mathcal{M}_{21} \quad \begin{array}{l} \max \sum_i^n y_i \\ Gx \geq y \\ \sum_i^n k_i x_i \leq K \\ x, y \in \{0,1\}^n \end{array}$$

$$\mathcal{M}_{22} \quad \begin{array}{l} \max \sum_i^n w_i y_i \\ Gx \geq y \\ \sum_i^n k_i x_i \leq K \\ x, y \in \{0,1\}^n \end{array}$$

$$\mathcal{M}_{31} \quad \begin{array}{l} \max \sum_i^n w_i y_i \\ \min \sum_i^n k_i x_i \\ Gx \geq y \\ x, y \in \{0,1\}^n \end{array}$$

where:
- x_i represent the "opening" decision variables (where to open a shop?);
- y_i represent the "covering" decision variables (which district is covered?);
- G represents the adjacency matrix;
- k_i represent the costs;
- w_i represent the "weight" of each district;
- K represents the budget.

The reader will note that all the above evaluation models share a lot of information. Consider the generic evaluation model $\mathcal{M}_{ij} = \langle A_{ij}, D_{ij}, E_{ij}, H_{ij}, \mathcal{U}_{ij}, \mathcal{R}_{ij} \rangle$. We have that $A_{11}, A_{21}, A_{22}, A_{31}$ all contain the variables x_i, while the last three contain also the variables y_i. $D_{11}, D_{21}, D_{22}, D_{31}$ all contain the geographical dimension represented by the adjacency matrix G, while the last three also contain a cost dimension (measured on the same ratio scale) and the last two the "commercial importance" dimension (presumably also measured on a ratio scale). H_{11} contains one criterion: minimise openings. H_{21} also contains one criterion: maximise coverage. H_{22} uses practically the same criterion with the slight modification of introducing "commercial importance" as a "weight" for each covered district. H_{31} uses two criteria: minimise costs and maximise weighted coverage. All evaluation models share an empty $\mathcal{U}$ set. $\mathcal{R}_{11}, \mathcal{R}_{21}, \mathcal{R}_{22}$ will all use a combinatorial optimisation algorithm, while $\mathcal{R}_{31}$ will use a bi-criterion optimisation procedure. It is natural to consider that during the decision aiding process most of such shared information will be preserved and re-used, as well as most of the intermediate results, the ones that allowed the process to evolve.

The above example shows that during a decision aiding process several different versions of the cognitive artifacts are established. However, such different versions are strongly related among them since they carry essentially the same information and only a small part of the model has to be revised. The problem is: is it possible to give a formal representation of how such an evolution occurs? In other terms: is it possible to show how a set of alternatives or some preferential information may change while shifting from one model to another? For this purpose we may use argumentation theory (see [43]) as a first step in integrating decision aiding methodology and formal reasoning languages.

It is out of the scope of this paper to describe in details how this approach works (the interested reader can see more in [66]). The basic idea is to use a set of rules which enables to express default preferences among models and problem formulations which can be "defeated" when exceptional situations occur. Under such a perspective the model of the decision aiding process turns to be useful since it allows to establish a set of possible problem formulations and evaluation models to be used in different contexts, thus preventing the necessity to re-start the modeling process each time from the beginning.

5 Conclusions

In this paper I introduced a model of what I call the "decision aiding process", that is the interactions occurring between (at least) a client, having a concern within a decision process, and an analyst who is expected to provide the decision aiding.

A first claim of the paper concerns the use of formal and abstract languages (and therefore of models of rationality) as a fundamental characteristic of the decision aiding approaches considered in the paper. A second claim is that a decision aiding process is a particular type of decision process aiming at establishing a "consensual" (between the client and the analyst) representation of the client's concern. Different approaches are possible in conducting a decision aiding process, characterised by the hypotheses done on the source of the models of rationality used through the process. Decision aiding approaches are independent from the methods used within them.

The model of the decision aiding process considers it as a distributed cognition process. Under such a perspective the paper introduced the cognitive artifacts such a process generates. The use of such a model by a participant within a decision aiding process allows to gain control and insight with respect to the interactions with his counterpart in the process. Moreover, it allows to show the importance of each artifact created during the process, in order to have useful and meaningful decision aiding. Last, but not least, the use of this model allows to focus on the defeasible character of the cognitive artifacts and to introduce the use of reasoning formalisms which enable to handle the revision and update of the artifacts as the decision process evolves.

