A Dynamic Model For Structuring Decision Problems

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Abstract

This paper develops a new model of decision problem structuring which synthesises a number of models and approaches cited in the decision making literature in general and the multi-criteria literature in particular. The model advocates a dynamic interaction between criteria and alternatives as a decision maker understands his preferences and expands the set of alternatives. This model endeavours to bridge the gap between prescriptive and descriptive approaches. It is prescriptive in its orientation, recommending an approach based on earlier prescriptive work. The model, however, is also validated empirically, based on the descriptive decision making literature and reported case studies of actual decision making.

1. Introduction

The structuring of decision problems is arguably the most important activity in the decision making process [22], [1], [20], [27]. According to Nutt [25], the failure rate for strategic decisions in general lies at about 50%, and the implementation rate for multicriteria decision-making efforts is even worse [14]. This suggests to us that existing decision problem structuring approaches are not entirely adequate to suit the needs of decision makers or, if they are, then decision makers are not using them. Practitioners and academics are calling for better decision problem structuring ([20], [32], and [38], to name a few); recognizing that, in general, improved decision structuring will improve the quality of the decision outcome. It is this call that motivates the work presented here.

In this paper we develop a conceptual model for multi-criteria decision problem structuring. Our starting position is consistent with that of Simon [29], where decision makers are assumed to be intendedly rational in their decision-making. This perspective of bounded rationality accommodates the persistent departure of decision makers' choice behaviour from strict economic rationality as a result of behavioural limitations, and is well documented (see, for

example, [19] or [3]). Also, this approach brings together our earlier work on process concepts in multicriteria decision making [13], [5], [6], and that of other authors, notably Wright and Goodwin [38].

Such rational approaches to problem structuring typically involve the determination of alternatives, criteria, and attributes to measure the criteria. The goal is then to develop ways in which these components can be generated and considered relative to each other. Previous efforts at decision problem structuring (which include [35], [17], [13], and [38]) address the creation of criteria and alternatives, and present arguments about their inter-relationships in a *static* way. The model we present here involves the *dynamic* interaction of criteria and alternatives, which helps explain where these components come from and how they can influence each other in the structuring process. We offer this model as a descriptive model of problem structuring behaviour, in that it accommodates a number of empirically validated models of decision making. We further offer this model as a prescriptive model, in that it follows from the earlier prescription of Henig and Buchanan [13], and others cited above.

The distinction, and the gap, between descriptive and prescriptive models is important and reflects the different perspectives adopted by the Psychology and Management Science research communities, respectively. The descriptive perspective focuses on how we actually *make* decisions and the underlying reasons for such behaviour. The prescriptive perspective considers how we *should make* decisions with a view to improving the quality of decision-making, both in terms of process and outcome.

This paper, then, bridges the gap between prescriptive and descriptive models of decision making. Prescriptive models lack empirical validity and often require a standard of rationality that is theoretically satisfying but practically unobtainable. Descriptive models, while rich in their description of real behaviour, are often context-dependent (in respect of both decision making context and decision maker cognition), thereby limiting their general applicability for prescription. One principle underlying our approach here is to draw heavily from both perspectives and synthesise them into an approach that has a well-reasoned foundation, clear empirical support and which potentially can be used in practice.

2. Defining Problem Structuring

Simon [31] proposed a three-phase decision process that continues to be the foundation for many decision making methodologies. The three phases of this well-known process model are intelligence, design and choice. Intelligence involves determining if a problem that has occurred actually requires a decision, which in turn involves some information gathering activities. Once the decision has been identified, the design phase begins – which we refer to as decision problem structuring – where alternatives, criteria and attributes are identified and considered. The final phase is choice which, based on identified criteria, describes the activity of selecting the most appropriate course of action (alternative). Since our emphasis is on multiple criteria, the identification and role of criteria in the design stage is of immediate and particular importance. Simon later added, but rarely discussed, a fourth stage entitled review activity, which involved reviewing past choices.

Despite the development of many models that describe and prescribe the structuring of decision problems, it remains as much art as it does science. There is no single agreed upon definition of this important aspect of the decision process. However, we adopt the definition provided by Keller and Ho [17]: the specification of states of nature, options, and attributes for evaluating options.

