5 NORMATIVE AND DESCRIPTIVE ASPECTS OF DECISION MAKING

Oleg I. Larichev

CONTENTS

Abstract: The problems of human behavior in decision processes are central in this chapter. The gaps between the requirements of decision methods and the possibilities of human information processing systems are analyzed. The qualitative model describing the decision maker’s behavior is proposed. The model defines the guidelines for the construction of decision methods justified from behavior point of view.

5.1 SPECIFIC FEATURES OF DECISION MAKING AS A BRANCH OF RESEARCH

Decision Making, as a branch of research, has two main features distinguishing it from other research disciplines such as Economics and Operations Research:

1. For typical Operations Research problems, the information needed to solve a problem is given in the problem's statement. Contrary to the latter, the initial statement of any decision making problem has elements of uncertainty connected with a lack of information on general criterion of the solution's quality and/or the consequences of the decision's variants. This is why information from a Decision Maker (DM) and experts is required for the solution of a decision making problem. It is possible to say that a statement of any decision making problem includes a priori unknown preferences of the DM. This is why inside any decision making method there are some procedures of information elicitation from the DM (or a group of DM).

2. The primary step in many economical studies and in Operations Research is the construction of models representing the *reality*, small pieces of the real world having a mathematical description. In contrast to the latter, typical Decision Making problems imply the construction of a *subjective* model representing the personal perception of such a decision problem by the DM as the primary step. This subjective model reflects the DM's policy in the situation of a choice.

The distinguishing features of Decision Making as a research branch make the DM the central figure of the decision making process. Therefore, behavioral aspects become the central features in this line of research.

The goal of this chapter is to look at the Decision Making field of research from this point of view, to summarize the existing knowledge about human behavior in the decision processes, to analyze the existing gap between descriptive and normative approaches in decision making, and to draw some criteria for the construction of decision aiding tools and to demonstrate the importance of behavior aspects.

5.2 THE GAP BETWEEN DESCRIPTIVE AND PRESCRIPTIVE

The source of the widely accepted gap between the requirements of decision methods to human beings and the possibilities of human information processing systems lies in the historical development of Decision Making as a research field.
Decision Making has two roots:

- economical utility theory;
- operations research.

5.2.1 Utilities and probabilities

Each portion of a purchased commodity (e.g., bread or tea) has its consumer utility. The law of marginal utility reads as follows: the marginal utility decreases, that is, subsequent portions of a commodity are less valuable to the consumer than initially, which is quite understandable from our everyday experience. If there exists a need for several commodities, the consumer attempts to allocate money to support a constant ratio of the utility of a commodity to the general measurement unit (dollars, rubles, etc.).

Stated differently, more money must be invested into commodities of higher utilities. The same human behavior is inherent to the problem of investments - more money is put into more useful areas of activity. Economists believe this is the only correct behavior and refer to the person making such a choice as *a rational person*. It is assumed that rational persons are intrinsically consistent and that transitivity of choice is appropriate to them.

Second, it is assumed that, when making a decision, a rational person maximizes his utility.

To conclude, what does the rational person do? First of all, they list all possible decisions and their consequences for which utilities (or money values) are determined. For each variant of a decision, the probabilities of all its outcomes are determined (no matter how). Next, the expected utility of each variant is calculated by summing the products of utilities by corresponding probabilities. The best variant is that which has the maximum expected utility.

J. von Neumann and O. Morgenstern laid the scientific foundation for the utility theory in their well-known "Theory of Games and Economic Behavior" [48]. The utility theory as presented in this book is axiomatic. The originators of the utility theory made use of so-called lotteries, where two results (outcomes) with respective probabilities exist, as simple problems of choice and demonstrated that if human preferences for simple problems (lotteries) satisfy some axioms, then human behavior can be regarded as maximizing expected utility.

The axioms used by the authors of [48] assert, for example, that a person can compare all outcomes and he/she is transitive, due to possibility of determining the probabilities under which lotteries constructed on pairs of outcomes (out of three) are equivalent, etc. The axioms are required to infer the theorem of existence of the utility function for a person that agrees with the axioms.

The internal utility function of the DM is used to measure the utility of any outcome. The theory presented in the classic book by J. von Neumann and O. Morgenstern needs a quantitative measurement of all utilities and probabilities.