The paper contains a number of recommendations (more or less partial) on how to conduct a decision aiding process and more precisely how to establish parts of the different outcomes of this process (a more thorough analysis, although still partial, can be seen in the two books: [13, 14]). Such recommendations can be seen as part of what I could call a "manual" for novice "decision aiders" who are making their first experiences or for experienced ones who want to understand "what has gone wrong".

However, we are far from having sufficient research findings and decision aiding "introspection" to be able to compile a real manual. A plan for future research should include the following items.

- More thorough analysis of the decision aiding process dynamics: how do we move from one artifact to another? How do we use the information obtained for one artifact to establish elements of another?

- A deeper analysis of the biases introduced in the client's problem situation perspective by the presence of the analyst's point of view. How the use of a decision aiding approach could influence the client/analyst interaction?

- More systematic analysis of real world decision aiding processes and comparison with the best practices observed at other professions (aiding people to make decisions).

- More experimental analysis of cognitive protocols concerning the interaction client/analyst (interaction language, modeling language, validation).

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References

[1] R.A. Abualsamh, B. Carlin, and R.R. McDaniel. Problem structuring heuristics in strategic decision making. *Organizational Behavior and Human Decision Processes*, 45:159–174, 1990.

[2] M. Allais. The so-called Allais paradox and rational decisions under uncertainty. In O. Hagen M. Allais, editor, *Expected Utility Hypotheses and the Allais Paradox*, pages 437–681. D. Reidel, Dordrecht, 1979.

[3] C.A. Bana e Costa. Les problématiques de l'aide à la décision : vers l'enrichissement de la trilogie choix-tri-rangement. *RAIRO/ Recherche Opérationnelle*, 30(2):191–216, 1996.

[4] C.A. Bana e Costa, L. Ensslin, E.C. Correa, and J.-C. Vansnick. Decision support systems in action: Integrated application in a multicriteria decision aid process. *European Journal of Operational Research*, 113:315–335, 1999.

[5] C. Banville, M. Landry, J.-M. Martel, and C. Boulaire. A stakeholder approach to MCDA. *Systems Research and Behavioral Science*, 15:15–32, 1998.

[6] D. Bell, H. Raiffa, and A. Tversky, editors. *Decision making: descriptive, normative, and prescriptive interactions*. Cambridge university press, Cambridge, 1988.

[7] V. Belton, F. Ackermann, and I. Shepherd. Integrated support from problem structuring through alternative evaluation using COPE and V-I-S-A. *Journal of Multi-Criteria Decision Analysis*, 6:115–130, 1997.

[8] V. Belton and T. Stewart. *Muliple Criteria Decision Analysis: An Integrated Approach*. Kluwer Academic, Dordrecht, 2002.

[9] K.J. Benson. The interorganizational network as a political economy. *Administrative Science Quarterly*, 20:229–249, 1975.

[10] P.L. Berger and Th. Luckmann. *The Social Construction of Reality: A Treatise its the Sociology of Knowledge*. Garden City, New York, 1966.

[11] M. Binbasioglu. Problem structuring support for collaboration and problem solving. *Journal of Computer Information Systems*, 40:54–63, 2000.

[12] K. Borcherding, T. Eppel, and D. von Winterfeldt. Comparison of weighting judgments in multiattribute utility measurement. *Management Science*, 37(12):1603–1619, 1991.

[13] D. Bouyssou, T. Marchant, M. Pirlot, P. Perny, A. Tsoukiàs, and Ph. Vincke. *Evaluation and decision models: a critical perspective*. Kluwer Academic, Dordrecht, 2000.

[14] D. Bouyssou, T. Marchant, M. Pirlot, P. Perny, A. Tsoukiàs, and Ph. Vincke. *Evaluation and decision models: stepping stones for the analyst*. Kluwer Academic, Dordrecht, forthcoming.

[15] S.C. Brailsford, C.N. Potts, and B.M. Smith. Constraint satisfaction problems: algorithms and applications. *European Journal of Operational Research*, 119:557–581, 1999.

[16] R.V Brown. Toward a prescriptive science and technology of decision aiding. *Annals of Operations Research*, 19:467–483, 1989.

