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Foreword

The author of this paper expresses an assessment of current approaches to research in multicriteria decision making that are more relevant from his point of view to the treatment of real life issues. The author is a prominent researcher in this field.

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New Directions in Multicriteria Decision Making Research

Oleg Larichev

1. Classification of Decision Problems

In reviewing modern literature on decision making one observes that most often it is defined as a process of choosing a decision alternative characterized by multicriterion estimates. Multicriteria problems are widespread due to their proximity to numerous real-life situations in which a number of different but essential parameters of the presented problem have to be taken into consideration. Let us begin with the classification of multicriteria decision making problem [4].

The first level of classification is existence (or absence) of an objective model representing the real problem. There is a class of decision making problems in which it is possible to build a reliable quantitative model as we do in operations research. In this case, the quality of solution is estimated by many criteria. The second wide class of decision making problems is the class in which we have only subjective model - decision maker's perception of reality.

With respect to the amount of information available to a decision maker, we can divide decision problems into two quite different classes: problems in which the decision maker can himself be an expert (as he or she is able personally to evaluate the decision options both as a whole and by separate criteria) and problems in which the roles of the decision maker and the experts involved differ considerably.

It is characteristic of the first class of problems that the decision maker has a holistic simulacrum of alternatives, i.e. a 'gestalt'. Very often this gestalt is much more meaningful than its formal presentation through a set of estimates on multiple criteria. Many problems of this kind arise, for example, when a buyer chooses everyday commodities [1]. Hereafter we shall refer to this class of problems as ***holistic choice problems***.

The second class of problem is inherent in cases in which the decision maker alone does not have enough information to perceive the characteristics of the alternatives. Here, the relevant data are furnished by the respective experts. The decision maker specifies the set of parameters (criteria) defining his attitude toward the problem under consideration, and formulates a decision rule. A problem of this kind could be exemplified by a choice among complex socio-economic systems. We shall refer to this class of problems as ***criteria-experts choice problems***.

The characteristic feature of decision problems is their novelty to decision makers. In some cases, with repetitive decisions, it is possible (on the basis of information about the implications of preceding decisions) to elaborate the best decision rule. In other cases one can define the best approximation for complex choice rules [5]. Much more complex are the problems of unique choice, in which either the problem itself or the choice environment are new.

The proposed classification of choice problems is presented in Figure 1.

		Criteria-experts choice	Holistic choice
Objective models with several criteria	Unique decisions	A	B
	Repeated decisions	C	D
Subjective models with several criteria	Unique decisions	E	F
	Repeated decisions	G	H

Figure 1.

Examples of different types of problems are the following. The A- and C-type problems are problems of multicriteria mathematical programming. The typical example of B-type is a choice of design parameters for different machines [18]. Many examples of E-type problems can be met in various books on decision analysis

[7] and multicriteria decision making [11]. The example of G-type problems is a problem of graduate admission [3]. F-type problems are frequently encountered in everyday life (job choice). We can cope with H-type problems by construction experts systems.

2. Axiomatic Methods and their Critique

The 1970s saw the final completion of the axiomatic decision theory based on the classic expected utility theory of Von Neuman and Morgenstern [13]. For the most common multicriterion decision problems, the axiomatic theory was logically embodied in MAUT - multicriterion (or multiattribute) utility theory. The methods, of axiomatic nature, are described in detail in [16]. These techniques involve the following: the problem of evaluation of decision alternatives is confined to the problem of axiomatic validation and construction of a utility function. Each set of axioms (e.g. axiom of existence, axiom of 'resolution', axiom of independence (cf. Fishburn, [5])) is related to a specific type of utility function. The validity of axioms is determined on the basis of information furnished by the decision maker. Depending on the data obtained, an inference is made that a particular type of utility function is appropriate.

From the formal point of view MAUT seems explicit and correct. Probably, therefore, many people treat this theory as the only scientifically-based validation of decision methods.