Von Neumann and Morgenstern’s theory assumes that probabilities are given as objectively known magnitudes. D.Savage [39] developed an axiomatic theory enabling one to measure simultaneously utility and subjective probability which gave rise to the model of Subjective Expected Utility (SEU) where the probability is defined as the degree of confidence in fulfillment of one or another event.

Together with the development of utility theory and SEU some findings appeared concerning human behavior in the lotteries choice. Well known is the so-called Allais’ paradox that was the object of hot disputes for several years [37]. People repeatedly demonstrated contradictory numerical evaluations of utility in the tasks of choice.

Inconsistent human behavior in lotteries choice was demonstrated [5]. Furthermore, it was demonstrated that people don't believe in Savage axioms [43]. The difficulties of checking axioms in the applications became evident.

The entire research on Decision Making theory was greatly influenced by the psychological studies of P.Slovic, A.Tversky, B. Fischhoff [14], et al., who demonstrated the existence of human errors made when evaluating event probabilities. The main causes of these errors can be represented as follows [14]:

- Judgement from representativeness: people judge about the membership of an object A to the class B only from its similarity to the typical representative of B disregarding the a priori probabilities.
- Judgement from availability: people often evaluate the probabilities of events on the basis of their own meeting with such events.
- Judgement from the anchoring point: if initial information is used as a reference point for determining probabilities, then it exerts significant influence on the result.
- Superconfidence: people place too much confidence in their evaluations of event probabilities.
- Tendency to eliminate risk: people try to eliminate risky situations as much as possible.

These work may bring into question the possibility of practical application of utility theory and SEU theory.
Clearly, it was the first demonstration of a gap between descriptive and normative.

5.2.2 Prospect theory

Attempts were made to update utility theory so as to eliminate the most salient discrepancies between theory and real human behavior. The Theory of Prospects [4, 15] is the most conspicuous attempt of this kind. By prospect we mean a game with probabilistic outcomes.

Prospect theory allows for three behavioral effects:

- certainty effect, that is, the tendency to give greater weights to determinate outcomes,
- reflection effect, that is, the tendency to change preferences upon passing from gains to losses, and
- isolation effect, that is, the tendency to simplify choice by eliminating the common components of decision variants.

All these effects being taken into consideration, the value of a lottery to gain outcomes x and y with respective probabilities p and q is defined by multiplying the utilities of the outcomes by the subjective importance of the probabilities of these outcomes. The function of the subjective importance of the probabilities has some specific features that allow one to avoid the Allais' paradox and give some explanations to other disagreement between the theory and human behavior.

The theory of prospects recommends to "edit" prospects before comparing them - for example, to eliminate identical outcomes with identical probabilities, to merge in one prospects with identical outcome, and so forth.

Despite the fact that the theory of prospects eliminates some paradoxes of choice stemming from the utility theory, it does not eliminate all problems and paradoxes appearing upon studying human behavior in the problems of choice. The possible paradoxes appear when editing the prospects. A solution of the problem depends very much on the way in which one “frames” it. Furthemore, the quite natural desire to round the probabilities and utilities leads to different results of the prospect comparison depending on the rounding [53].

The prospect theory, as well as the utility theory relies on an axiomatic basis. A common problem with all axiomatic theories is the validation of the axioms allowing one to use one or another form of the function of utility (value) of the theory.

The common feature for the utility theory, SEU and the prospect theory is the same representation (model) of the decision problem: in the form of the holistic parameters of the utility (value) and probability. In the middle of the 70-ies a different model became more popular and promising: the multicriteria description of the positive and negative factors influencing the choice. The reason is that utilities and probabilities manifest itself in the multiple criteria of alternatives’ evaluation.

5.2.3 Multiattribute utility theory

The next step in the evolution of the utility theory was marked by the transition to the multicriteria or Multiattribute Utility Theory - “MAUT” [16]. The construction of a strict and harmonic mathematical theory of utility under multiple criteria was a great merit of R. Keeney and H. Raiffa. The theory is constructed axiomatically, where the general axioms of connectivity and transitivity on a set of alternatives, etc., are complemented by the axioms (conditions) of independence. There exist many conditions [12] which conceptually define the possibility of comparing alternatives in one criteria, while the estimates in other criteria are being fixed (at different levels). For example, the condition of the preference independence states that comparisons of alternatives in two criteria are valid if their estimates in other criteria are fixed at any level. If the conditions of such a kind are met for all pairs of criteria, then the existence of a utility function in different forms is proved. We note that the Multicriteria Utility Theory is directed to the problems where existence of many alternatives justifies great efforts that are required to construct a utility (value) function.

