DIMACS Technical Report 2003-38
November 14, 2003

On the concept of decision aiding process

by

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[1]This paper has been prepared while I was visiting DIMACS, Rutgers University, under NSF CCR 00-87022 grant

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ABSTRACT

The paper presents the concept of decision aiding process as an extension of the decision process one. 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: the “products”, or cognitive artifacts the process will deliver at the end. Finally the decision aiding process is considered as a more general reasoning process to which recent artificial intelligence findings in argumentation could apply.

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 is very often the case that we will ask help in order to do so: a good friend, a lawyer, a physician, a psychotherapist, a counsellor, a social worker, an expert in "something", an Operational Research consultant, are the typical persons to whom we may seek advice before making up our mind and do something.

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 models. 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 to reduce the ambiguity structured in human communication ([109]).

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, [16]), 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 ([46], [47]) human language is THE vehicle of the therapy and this thanks to the multiple meanings and interpretations allowed by human ambiguous communication. From hereafter when I use the term decision aiding it will always refer to the use of a formal and abstract language.

My first claim therefore will be that doing decision aiding using a formal and abstract language is a choice (and not a natural situation). As such, both who asks for such a decision aiding and 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 for using such an approach. Indeed the literature (see for instance [97]) 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 [97]). In section 3 I will go through more details as far as the decision aiding process is concerned, outlining a descriptive 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 thesis of the paper will be resumed and discussed in the conclusive section.

2 The Decision Process

The concept of decision process is due to Simon ([89]). 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 [40], [62], [61], [95], [37], [102], [90], [91]). The use of this concept in decision theory introduced two major innovations:
- rationality is expected to be referred 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 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 appear appear that such an approach could not account for the complexity of organisational decision making (see [60], [70], [71], [73], [72], [56], [38], [9], [20], [75]).

The observation of organisational decision processes lead 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 constitute a rational entity.

I am not going to further discuss the issue of the decision process and its models. I would like to emphasise only that different decision approaches in decision theory are intimately related on how the decision process is considered.

2.1 Decision Making and Decision Aiding

The difference between these two concepts has already been discussed by Roy in [82] (see also [14]), 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 an analyst exists 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 setting we consider the decision maker as endowed with decision power and therefore also responsible for the decision to take.

On the other hand a decision aiding context implies the existence of at least two distinctive 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 on his turn analyst for another client). For simplicity I will only consider the simpler setting with only these two actors present and use with no distinction 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 my attention 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, domain independent. The task can be resumed 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 improves 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 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 makes part of the system's organisation, see [58]).

I consider the decision aiding process to be a particular type of decision process. In order to do so I need to use a descriptive model of the decision process.

2.2 A descriptive model of the decision process

In the following I will make extensive use of a descriptive model of decision process introduced in [75]. This precise model originated in order to describe inter-organisational decision processes, but is sufficient 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 as "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 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".*

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 [75] the following characteristic states were suggested:
- controlled expansion;
- uncontrolled expansion;
- controlled reduction;
- stalemate;
- dissolution;
- institutionalisation;

in order to show the different directions to which the state of the process can evolve. For more details the reader can see [75]. Recognising the present state and fixing a desired state to reach can help in understanding the strategy to follow within the decision process.

I am not going to further analyse this concept. My claim is that in decision aiding contexts it 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" through the use of the technical and methodological skills of the analyst and the domain knowledge of the client. Such an hypothesis implies that the two actors engage themselves in a decision process, that is the decision aiding process is a special type of decision process.

2.3 Decision Aiding approaches

In the literature ([6, 12, 31, 43, 83, 85, 25]) on decision theory and decision aiding we may 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 approaches, 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 Decision Maker's (DM) 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 DM's rationality model, the process of obtaining this model, and the interpretation of the answers that are provided to the DM 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 DM 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 DMs 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: [29, 30, 106, 54, 79, 86, 108]

- **Descriptive approaches**

  Descriptive approaches derive rationality models from observing how DMs 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 DMs 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, 37, 39, 40, 61, 62, 78, 95, 98, 99, 107]

- **Prescriptive approaches**

  Prescriptive approaches *discover* rationality models for a given DM 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 DM in a particular context. Indeed the DM 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 DM'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, 42, 52, 83, 100, 101, 103, 111]