Woolley and Pidd [39] propose a scheme for categorising definitions and approaches to problem structuring. Although their review of problem structuring may appear dated, their categorisation captures the philosophical differences of these approaches. Their four streams are:

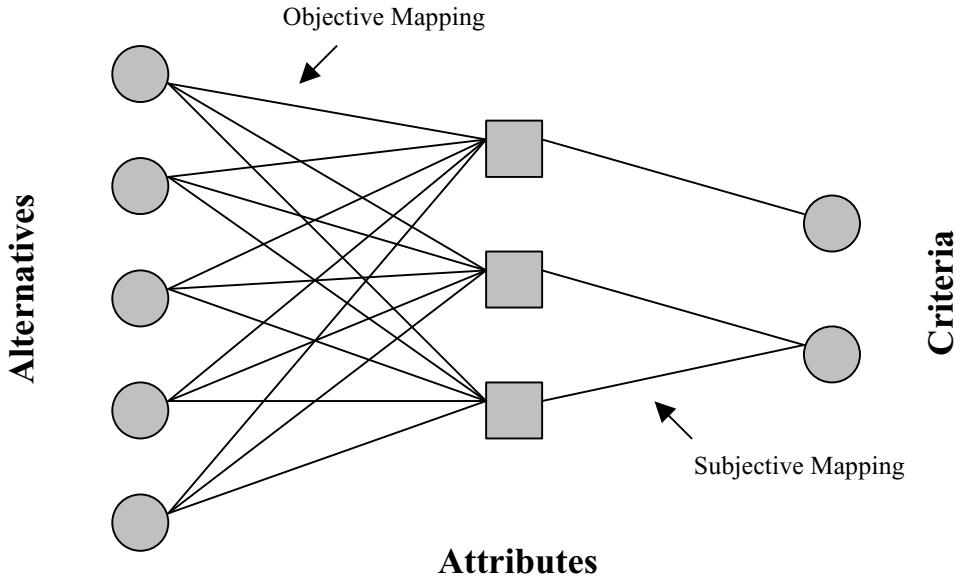
- A *Checklist Stream,* where problems are seen as failures or breakdowns, so a step-by-step procedure is sufficient to correct the problem.
- A *Definition Stream,* where problems are seen as a collection of elements such as criteria and alternatives, and the goal is to put these elements, or variables, into some sort of (decision) model.
- A *Science Research Stream,* where quantitative data is gathered in an effort to uncover the "real" problem and its underlying structure.
- A *People Stream,* where problems are individual and/or social constructions of differing realities, so problems do not exist as concrete entities, but from different perceptions.

We give particular attention to the definition and science research streams as most approaches for structuring decision problems fall into one of these. The checklist stream addresses simple, routine decision problems, such as diagnostic checking. Soft Systems Methodology [7], where multiple perspectives are considered, is one example of the last stream. In terms of streams two and three, an important distinction should be made. Problem structuring approaches that assume a particular structure a priori belong to the definition stream. Most decision problem structuring (including our proposed approach) falls into this stream. For example, Decision Analysis [16] and [28], assume a particular structure of criteria (that is, an objectives hierarchy) and alternatives and seek to formulate the decision problem according to that structure. Stream three, however, is more consistent with traditional Operations Research (OR) modelling. Here, data are uncovered about the problem and, based on this data, an appropriate structure is used, typically some type of OR model. While a range of models potentially exists, the particular choice of model is determined from scientific research of the problem data; that is, it comes from the data rather than being a priori assumed. In addition to OR modelling, stream three is well exemplified by Gordon *et al*.'s [12] nine generic problem structures, which include new product, distribution channel, acquisition, divestment, capital expenditure, lease-buy, make-buy, pricing, and manpower planning problem structures. Our proposed approach is firmly grounded in the *Definition* stream.

We note that while Woolley and Pidd's *People* stream seems conceptually different from the others, one can argue that the other three streams might be occurring within the differing realities of the many individuals involved in a particular decision problem. That is, the first three streams might capture the different structuring approaches available, while the fourth stream recognises that not all decision makers structure a given decision problem in the same way. As we point out later, this latter statement seems to be true.