Along with the works on MAUT construction, the mid-1970s witnessed the emergence of new papers questioning the very fundamentals of axiomatic methods, i.e. questioning their ways of eliciting data from experts and decision makers. In relation to expected utility theory, this kind of paper had appeared still earlier (e.g. the well-known Allais paradox; Raiffa [14]). However, the crucial article in this respect was the one by Tversky and Kahneman [19] which casts doubt on the possibility of correctly obtaining event probability estimates. Such possibilities were not questioned at all in the well-known works on validation of axiomatic techniques.

The Tversky and Kahneman papers were accompanied by the works of Slovic, Lichtenstein, and Fischoff, providing an analysis of actual human behavior in complex decision problems [17]. The general conclusion from all these works seems rather unfavorable for the MAUT proponents: the capacities of human beings in information processing are rather limited and only the flexibility of humans, their ability to adapt, conceals these constraints from researchers.

The recent works mentioned above are descriptive and study human behavior in decision problems. Thei behavior is not simply a deviation from the 'optimal' one (relating to the expected behavior within the normative techniques) - it is entirely different in nature from the assumptions in the earlier model. This questions are the very fundamentals of MAUT.

Due to all this, the current state-of-the-art of decision theory and methods is rather obscure. The most solid structure of decision theory - MAUT - is seriously shaken: the MAUT-based techniques are at least in no way superior to other, so-called heuristic methods. In fact, there are many such methods in decision making practice. There are the well-known direct incomparability threshold techniques, man-machine techniques and the like. Many have been successfully applied to practical problems.

Of course, many of the existing decision techniques are well suited to the peculiarities of particular practical problems. No doubt they are quite useful. But there is always a question: can there be a scientific basis for choice of a particular decision technique? How can one distinguish between the 'suitable' and 'unsuitable' methods for different practical situations?

2.1 Capacities of man in decision problems and their limits

The question of what man can and cannot do in decision problems is at present one of the most debatable. As was previously mentioned , a number of papers in recent years had conclusions pointing to the limited capabilities of man in numerous decision problems [15, 19].

What can we confidently say about the actual capabilities of decision makers and experts in decision problems? First of all, it is worth noting that the capabilities of human beings depend, to a considerable degree, on the type of problem handled. Second, they depend heavily on the way of obtaining the relevant information from people.

First of all, let us review the basic (and most indisputable) facts characterizing the human information processing system. At present, the majority of psychologists believe that the hypothesis that people possess both short-term and long-term memories is rather credible, and that the short-term memory capacity is very limited: it contains seven blocks, seven structural data units [8]. Simon [16] believes that

> *the evidence is overwhelming that the human information processing system is basically serial in its operation: that it can process only a few symbols at a time and that the symbols being processed must be held in special, limited memory structures whose content can be changed rapidly.* (p.53)

The limited size of short-term memory means that one has to adapt to problems which involve complex information processing, seeking ways to find the solution. Hence it is worth mentioning *plasticity* as the second major characteristic of man when processing complex information. Man either adapts to a complex problem or adapts it to his own capacities. Several heuristics may be used by people in handling complex multicriterion choice problems [12].

Heuristic methods may also be employed by people when assigning probabilistic estimated [19].

The third key characteristic of a man is his ability for learning from his previous actions (most often by trial-and-error technique). As a result, long-term memory (with its practically unlimited capacity) accumulates data on preceding problems and the outcomes of their solutions.

These three major characteristics of the human information processing system throw light on people's behavior in various decision problems. It is clear that in case of repetitive decision problems man can accumulate in long-term memory the standard form of the problems and the respective solutions worked out in the process of learning.

The decision maker's capacity in holistic choice problems are enormous as he is able to use his gestalt of the alternatives as a structural data unit. As a rule, this gestalt is more complete than the respective set of attributes characterizing the alternatives.

The problem which are most complex to handle are those 'unique criteria-experts choice' problems where one is unable to pick out a standard decision or a holistic image of the alternatives from long-term memory as none is available. When facing such problems, the decision maker has to consider separately the assessments of the alternatives on all relevant criteria, which is an excessive load on short-term memory. This can lead to conflicting and differing answers on the part of decision makers and to the application of simplistic heuristics.

number of classes to decide between (from two to four) in one and the same problem, the subjects considerably simplified their strategies. The increased pressure on the frame of reference forced the subjects to switch to quite primitive ways of transferring a part of the set of criteria to act as constraints.