- **Constructive approaches**

  Constructive approaches are expected to help a DM to *build* his/her own rationality models for a given DM 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 DM 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 DM'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, 76, 94]) 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 DM 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: [17, 33, 34, 49, 51, 81, 83, 87, 110]

3 A model of the Decision Aiding Process

I consider the decision aiding process as a distributed cognition process. Under such a perspective the process will generate a number of cognitive artifacts which are supposed to be shared between the participating actors. Nevertheless, my point of view will be operational and not cognitive. I will try to analyse the artifacts such a process generates as if they were deliverables within a contract. More precisely I consider at least the following artifacts in such a process:
- a representation of the problem situation;
- a problem formulation;

- an evaluation model;
- a final recommendation.

Such a suggestion is based on real world decision aiding experiences (see [76],[94])

3.1 The problem situation

A representation of the problem situation is the result of an effort aimed to reply to questions of the type:
- who has a problem?
- why this is 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 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 the two actors.

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 to 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 the clients". Different problem formulation 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 by 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:

$$\Gamma = \langle A, V, \Pi \rangle$$

where:
- 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 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],[73],[85], for a detailed example see [94]).

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 in 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 traditionally are the decision aiding models conceived through any operational research, decision theory, 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:

$$\mathcal{M} = \langle A^*, \{D, E\}, G, \mathcal{U}, \mathcal{R} \rangle$$

where:
- A^* a set of alternatives on which the model will apply;

- D is a set of dimensions (attributes) under which the elements of A are observed, measured, described etc. (such a set can be structured, for instance through the definition of an hierarchy);
- E is a set of scales associated to each element of D;
- G is a set of criteria (if any) under which each element of A^* is evaluated in order to take in account the client's preferences;
- $\mathcal{U}$ is an uncertainty structure;
- $\mathcal{R}$ is a set of operators enabling to obtain synthetic information about the elements of A or of $A \times A$, namely aggregation operators (of preferences, of measures, if uncertainties etc.).

The reader can observe that large part of the existing decision aiding models and methods can be represented trough the above description. Besides, such description allows to focus 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 from the adopted method. The fact that we work with only one evaluation dimension, a single criterion, 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 or difference 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 [12]). 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 subjects to validation processes, namely (see [50]):
   - 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 the 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 where 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 him, that he understands it and that he should be able to use its conclusions (the client should feel “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.

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 by such legitimation. No legitimation, No implementation.

4 How to use the model?

We can distinguish two different uses of 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], [10], [15], [21], [22], [27], [26], [28], [44], [48], [55], [53], [57], [59], [69], [77], [92], [93], [96], [114]). A common characteristic of such literature is the emphasis on the claim that supporting decisions should not be limited in 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. The issue is: how we establish the correct problem formulation?

Problem structuring methodologies aim to help decision makers to better understand their concerns ([81], [48], [17], [51]), better justify and legitimate their conclusions ([49] and ease the validation process ([50], [74]).

Several among the problem structuring methodologies consider that decision aiding IS problem structuring (see for instance [17], [81], [32]). In other terms the quantitative aspects on which usually evaluation models 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 [42], [7], [8]) limit their problem structuring methodology by adopting a precise shape for the evaluation model (using value functions) under again 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 [68], [69], chapter???? within [81], [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) in 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 descriptive 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 to fill such a gap. It is a descriptive model (showing how the decision aiding process gets structured) and at the same time is constructive since 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 they 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 we are going to present with more details how such artifacts can be constructed suggesting empirical procedures for the conduction 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], [24], [88]). "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. Actually he might not necessary be a decision maker. The advice could be asked:
- for a (a priori or a posteriori) justification purpose;
- in order to understand a problem, but where 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 the other actors could 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 [75]) showing how a concern projects to another one (usually from simple very specific concerns to more general and abstract ones). Usually such a relation results to a tree where the leaves 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 to the concern "lake management" (associated to the local authority: the local province).*

In order to reply the second question we can associate to each object the resources committed 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 content's 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 going to decide about"? We might call this set of decision variables or alternatives or potential decisions. What is important to establish with sufficient clarity at this stage is what the set A do represent (for instance: suppliers or bids or combinations of bids etc.) and how (are they quantities, alternatives, combination of actions etc.).