[17] R.V. Brown and A. Vári. Towards a research agenda for prescriptive decision science: The normative tempered by the descriptive. *Acta Psychologica*, 1-3:33–48, 1992.

[18] J. Buchanan, E.J. Henig, and M. Henig. Objectivity and subjectivity in the decision making process. *Annals of Operations Research*, 80:333–345, 1998.

[19] E. Capurso and A. Tsoukiàs. Decision aiding and psychotherapy, 2003. Bulletin of the EURO Working Group on MCDA, Fall 2003, Available on line at http://www.inescc.pt/∼ewgmcda.

[20] P. Checkland. *Systems thinking, systems practice*. J. Wiley, New York, 1981.

[21] P. Checkland and J. Scholes. *Soft Systems Methodology in Action*. J. Wiley, New York, 1990.

[22] P. Chu, H. Moskowitz, and R.T. Wong. Robust interactive decision-analysis (RID): an overview. *Acta Psychologica*, 68:255–269, 1988.

[23] M.D. Cohen, J.G. March, and J.P. Olson. A garbage can model of organizational choice. *Administrative Science Quarterly*, 17:1–25, 1972.

[24] J. Corner, J. Buchanan, and M. Henig. Dynamic decision problem structuring. *Journal of Multi-Criteria Decision Analysis*, 10(3):129–142, 2001.

[25] J.F. Courtney and D.B. Paradice. Studies in managerial problem formulation systems. *Decision Support Systems*, 9:413–423, 1993.

[26] A. David. Models implementation: A state of the art. *European Journal of Operational Research*, 134:459–480, 2001.

[27] B. De Marchi, S.O. Funtowicz, S. Lo Cascio, and G. Munda. Combining participative and institutional approaches with multicriteria evaluation. an empirical study for water issues in Troina, Sicily. *Ecological Economics*, 34:267–282, 2000.

[28] L.C. Dias and A. Tsoukiàs. On the constructive and other approaches in decision aiding. In C.A Hengeller Antunes, J. Figueira, and J. Clímaco, editors, *Proceedings of the 56th meeting of the EURO MCDA working group*, pages 13–28. CCDRC, Coimbra, october 2004.

[29] C. Eden. Cognitive mapping. *European Journal of Operational Research*, 36:1–13, 1988.

[30] C. Eden. Cognitive mapping and problem structuring for system dynamics model building. *System Dynamics Review*, 10:257–276, 1994.

[31] C. Eden, S. Jones, and D. Sims. *Messing About in Problems*. Pergamon Press, Oxford, 1983.

[32] P.C. Fishburn. *Utility Theory for Decision Making*. Wiley, New York, 1970.

[33] P.C. Fishburn. Nontransitive measurable utility. *Journal of Mathematical Psychology*, 26:31–67, 1982.

[34] S. French. *Decision theory - An introduction to the mathematics of rationality*. Ellis Horwood, Chichester, 1988.

[35] J.K. Friend and A. Hickling. *Planning under pressure: the strategic choice approach*. Pergamon Press, New York, 1987.

[36] J.-L. Genard and M. Pirlot. Multiple criteria decision aid in a philosophical perspective. In D. Boyssou, E. Jacquet-Lagrèze, P. Perny, R. Slowinski, D. Vanderpooten, and Ph. Vincke, editors, *Aiding decisions with multiple criteria: essays in honour of Bernard Roy*, pages 89–117. Kluwer Academic, Dordrecht, 2002.

[37] J. Habermas. *Logic of the social sciences*. MIT Press, Boston, 1990.

[38] A. Hatchuel. Towards design theory and expandable rationality: The unfinished program of Herbert Simon. *Journal of Management and Governance*, 5:260–273, 2001.

[39] A. Hatchuel and M. Molet. Rational modelling in understanding and aiding human decision making: About two case studies. *European Journal of Operational Research*, 24:178–186, 1986.

[40] P.C. Humphreys, O. Svenson, and A. Vári. *Analysis and aiding decision processes*. North-Holland, Amsterdam, 1983.

[41] D. Kahneman, P. Slovic, and A. Tversky. *Judgement under uncertainty - Heuristics and biases*. Cambridge University Press, Cambridge, 1981.

[42] D. Kahneman and A. Tversky. Prospect theory: An analysis of decision under risk. *Econometrica*, 47:263–291, 1979.