After the development of “MAUT”, critical comments were made about possibilities of validating all axioms and conditions needed for the existence of a multicriteria utility function in one or other form. For example, the sum of the importance coefficients of the criteria is to be equal 1 for the existence of a utility function in the additive form [17]. The question is: if we take into account the possible small errors in the measurement, which value of the sum is close to 1? [51].

In the construction of one dimensional utility functions the lotteries were used as the preferences elicitation tool. But human behavior in a lottery choice is inconsistent [5].

Again there is an evidence of a gap between the requirements of the decision methods (normative) and the possibilities of the human information processing system (descriptive).

5.2.4 Multicriteria counterparts of the well-known problems of operations research

The second root of Decision Making as a branch of research is Operations Research.

The introduction of multiple quality criteria enables one to obtain multicriteria counterparts of the well-known problems of the operations research. For example, additional criteria are readily built into the generalized transportation problem [49] which can be formalized as a multicriteria problem of linear programming for which multitude of methods were developed [46]. Also, there are multicriteria assignment problems [22], multicriteria bin packing problems [24] which are counterparts of the well-known Operations Research problems.

There exist a great deal of the man-computer procedures enabling DM to examine the domain of the admissible decisions and at the same time to establish a compromise between the criteria [46].

The man-computer procedure consists of alternating phases of analysis (performed by the DM) and optimization (performed by the computer). Each phase can consist of more than one step.

Optimization phase (computer):

- using the information received from the DM at the preceding step, a new decision is computed and auxiliary information for the DM is generated.

Analysis phase (DM):

- the presented decision (or decisions) is estimated and its admissibility is determined. If the answer is positive, then the procedure terminates; otherwise, auxiliary information is considered;
- additional information is communicated to enable computation of a new decision.

The man-computer procedures differ in content and execution of the above steps. Their efficiency depends mostly on the nature of the DM-computer interaction that is represented in terms of the quality and quantity of the information.

Together with the development of many man-computer procedures, there appeared papers with the evaluation of such procedures from the behavioral point of view [18, 25]. The analysis demonstrated that many operations required from people in the framework of the man-computer procedures are difficult for the human information processing system. People show intransitivity in the process of choice, show suspiciously fast convergence to the solution and so on.

Again we witness here the evidence of a gap between descriptive and normative.

All the gaps mentioned above lead us to the question: what could be said about a human being as a DM?

5.3 THE QUALITATIVE MODEL OF THE HUMAN DECISION MAKER

On the level of the existing knowledge it is possible to summarize the evidence about human behavior in the decision processes in the following way.

5.3.1 The features of the human information processing system

A. Limited span of the working memory.

According to cognitive psychology [45], human beings have a limited span of the short -term memory. In repeated tasks the span of the working memory could be enlarged [9] but it takes both time and efforts.

That is why the DM cannot simultaneously pay attention to many factors (or evaluations of alternatives upon criteria) in the new decision tasks. As a matter of fact, for the new tasks DM has no possibility to create the internal structure of the necessary knowledge.

This limitation manifests itself in such known facts as:

The DM is trying to simplify the description of the decision situation by replacing some of the criteria by limitations, by eliminating some of the criteria, by grouping the alternatives and so on [25]. Such behavior is the unconscious desire to decrease the load on the short-term memory.

Experienced DMs have usually the skill of simplifying the decision situation in the best possible way. For inexperienced DMs a significant increase in the number of contradictions for more complex decision tasks is typical [25]

B. Limited exactness in quantitative measurements.

According to the existing knowledge, a human being is not an exact measurement device producing quantitative measurements. The famous experiment of A.Tversky [47] demonstrated that people neglect small differences in the evaluations. It is the reason for the intransitive behavior in some problems of choice. Inability to take into account small differences in the evaluation leads to the elimination of the dominating alternatives by the conservation of the dominated ones [19].