Where such information do comes from? A source is of course the client who might be able to provide directly at least part of the set A (for the cognitive problems associated to this activity see [67]). The actors and their concerns as identified in the problem situation representation can be also sources. However, quite often the elements of the set A have to be "designed" (see [35]), in the sense that such a set does not already exist somewhere (and we just have to found it), but has to be constructed from existing or yet to be expressed information (the reader can see examples of such process in [42]: 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 [42] suggests) or using an "expandable rationality" (see [35]) allowing to make evolve the set of alternatives. 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 A will only be fixed when the evaluation model will be established, but the effort of constructing the set 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 A. At this stage the elements of V do not have any formal properties and not necessarily define a structure (such as an hierarchy). They simply represent what the client knows or wishes to know about the set 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 ([26], [27]) or Checkland's soft systems methodology ([18]).

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 do we expect to do with the set 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 [13]);
- 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 [83]), consisting in partitioning the set A.

Let us focus on this third attitude. Partitioning the set A implies to establish a set of categories to which each element of 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 they result from the comparison of the elements of 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 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 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 to "robust" decision aiding. I will not further discuss this issue which already attracted the interest of several researchers (see [113], [104], [105], [45], [80], [19], [84]).

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 Π is an anticipation of the final solution and as such 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 Decision Analysis 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 to 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 such dimensions might already be introduced under form of 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 (E) of such 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 (the nominal definition of A^*) exists. Usually the set D is constructed using the set Γ as a starting point. Typically the construction of D involves structuring Γ (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 G 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 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 as example the use of a semi-order as preference structure for a dimension endowed with a ratio scale) and therefore requires a careful elaboration. Further on it should be clear that if we are looking for a "‘rich" (in information) final result (such as an optimal solution) then the preference structures of the criteria ought to be "rich" themselves. Criteria (or the single criterion) have to be expressed on ratio or interval scales allowing to establish a value function on the set A^*.

Last, but not least, the set G 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 [43], [103], [85].

At this point an element which has to be added to the model is the presence of any uncertainty structure Ω. 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 the different results to which such a choice may lead.

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 to 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 depend on 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 (or value functions) 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 [12]) such as non monotonicity, dependence on circuits, difference forms of manipulability etc. in ranking procedures. The analyst should establish a set of properties that the method should fulfil (not necessarily of normative nature, but simply prescriptive ones) and make aware the client of the possible side-effects of a potential method to use. Under such a perspective the axiomatic study of the methods is a key knowledge for the analyst since it allows 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 by the client and his/her knowledge, others more or less arbitrary interpretations of such 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 [65], [11]). If for instance R is based on the construction of a comprehensive 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 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 R is and what the available information is, the establishment of these parameters requires precise procedures and interaction protocols with the client (see [66], [64], [112], [107]).

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 right hand 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 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 ([23], [36], [49])? 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 which could conflict with such an organisation implies assuming 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*. 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 process.

Example 4.3 *An agent wants to make something this evening. (S)he might see a friend or go outside alone or stay at home. In the last case the options are either to watch TV or to go to bed. If (s)he goes outside alone, the options are either to go to a restaurant (and then a restaurant has to be identified) or to a concert (and then a concert has to be identified) or to go to the bar in front of the house. If (s)he is going to meet a friend then, potentially, there are Helen, Mary and Bob and they could meet either to go to a cinema (and then a movie has to be identified) or to go to disco (then a disco has to be identified) or meet somewhere else (where?). The agent decided that prefers to meet a friend. But then Helen is not available, Mary does not like neither cinema nor disco (she wants to come to the agent's home), while Bob is available for everything. The agent at this point decides that these solutions are not really satisfactory and that (s)he prefers to go outside alone. However, now there is no more time to find a restaurant or a concert and therefore decides to go to the bar in front of the house.*

Suppose that for the different decisions of this agent a decision support is asked. In such a situation the descriptive model of the decision aiding process can turn to be useful since it allows to fix which elements have to be modified and why. Coming back to the example we may consider it as a planning problem and call the possible plans the agent may execute as π_j, each of them composed by sequences of actions $\alpha_i(x_1, \cdots x_n)$ where the x represent variables which can can be instantiated within definite domains. The problem could then be described as follows ('|' represents execution of two actions contemporaneously, while ';' represents execution of two actions sequentially):
π_0: `do_something_this_evening`(x_1)
$x_1 \in \{\pi_1, \pi_2, \pi_3\}$ where
π_1: `(find_a_friend(`x_2`)`$|$`find_a_place(`x_3`))`;`see_friend(`x_2, x_3`)`
π_2: `go_outside(`x_4`)`
π_3: `stay_home(`x_5`)`
$x_2 \in F = \{$`Helen,Mary,Bob`$\}$
$x_3 \in L = \{$`Cinema,Disco,Other`$\}$
$x_4 \in \{\pi_4, \pi_5, \pi_6\}$ where
π_4: `(find_restaurant(`x_6`)`;`go_restaurant(`x_6`))`
π_5: `go_to_bar`