Most decision modelling/structuring, and especially multicriteria decision making, is based on a conceptualisation in terms of criteria and alternatives. Criteria and alternatives are mutually defined, and are the fundamental components of any multicriteria decision problem. Criteria reflect the values of a decision maker and are the means by which alternatives can be discriminated. Alternatives are courses of action which can be pursued and which will have outcomes measured in terms of the criteria. Henig and Buchanan [13] and Buchanan *et al.* [6] present a conceptualisation of the multicriteria decision problem structure in terms of criteria and alternatives, with attributes as the bridge between them. More precisely, attributes are the objectively measurable features of the alternatives. Therefore, the decision problem was structured so as to separate the subjective components (criteria, values, preferences) from the

objective components (alternatives and attributes), with a view to improving the decision process. This model is presented in Figure 1.



1. Mapping Between Criteria and Attributes, Attributes and Alternatives [6].

Figure 1 is a static conceptualisation, or model, of a decision problem consistent with Woolley and Pidd's [39] definition stream. It presents a framework comprising the components of criteria, alternatives, attributes and their interrelationships, and proposes a partition into subjective and objective aspects.

Recent discussions have occurred in the literature regarding the creation of and inter-relationships between all these structuring elements. Keeney [15] provides a way of thinking whereby criteria are identified first in the decision making process, then alternatives are creatively determined in light of such criteria and choice is then made. Known as value-focused thinking (VFT), this has been advocated as a proactive approach wherein explicit consideration of values leads to the creation of opportunities, rather the need to solve "problems." However, Wright and Goodwin [38] suggest that values are not sufficiently well formed in the early stages of decision making to be able to do this. They agree with March [21] that values and criteria are formed out of experience with alternatives and suggest decision simulations as a way to discover hidden values and, subsequently, promising alternatives. Subsequent comments by noted researchers in the same issue as their paper appear to agree with them, but argue that such simulations might have difficulties in practice.

We call the process of first determining alternatives, then applying value and preference information to them in order to make a choice, alternative-focussed thinking (AFT), as do many others. It is clear from the descriptive decision making literature that AFT is easily the more dominant procedure (for example, [24]). This is also the case when one considers the prescriptive multicriteria decision making literature. The majority of these prescriptive models explore decision maker values in the context of an already fixed and well-defined set of alternatives. This imbalance is not surprising. In Figure 1, alternatives are objective, and in the experience of most decision makers, they are usually concrete and explicit; they are what decision makers most often confront. In contrast, criteria are subjective, abstract and implicit, and their consideration requires hard thought. Therefore, it makes some sense descriptively to

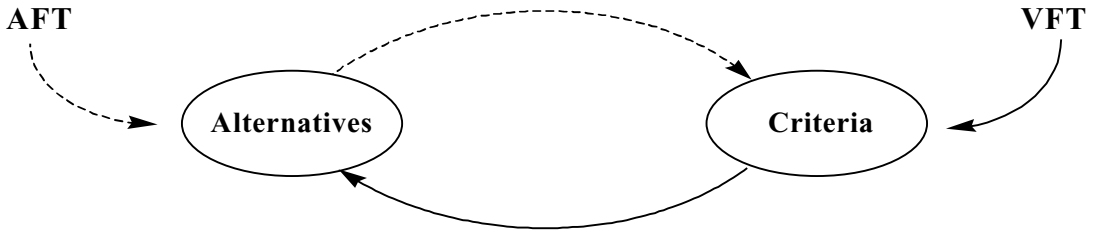
start a decision process with what is obvious and measurable, such as alternatives. This discussion gives rise to the conceptual model of problem structuring presented in the next section.

3. A Dynamic Model

The model presented in Figure 1 merely specifies problem structuring *elements* and does not give rise to a *process* of problem structuring. It does not specifically address the process of how preferences can be better understood or how the set of alternatives can be expanded. How are the elements of such a structure (criteria, attributes and alternatives) generated to begin with? That is, where do alternatives come from? And where do criteria come from?

In order to address these questions, we build upon the model in Figure 1. It is difficult to determine which should or does come first – criteria or alternatives – since both are vitally important to the decision problem structuring process. However, our own casual observations of decision-making activity suggest that both generate the other interactively. This is supported by the literature. For example March [21], as cited by Wright and Goodwin [38], argues that experience with and choice among alternatives reveals values – and by implication, criteria. This is the thrust of Wright and Goodwin. Decision makers need to "test drive" – undertake a decision simulation of – the alternatives in order to find out what they really want.