[43] A.C. Kakas, P. Mancarella, and P.M. Dung. The acceptability semantics for logic programs. In *Proceedings of ICLP94*, pages 504–519, 1994.

[44] R.L. Keeney. *Value-Focused Thinking. A Path to Creative Decision Making*. Harvard University Press, Cambridge, 1992.

[45] R.L. Keeney and H. Raiffa. *Decisions with multiple objectives: Preferences and value tradeoffs*. J. Wiley, New York, 1976.

[46] L.R. Keller and J.L. Ho. Decision problem structuring: generating options. *IEEE Transactions on Systems, Man and Cybernetics*, 18:715–728, 1988.

[47] P. Kouvelis and G. Yu. *Robust discrete optimization and its applications*. Kluwer Academic, Dordrecht, 1997.

[48] J. Lacan. *The Language of the self : the function of language in psychoanalysis*. John Hopkins Press, Baltimore, 1968.

[49] J. Lacan. *Écrits*. Seuil, Paris, 1995. first edition in 1966.

[50] M. Landry. A note on the concept of problem. *Organization Studies*, 16:315–343, 1995.

[51] M. Landry, C. Banville, and M. Oral. Model legitimisation in operational research. *European Journal of Operational Research*, 92:443–457, 1996.

[52] M. Landry, J.L. Malouin, and M. Oral. Model validation in operations research. *European Journal of Operational Research*, 14:207–220, 1983.

[53] M. Landry, D. Pascot, and D. Briolat. Can DSS evolve without changing our view of the concept of problem? *Decision Support Systems*, 1:25–36, 1983.

[54] O.I. Larichev and H.M. Moshkovich. Unstructured problems and developmennt of prescriptive decision making methods. In P. Pardalos, Y. Siskos, and C. Zopounidis, editors, *Advances in Multicriteria Analysis*, pages 47–80. Kluwer Academic, Dordrecht, 1995.

[55] B. Lehaney, S. Martin, and S. Clarke. A review of problem structuring methodologies. *Systemist*, 19:11–28, 1997.

[56] R.D. Luce and H. Raiffa. *Games and Decisions*. J. Wiley, New York, 1957.

[57] D.G. MacGregor, S. Lichtenstein, J. Baron, and P. Bossuyt. Problem structuring aids for quantitative estimation. *Journal of Behavioral Decision Making*, 4:101–120, 1991.

[58] K. Mackenzie. Virtual positions and power. *Management Science*, 32:622–642, 1986.

[59] I. Masser. The representation of urban planning-processes: An exploratory review. *Environment and Planning B*, 10:47–62, 1983.

[60] A.P. Massey and W.A. Wallace. Understanding and facilitating group problem structuring and formulation: mental representations, interaction, and representation aids. *Decision Support Systems*, 17:253–274, 1996.

[61] M.R Maturana and F.J Varela. *Autopoiesis and Cognition*. Reidel, Dordrecht, 1984.

[62] J. Mingers and J. Rosenhead. Problem structuring methods in action. *European Journal of Operational Research*, 152:530–554, 2004.

[63] H. Mintzberg, D. Raisinghani, and A. Théoret. The structure of unstructured decision processes. *Administrative Science Quarterly*, 21:246–272, 1976.

[64] H. Montgomery. Decision rules and the search for a dominance structure: towards a process models of decision making. In P.C. Humphreys, O. Svenson, and A. Vári, editors, *Analysing and aiding decision processes*, pages 343–369. North Holland, Amsterdam, 1983.

[65] H. Montgomery and O. Svenson. On decision rules and information processing strategies for choices among multiattribute alternatives. *Skandinavian Journal of Psychology*, 17:283–291, 1976.

[66] P. Moraïtis and A. Tsoukiàs. Decision aiding and argumentation, 2003. Presented at EUMAS-03 Workshop, Available on line at http://www.lamsade.dauphine.fr/∼tsoukias/recent.html.

[67] V. Mousseau. Eliciting information concerning the relative importance of criteria. In P. Pardalos, Y. Siskos, and C. Zopounidis, editors, *Advances in Multicriteria Analysis*, pages 17–43. Kluwer Academic, Dordrecht, 1995.