The experiments demonstrated that people can poorly measure the probabilities in the quantitative way (see above). The change in the method of measurement, the transfer from the quantitative to the verbal probability allows one to decrease significantly the number of the preference reversals [13].

It was demonstrated in the experiments [28] that slightly different procedures of the quantitative measurements for the same variables give quite different results.

C. Human errors and contradictions.

It has been known since the time of antiquity that "To err is human". People err when processing information. There could be different reasons for such a behavior: weariness, lack of attention, habitual heuristics and so on.

5.3.2 The features of human behavior in the decision processes

A. Absence of preconceived decision rules in new decision tasks.

As many researchers supposed, the DM has no preconceived decision rules. As noted in [52] it can be hardly expected that the utilities and numbers expressing the subjective estimates of the objects and situations are just stored in our minds until elicited.

To develop a decision rule the DM needs time and some learning procedures. Usually people use some kind of a "trial and error " approach in such procedures.

B. Search of the dominance structure.

At every step of the decision making procedures people pay attention to a limited number of objects. This is a possible explanation to the psychological theory of human behavior in the decision tasks-the search of the dominance structure [32]. According to the theory, in the case of the limited number of alternatives people make a preliminary selection of the potentially best alternative and compare it pair-wise with other alternatives , trying to check the fact of dominance.

In the case of a larger number of alternatives, people use initially the strategy of eliminating by aspects and after that utilize a more elaborated process (like the search of dominance) for a smaller number of alternatives.

C. Minimization of human efforts.

J. Payne et al. [35] suggested and substantiated another theory of human behavior upon choosing the best multicriteria alternative(s) that can be called the theory of the constructive processes.

When comparing multicriteria alternatives, people can use various strategies. The studies of J. Payne et al. [35] have demonstrated that in the process of the decision making subjects often choose a strategy depending on the specific features of the alternatives under consideration (their evaluations by criteria). Here, the human preferences of the alternatives and criteria are very unstable. At the local stages of the comparison, rules (or their parts) can vary depending on the relation between the required human effort and the accuracy of choice.

As J. Payne et al. notes, such a behavior is a characteristic of the untrained subjects. People experienced in the decision making, as well as regular decision makers have their preferable strategies for solving problems.

5.3.3 The features of human behavior in organizations

A. Satisfactory decisions.

The studies of economists and psychologists provided an insight into the human decision making in large organizations.

Ch. Lindblom [31] notes the officers organizations try to make as small changes in the existing policy as possible to be able to adjust to the environmental changes. It is not only easier to work out such changes, but also to coordinate them within an organization. The sequence of changes is mostly the means for forming the current policy. Lindblom also believes that this way of solving problems is more realistic because it requires less effort and is more customary for the managers. On the other hand, this approach is more conservative and is not adjusted to dramatic changes in the policy.

Similar discoveries were made by H.Simon [41] who introduced notion of satisfactory decisions as a counter to the optimal ones. In organizations, the life itself brings people to seek satisfactory decisions - the environment is too complicated to be described by a model, the multiple criteria are defined incompletely, there are many active groups influencing the choice, etc. This natural behavior of the personnel resulted in the loss of the strategic objectives amid the petty, everyday routine.

B. Taking the power in the hands.

The desire to have the decision situation under control is typical for the behavior of a DM in organizations. It means that the DM is trying to control all stages of the decision making, all transformations of the information influencing a decision.

Speaking differently, the DM is trying to have the power in the hands. In the case when it is necessary for him/her to take into account the interests of different active groups, the DM is looking for a mutually satisfying decision. [27] but he/she is always trying to implement the principal components of own policy.

5.4 HOW TO REDUCE THE GAP BETWEEN DESCRIPTIVE AND PRESCRIPTIVE

The above features of human behavior define the numerous gaps between the requirements of the different normative methods and the possibilities of human beings to meet such requirements. The discrepancy manifests itself in human errors and contradictions badly influencing the results of an analysis, as well as in mistrust in the results of the DM to the results presented by an analyst and so on.

There are several remedies to save the situation. First, it was the idea to improve the human performance in the process of choice: to teach people how to use the axiomatic methods or to train them to make the quantitative measurements.

Unfortunately, we do not have any evident confirmation of success for this approach. Even more, it became clear that many features of human behavior could be explained by the basic organization of the human information processing system [42].