Henig and Buchanan [13] proposed that attributes form the bridge between criteria and alternatives and act as a translation mechanism. That is, as we soon illustrate by example, a decision maker moves from considering criteria to attributes to alternatives. This idea, together with the above discussion, gives rise to a new model of decision problem structuring involving these components. Our proposed model is presented simply in Figure 2, without attributes. The model shows criteria and alternatives joined in a sort of causal loop, with entry into the loop either using AFT (dotted line) or VFT (solid line). This interactive model states that thinking about alternatives helps generate criteria, *and vice-versa*. That is, neither of these two structuring elements can be thought of alone, independent of the other.



2. A Dynamic Model of Problem Structuring, Relating Alternatives and Criteria

As an illustration of the dynamic model of Figure 2, consider a car purchase decision. While driving down the road in your car, you decide it is time to replace your car. Perhaps you think that the car is old and costs a lot to repair, and it does not have the acceleration it used to have. Thus, you have begun to identify a gap in performance, between what you have and what you want. In Simon's terminology, identification of a gap belongs in the intelligence phase; Nutt [24], in his description of decision-making cases, suggests that all decision structuring begins

with a gap. The gap in this illustration is a gap in values or criteria, which suggests that the process began with VFT, since you are loosely thinking about criteria (or, at least, discrepancies in criteria). But where did these thoughts about performance, about criteria, come from? They most likely originated from some consideration of alternatives; perhaps comparing your present car with a recollection of your car when it was new. It is therefore not entirely clear whether you necessarily started with VFT or AFT, and continuing the backward regression could justify starting with either. Perhaps where you started does not matter. However, you do start on the "decision journey" and you initially give your attention to either criteria or alternatives. Let us just say that in this illustration, your initial focus is on criteria.

However, as you drive your car, you begin to notice that certain other cars also look appealing, say Brand X, since they appear quick to accelerate, reasonable in price, and are about the size of your current car. In terms of our model, then, you now have moved in your thinking from the criteria oval to the alternatives oval. So, you go to the closest Brand X dealership to investigate further the Brand X cars you have observed while driving. You quickly notice that their prices generally are very reasonable and you "test-drive" a few of them; that is, you experience first hand some of the alternatives and learn more about their attributes. You discover that while they are quick and about the same size as your current car, they also seem more "tinny" than your sturdy old car. You thus start thinking about safety issues and how the modern highway is full of sport utility vehicles (which have high profiles). You deem that your small compact is no longer appropriate on the same road as such vehicles, so safety becomes a salient issue in this decision problem. By considering these particular attributes of the alternatives, you now have surfaced a new and different objective (that is, you have moved back over to the criteria oval in Figure 2).

Next you start to investigate other car brands (alternatives), and realise that there are a range of other manufacturers that address your previously stated criteria, as well as this new criterion of safety. Test-driving these new models then leads to further new criteria (such as a "roominess" or "salvage value" criterion), and so the iteration between criteria and alternatives continues. How choice ultimately is made is not our concern in this paper, but as outlined here, structuring is shown as a dynamic interaction between criteria and alternatives. It demonstrates one problem with just VFT, as implied in a quote by Nutt ([24], page 247), who paraphrased Wildavsky [37], "…managers do not know what they want until they can see what they can get." It also highlights the main problem with just AFT. AFT would require a decision maker to generate all alternatives a priori, perhaps only Brand X and a few others, then apply preferences to choose from among this set. No opportunity would have been available in such a procedure for discovering what is truly wanted in the decision problem, since values and criteria would have been considered too late in the decision problem structuring process.

4. Validating The Model Descriptively

This section considers the empirical or descriptive validity of the dynamic model. The first test determines whether or not our model accommodates current descriptive theories and models of decision making. There are many descriptive theories of decision making. Many descriptive models deal with the entirety of the decision making process [22], [23], or just with the choice phase [10], [33]. However, we pay particular attention here to those decision making models that on the surface concentrate mainly on decision problem structuring. Consequently, we consider three of the more enduring and valid models in the descriptive literature, relative to our dynamic model: Recognition-Primed Decisions [18], Image Theory [4] and the Garbage Can Model [8].