[68] V. Mousseau. Compensatoriness of preferences in matching and choice. *Foundations of Computing and Decision Sciences*, 22(1):3–20, 1997.

[69] V. Mousseau, L.C. Dias, J. Figueira, C. Gomes, and J.N. Clímaco. Resolving inconsistencies among constraints on the parameters of an MCDA model. *European Journal of Operational Research*, 147(1):72–93, 2003.

[70] S.E. Newstead, V.A. Thompson, and S.J. Handley. Generating alternatives: A key component in human reasoning? *Memory and Cognition*, 30:129–137, 2002.

[71] M.F Norese. A multidimensional model by a multiactor system. In B.R Munier and M.F Shakun, editors, *Compromise, Negotiation and Group Decision*, pages 263–276. Reidel, Dordrect, 1988.

[72] M.F. Norese. A process perspective and multicriteria approach in decision-aiding contexts. *Journal of Multicriteria Decision Analysis*, 5:133–144, 1996.

[73] M.F Norese and A. Ostanello. Planning processes and technician interventions: an integrated approach. *Sistemi Urbani*, 2:247–259, 1984.

[74] M.F. Norese and A. Ostanello. Identification and development of alternatives: introduction to the recognition of process typologies. In A.G. Lockett

and G. Islei, editors, *Improving Decision Making in Organisations*, LNEMS 335, pages 112–123. Springer-Verlag, Berlin, 1989.

[75] P.C Nutt. Types of organizational decision processes. *Administrative Science Quarterly*, 19:414–450, 1984.

[76] A. Ostanello. Action evaluation and action structuring - Different decision aid situations reviewed through two actual cases. In C.A. Bana e Costa, editor, *Readings in multiple criteria decision aid*, pages 36–57. Springer Verlag, Berlin, 1990.

[77] A. Ostanello. Validation aspects of a prototype solution implementation to solve a complex MC problem. In J.N Clímaco, editor, *Multicriteria analysis*, pages 61–74. Springer Verlag, Berlin, 1997.

[78] A. Ostanello and A. Tsoukiàs. An explicative model of 'public' interorganizational interactions. *European Journal of Operational Research*, 70:67–82, 1993.

[79] E. Paschetta and A. Tsoukiàs. A real world MCDA application: evaluating software. *Journal of Multi-Criteria Decision Analysis*, 9:205–226, 2000.

[80] M. Pidd. From problem-structuring to implementation. *Journal of the Operational Research Society*, 39:115–121, 1988.

[81] E.C. Poulton. *Behavioral decision theory: A new approach*. Cambridge University Press, Cambridge, 1994.

[82] H. Raiffa. *Decision Analysis - Introductory lectures on choices under uncertainty*. Addison Wesley, Reading, MA, 1970. traduction française: Analyse de la décision : introduction aux choix en avenir incertain, Dunod, 1973.

[83] D. Rios Insua and J. Martin. On the foundations of robust decision making. In S. Rios, editor, *Decision theory and decision analysis: trends and challenges*, pages 103–111. Kluwer Academic Publishers, 1994.

[84] J. Rosenhead. *Rational analysis of a problematic world*. J. Wiley, New York, 1989. 2nd revised edition in 2001.

[85] B. Roy. Decision science or decision-aid science? *European Journal of Operational Research*, 66:184–203, 1993.

[86] B. Roy. *Multicriteria Methodology for Decision Aiding*. Kluwer Academic, Dordrecht, 1996.

[87] B. Roy. A missing link in OR-DA, Robustness analysis. *Foundation of Control Engineering*, 23(3):141–160, 1998.

[88] B. Roy and D. Bouyssou. *Aide Multicritère à la Décision : Méthodes et Cas*. Economica, Paris, 1993.

[89] L.J. Savage. *The Foundations of Statistics*. J. Wiley, New York, 1954. second revised edition, 1972.

[90] G. Schaffer. Savage revisited. In D. Bell, H. Raiffa, and A. Tversky, editors, *Decision Making: descriptive, normative and prescriptive interactions*, pages 193–235. Cambridge University Press, Cambridge, 1988.

[91] M.F. Shakun. Airline buyout: evolutionary systems design and problem restructuring in group decision and negotiation. *Management Science*, 37:1291–1303, 1991.

[92] H.A. Simon. *Administrative behaviour: a study of Decision Making Processes in Administrative Organizations*. Mac Millan, New York, 1947.