The second reaction to the gaps is the following: human behavior is not important factor in the decision processes. One could take evaluations in the qualitative form but transform them quickly in the qualitative form appropriate for many decision methods. On the final stage of the decision process it is possible to use the so-called sensitivity analysis to check the influence of the different factors on the output of an the analysis.

Unfortunately, the task of sensitivity analysis is very complex. It is an independent difficult problem and only the skill of an analyst could shed light on the influence of the different factors.

The approach we have taken [26, 30] differs from the others. From our point of view it is necessary to adapt the decision methods to human behavior.

A possible way to close the gaps consists of taking the behavior finding concerning human behavior as constrains for the normative decision aiding methods [26]. By going on such a way it is possible to use the qualitative DM model described above as a base for the construction of the decision aiding tools and the decision support systems.

In other words, on the basis of the behavior findings it is possible to formulate special requirements to the characteristics of the decision aiding methods [30].

5.5 BEHAVIORAL REQUIREMENTS ON THE METHODS OF DECISION MAKING

The knowledge about human behavior in the decision processes allows us to define the requirements for the methods for the decision making [26].

5.5.1 Measurements

The methods must be adjusted to the language of the problem description that is natural to the DM and their environment. To be socially acceptable, the decision method must be readily adjustable to the accepted way of discussing problems in a particular organization.

The kind of a “natural language“ depends on the type of the problem. For so -called ill-structured [40] problems the combination of the quantitative and qualitative variables is typical. It is true, for example, for the multicriteria counterparts of the well-known problems of operations research. One has usually an objective quantitative model for such problems. The criteria for the evaluation of the decision’s quality are some functions from the quantitative variables. Therefore, for such problems the quantitative language of measurement is natural.

There are many ill-structured and some unstructured problems where main variables (or criteria) have an objective quantitative nature like distance, money, a number of residents and so on [16]. Here also the quantitative language is natural and widely accepted.

For typical unstructured [30] problems, this usually means that the estimates of the criteria and, consequently, the estimates of the variants by the criteria are presented in a verbal form. The verbal estimates are located usually on the ordinal scales of the criteria. Such estimates create an adequate language for describing unstructured problems.

The decision method must be adjusted to such a description. Hence, by defining one or another form of verbal scales the DM defines the "measurer" for the experts estimating alternatives on these scales. The same verbal estimates are used by the DM to define the requirements to alternatives, that is, the decision rule.

Additionally to the kind of a problem, the methods of measurement are to be defined by an uncertainty level of evaluations upon criteria. The uncertainty level demonstrates itself in the ability of having an exact measure of the variable. In the case of exact measurements made by a measurement device one has negligible level of uncertainty. In case of the human measurements, levels of uncertainty are defined by the possibilities of a human being to give the information in a different form and with different reliability.

5.5.1.1 Quantitative human measurements

For the situation where the quantitative language of measurement is accepted it is necessary to take into account the characteristics of a human being as a measurement device.

The estimates on the criteria scales must reflect changes in the value (utility, preference, importance, distinctness, etc.) of an alternative with a corresponding change of the estimate by a given criterion. It is known that people can poorly estimate and compare objects of close utilities. With the continuous scales, slight distinctions in the estimates can result in different comparisons of the alternatives. Indeed, all other estimates being equal, the preferableness of an alternative will be defined by one insignificant difference.

The experiment of A. Tversky [47] that demonstrated the stable intransitivity of choice was based precisely on this property. The subjects were given successive pairs of alternatives where the gain slightly increased with a slight increase in the payment. And they persistently preferred to get a higher gain for a slight increase in the payment. Yet, when given the alternatives from the first and the last pairs, they persistently preferred the first one, because they could not admit such a great increase in the payment even for a corresponding increase in the gain. In our view, the continuous scale of the estimates prevented the subjects from seeing the gradual transition from quantity to quality. If the same subjects were given the same task but with the ordinal (qualitative or verbal) estimates of the payment and the gain, then a transitive relationship could easily result.