π_6: `(find_concert(`x_7`);go_concert(`x_7`))`
$x_5 \in \{$`TV,bed`$\}$
$x_6 \in \{r_1, \cdots r_n\}$
$x_7 \in \{c_1, \cdots c_n\}$.

The problem formulation in this case will be $\Gamma_1 = \langle A_1, V_1, \Pi_1 \rangle$ where A_1 is the set of any possible plan among the above not necessarily instantiated with precise values for the variables, V_1 includes pleasure and friends availability and Π_1 is a choice (of the best thing to do this evening) statement. An alternative problem formulation could be $\Gamma_2 = \langle A_2, V_2, \Pi_2 \rangle$ where A_2 is like A_1, V_2 concerns time availability and Π_2 is always a choice statement. However, Γ_2 will occur only exceptionally (when time becomes a critical issue).

The intuitive reasoning of the above agent could be: usually friends are always available, therefore usually this an irrelevant dimension for my choice. However, in the case friends are not available then "with who I may meet" might become a priority. The above idea corresponds to the establishment of two evaluation models where $\mathcal{M}_1$ is "preferred" to $\mathcal{M}_2$:

- $\mathcal{M}_1 : \langle\ A = \{\pi_1, \pi_2, \pi_3\}$,
  $D =$ pleasure,
  $G = \{$pleasure : $\pi_1 >_p \pi_2 >_p \pi_3\}$,
  $\Omega = \emptyset$,
  $\mathcal{R} =$ choice)$\rangle$
- $\mathcal{M}_2 : \langle\ A = \{\pi_1(x_2, x_3) : (x_2, x_3) \in F \times L\}$,
  $D =$ attractiveness, the associate scale being $\{$Interesting,Acceptable,Non-interesting$\}$
  $G = \{$pleasure :I>A>N,
  $\Omega = \emptyset$,
  $\mathcal{R} =$ (classification, $\rangle$

Applying $\mathcal{M}_1$ the agent will choose π_1. In implementing this solution there are potentially 9 alternatives, but the result of the inquiry leads to only four:
$\{$(Bob,Cinema;BC),(Bob,Disco;BD),(Bob,Other;BO),(Mary,Other;MO)$\}$. The agent therefore has to apply $\mathcal{M}_2$. For this purpose (s)he uses the following model:
- all alternatives involving Helen are N;
- all alternatives involving Mary and Cinema or Disco are I;
- all other alternatives are NI.
All solutions are unsatisfactory and the solution set is empty.

The agent has to reconsider his problem and will be oriented in implementing his second best option: π_2. However, meanwhile the time dimension became critical. Therefore problem formulation Γ_2 becomes relevant, leading to the following evaluation model:
$\mathcal{M}_3 : \langle\ A = \{\pi_4, \pi_5, \pi_6\}$,
$D =$ (time forecast for each plan,
$t(\pi_4) = 1000, t(\pi_5) = 10, t(\pi_6) = 1000)$,
$G = \{$time : $x >_t y$ **iff** $t(x) < t(y)\}$,

$\Omega = \emptyset$,
$\mathcal{R} =$ choice)$\rangle$
and the choice will be plan π_5 which finally is implemented.

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 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 [41]) as a first step in integrating decision aiding methodology and formal reasoning languages.

It is out of the scope of the paper to describe in details how this approach works (the interested reader can see more in [63]). The basic idea is to enhance the reasoning capacity of the agent with a set of rules which enable him to express default preferences among models and problem formulations which can be "defeated" when exceptional situations occur, resulting in using the models which are preferred only under such exceptional circumstances. Under such a perspective the descriptive 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 modelling process each time from the beginning.

5 Conclusions

In this paper I introduced a descriptive 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 to establish 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.

The descriptive 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 the 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.

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