To summarize this part of the validity tests, we feel that at least two of the currently popular descriptive models of decision-making (Recognition Primed Decisions and Image Theory) provide empirical support for our model. That is, there are elements of these two models that indicate that decision makers develop some sort of interaction between criteria and alternatives, which forms the basic concept underpinning our model. This interaction, however, is not necessarily valid for all descriptive models of the decision making process. One might argue that the Garbage Can Model has no real structuring phase at all, so no current model of problem structuring would seem to fit this model.

Our second validation test determines if empirical evidence seems to be explained by our model. We use two previously published large sample studies of decision cases involving real managers, both by Nutt [24], [26]. These studies provide empirical support for Figure 2 as a descriptive model of the problem structuring process for some decision makers. That is, Nutt's [24] *Reframing* formulation process and Nutt's [26] *Cyclical Search* alternative uncovering process each seem to be similar to our model. However, we note that each of these processes were the least used in Nutt's two studies. This is not surprising. It is well known that when using iterative processes, a decision maker's tendency toward satisficing often results in premature termination – this is what satisficing is. In practice, decision makers seem to stop early and consequently do not gain the benefits from that extra iteration.

Also, since these two models of *Reframing* and *Cyclical Search* were the most successful in Nutt's studies, this suggests that Figure 2 has potential as a good prescriptive model for the decision problem structuring process.

5. Discussion

Watson [36] and Dando and Bennett [9], among others, reject the supremacy of the rational model of decision making as being impractical and at odds with actual decision making behavior. The tendency for decision makers to discard values and even attributes is well documented. French [11] and Kasanen, *et al*. [14] argue that the assumptions assumed by many methods may not agree with the practical findings of behavioral science. It should not be surprising, then, that some non-quantitative methods, apparently without any rational basis, attract the attention of decision makers. This suggests that there is a demand for decision making tools provided they are tailored to actual decision maker behavior. Furthermore, Henig and Buchanan [13], conclude that the decision making process should not focus on selection, which is at the heart of the rational decision making paradigm, but rather involve understanding and expanding. They advocate a shift in the rational model of decision making and not a total rejection of it. The goal of finding "the right answer" is not what decision making should be all about.

The reader may now justifiably ask, "so which method do you recommend for the decision maker who needs advice?" Our answer is: clearly, any method that endeavors to understand and expand - in this case, as applied to alternatives and criteria. Figure 2 shows how this is done; criteria not only evaluate the alternatives but also generate them. Alternatives are not only to be ranked and selected by criteria, but they also reveal criteria. This paper does not suggest a method for doing this in detail, but we have outlined here the theoretical, empirically grounded, foundation for decision problem structuring. This shifts the focus of methods away from techniques of selection, which are too technical, and should attract at least a few decision makers.

We reserve the development of a method for doing this for future research. Certainly, the decision simulation ideas mentioned by Wright and Goodwin [38] could be part of this

development, and the literature on creativity should contribute as well (for example, [2]). However, we anticipate that decision makers should iterate between alternatives and criteria, at least twice, regardless of where they enter the loop. Certainly, more experienced decision makers might have an established history of such iterations, and they may not need as many new iterations as those less experienced. As Simon [30] has pointed out, the observed behavior of decision makers is to satisfice. In terms of our model, this means they perform only one iteration and prematurely stop the decision making process. The entire point of our model is that they can do better in their decision making if they perform two or more iterations.

We have restricted our discussion to the field of multi-criteria, since most real-life problems involve more than a single criterion. We note that our model, which attempts to allow decision makers to understand and expand their thoughts regarding criteria and alternatives, is similar to ideas mentioned by others in this field. Vanderpooten [34] argues that in any multi-criteria procedure, iteration should, or perhaps does, occur between two phases of the decision making process: learning and search. He states that decision makers do not have well formed preferences when facing a decision problem. Preference structures become better formed as decision makers relate past experiences and present explorations of alternatives to the decision problem at hand. He further states that the decision process is an iterative sequence of such activity, which appears conceptually similar to what we propose in this paper. Also, Kasanen, *et al*. [14] discuss how decision alternatives are not well developed during most decision processes and therefore need to be developed further using creative methods. They further discuss how not all decision-relevant criteria are known by the decision maker at the start and need to be discovered during the decision process. We think that our model helps address these problems in a practical way.

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