Thus a large body of research confirms the limited capabilities of decision makers with respect to decision problems. The constraints on the way a problem can be handled depend considerably on the type of problem, the way the data is elicited, and on the complexity of the problem. Of course, there is a marked dependence on the motivation of the person who is handling the problem. With any given amount the motivation, however, there are still certain limits to decision makers capabilities. Often it is hard to identify these limits, as they may be disguised through the ability of a person to adapt to a specific problem. Thus, in a problem involving the direct evaluation of multiattributed alternatives, only the analysis of the decision maker's decisions according to the criteria of transitivity, stability, and the complexity of the decision rule employed provides the possibility of identifying the actual capabilities of the decision maker. The application of any of these three criteria on its own does not provide an adequate understanding of the decision maker's behavior.

3. Analysis of Elementary Operations of a Decision Maker

New results in psychological research give us the possibility to study existing decision making methods from the psychological point of view.

A question arises how to estimate the validity of those methods. The following approach is suggested: it is necessary to study thoroughly the phases of a decision maker's choice while segregating simple information processing operations. Then the decision maker's capabilities in performing these operations must be evaluated. Such estimates permit us to characterize the validity of decision methods as a whole.

All information processing operations performed by a decision maker may be classified into three groups: operation with criteria; operation with values of criteria; operation with alternatives.

An operation is referred to as elementary one if it cannot be broken down to other operations associated with the objects of the same group.

All these operations are classified by the following categories:

- complex (C), if there are results of psychological research indicating that in implementing these operations the decision maker makes a lot of contradictions or employs simplified strategies (e.g. disregard some of the criteria);
- admissible (A), if there are results of psychological research indicating that either these operation are routine for the decision maker or there are indications that he is able to perform them with a small number of contradictions and using complex strategies, for example, combination of criteria values;
- uncertain (U, UC, UA), if there are no results of psychological research concerning these operations, but by analogy with the known facts we can make a preliminary conclusion about admissibility (UA) or complexity (UC) of an operation.

On the basis of a review of existing multicriteria methods the list of elementary operations [1] is formulated (see Table 1).

The detailed explanation of elementary operation's general estimates is given in [4]. Those estimates can be explained in many cases by main characteristics of human information processing system which were analyzed in [4, 10].

On the basis of estimates of elementary operations we can evaluate the validity of many existing decision making methods. Two examples illustrate the idea.

(1) The method of weighted sum of criteria estimates. The utility (U) of multicriteria object is equal to

$$U = \sum_{i=1}^{N} w_i x_i$$

where x_i - an estimate of the object on i-th criterion ($i = 1,\ldots,N$), w_i - weight of i-th criterion.

This method is based on operation 011 which is complex. There are results of psychological studies indicating the decision maker provides a lot of contradictions. So, this method invalid from this point of view.

(2) Geoffrion-Dyer method [6] for multicriteria linear programming problems. The operation performed by a decision maker in the framework of this method can be decomposed to 023 and 031. These operations are complex.

Table 1.

Operation number	Name of elementary operation	General estimate
	01 Operational with criteria	
011	Assignment of criteria weights	C*
012	Criteria ordering by significance	A*
013	Nomination of probabilities	C
	02 Operations with criterion estimations of one alternative	
021	Comparison of two values on a single criterion scale	A
022	Comparison of two criteria values variation	A
023	Quantitative definition of a criterion vallues variation that is equivalent to variation of another criterion value	UC
024	Assignment of satisfactory value by single criterion	UA
	03 Operations with multicriteria alternatives	
031	Comparison of two alternatives and identification of the better one	C*
032	Choice of the best (worst) alternative from a set	C*
033	Determination of an "ideal" alternative the degree of proximity to which determines the quality of the current solution	C
034	Comparison of holistic images of two alternatives	UA
035	Classification of alternatives	A*

*Depends on the size of the problem.

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