[93] P. Slovic and S. Lichtenstein. Preference reversals: A broader perspective. *American Economic Review*, 73:596–605, 1983.

[94] P. Slovic and A. Tversky. Who accepts Savage's axiom? *Behavioral Science*, 19:368–373, 1974.

[95] G.F. Smith. Towards a heuristic theory of problem structuring. *Management Science*, 34:1489–1506, 1988.

[96] G.F. Smith. Representational effects on the solving of an unstructured decision problem. *IEEE Transactions on Systems, Man and Cybernetics*, 19:1083–1090, 1989.

[97] I. Stamelos and A. Tsoukiàs. Software evaluation problem situations. *European Journal of Operational Research*, 145:273–286, 2003.

[98] O. Svenson. Decision making and the search for fundamental psychological regularities: what can we learn from a process perspective? *Organisational Behaviour and Human Decision Processes*, 65:252–267, 1996.

[99] K. Sycara. Problem restructuring in negotiation. *Management Science*, 37:1248–1268, 1991.

[100] A. Tsoukiàs. From decision theory to decision aiding methodology. Technical Report 2003-21, DIMACS, Rutgers University, 2003.

[101] A. Tversky. Intransitivity of preferences. *Psychological Review*, 76:31–48, 1969.

[102] A. Tversky. Elimination by aspects: A theory of choice. *Psychological Review*, 79:281–299, 1972.

[103] A. Tversky. On the elicitation of preferences: Descriptive and prescriptive considerations. In D. Bell, R.L. Keeney, and H. Raiffa, editors, *Conflicting objectives in Decisions*, pages 209–222. J. Wiley, New York, 1977.

[104] D. Vanderpooten. Modelling in decision aiding. In D. Bouyssou, E. Jacquet-Lagrèze, P. Perny, R. Slowinski, D. Vanderpooten, and Ph. Vincke, editors, *Aiding Decisions with Multiple Criteria: Essays in Honour of Bernard Roy*, pages 195–210. Kluwer Academic, Dordrecht, 2002.

[105] A. Vári and J. Vescenyi. Pitfalls of decision analysis: Examples of r and d planning. In *Analysing and aiding decision processes*, pages 183–195. North Holland, Amsterdam, 1983.

[106] Ph. Vincke. *Multicriteria Decision-Aid*. J. Wiley, New York, 1992.

[107] Ph. Vincke. Robust and neutral methods for aggregating preferences into an outranking relation. *European Journal of Operational Research*, 112(2):405–412, 1999.

[108] Ph. Vincke. Robust solutions and methods in decision aid. *Journal of Multi-Criteria Decision Analysis*, 8(3):181–187, 1999.

[109] J. von Neumann and O. Morgenstern. *Theory of games and economic behavior*. Princeton University Press, Princeton, 1944. Second edition in 1947, third in 1954.

[110] D. von Winterfeldt and W. Edwards. *Decision Analysis and Behavorial Research*. Cambridge University Press, Cambridge, 1986.

[111] L.S. Vygotsky. *Mind in Society*. Harvard University Press, Cambridge, 1978.

[112] P.P. Wakker. *Additive representations of preferences - A new foundation of decision analysis*. Kluwer Academic, Dordrecht, 1989.

[113] P. Watzlawick, J.H. Beavin, and D.D. Jackson. *Pragmatics of Human Communication*. W.W. Norton, New York, 1967.

[114] P. Watzlawick, J.H. Weakland, and R. Fisch. *Change; principles of problem formation and problem resolution*. Norton, New York, 1974.

[115] E.U. Weber and O. Çoskunoğlu. Descriptive and prescriptive models of decision making: implications for the development of decision aid. *IEEE Transactions on Systems, Mans and Cybernetics*, 20:310–317, 1990.

[116] M. Weber and K. Borcherding. Behavioral influences on weight judgments in multiattribute decision making. *European Journal of Operational Research*, 67:1–12, 1993.

[117] H.-Y. Wong and J. Rosenhead. A rigorous definition of robustness analysis. *Journal of the Operational Research Society*, 51:176–182, 2000.

[118] R.N. Woolley and M. Pidd. Problem structuring: a literature review. *Journal of the Operational Research Society*, 32:197–206, 1981.