Some of the results of our experiments in choosing a summer country-house [33] are indicative for the inconvenience of the continuous scales. Two continuous-scale criteria, the cost and the size of the territory, were used in these experiments. It was noted that for insignificant discrepancies in the evaluation of the country-house the subjects do not necessarily find the alternatives that dominate the remaining ones. The subjects sometimes eliminated from the subset of the best alternatives (even if their number is only in the range from four to seven) an alternative dominating one of the remaining alternatives. This observation can also be attributed to the fact that insignificant (5-7%) variations in the cost do not affect appreciably the values of the alternatives. Though the subjects assert that `the cheaper the better' if this difference is pointed out, on the whole they agree that both variants have the same utility.

The experiments suggest that the quantitative measurements are the most sensitive to small errors and differences in the DM answers, which gives rise to the question of the accuracy of human measurements, especially under indefiniteness. It is well known that in physics the accuracy of measurements depends on the precision of the instrumentation. The same applies to human measurements. The available results of the experiments are indicative for the fact that man cannot make precise quantitative measurements.

It means that while performing the quantitative measurements it is much better to replace the continuous scales by the ones with discrete evaluations. Such evaluations could represent some intervals on the continuous scales which have a meaningful interpretation for the DM. Sometimes it is preferable to use for such intervals verbal labels like “expensive”, “cheap” and so on for the cost evaluation.

5.5.1.2 Transition from qualitative notions to numbers

For the situations where qualitative language of a problem’s description is natural (unstructured problems) let us discuss the attempts to combine the qualitative measurement scales and the quantitative representation of the results. First of all, we should mention the simple means of establishing a mutual correspondence between the primary qualitative measurement scale and the quantitative scale of scores where the primary measurements are carried out in a qualitative form and (independently of the expert's will) are assigned certain numbers which are then used to estimate the variants of the decisions. This method of measurement is not reliable because no logical basis underlies the assignment of one or another numerical value to the primary estimates. The worst of it is that the numbers are further treated as the results of the objective physical measurements. For example, when estimating the quality of the objects by multiple criteria, the scores by criteria are regarded as the results of the quantitative measurements and are often multiplied by the weights of the criteria and summed up.

When considering the problems of a political choice, Dror [6] drew attention to the fact that people assign different numerical estimates to the same verbal definitions. We do not think that this necessarily means that one person believes that this event occurs with 70% probability and that 70% refers to a highly probable event, whereas another person believes that this event occurs with 90% probability and that 90% refers to a highly probable event. Both experts are, possibly, sure that this event is `very probable,' but when they are asked to evaluate this probability numerically (for example, in terms of a percent or somehow else) they replace their ignorance of this number by some (rather arbitrary) number. Human estimates corresponding to the same verbal definition on the scale were experimentally shown to have a rather great dispersion [50] which is especially great for the estimates representing the mean `neutral' level of the quality.

The second popular approach is that of the theory of fuzzy sets where measurements are carried out in terms of the descriptive qualitative values which are then transformed to the quantitative form by the means of a given membership function assigning numbers to any word.

To what extent is this transformation reliable? To what extent is man error-free? It is obvious that a person constructing the membership function performs approximately the same operation as when establishing the correspondence between the qualitative and the quantitative scales where the DM cannot evaluate the effect of small deviations in the estimates on the resulting comparison of the alternatives. The references to the check for sensitivity after quantitative measurements are of no avail. Indeed, in the presence of the multiple quantitative parameters the sensitivity check becomes an independent involved problem that can be solved only by eliciting from the DMs information that they hardly can provide.

5.5.1.3 Comparative verbal probabilities

Some experiments focus on the relationship between the language of measurement and the degree of indefiniteness of the events [8]. For example, the subjects were asked to estimate the chances of basketball teams to win in games between them. The experimenters noticed that in the case of an unknown team (higher indefiniteness) the experts were able to discriminate only two levels of verbal probabilities in comparative forms — for example, ‘it is believed that the host always plays better than the guests’.. It is stated [8] that compelling people to quantify the probability estimates in the situations where only a few levels of indefiniteness can be discriminated can result in erroneous estimates. This example shows that some measurements can be carried out only in a verbal form with the use of the `more probable than' relationships. Methodical studies of the comparative probabilistic estimates [11] demonstrated that the comparative probabilities are much more frequently used by the common people (both adults and children) than quantitative estimates of the probabilities of events. The experiments used tasks such as the estimation of the probabilities of hitting the sectors of a rotating disk and estimating the winners in competitions and games. The authors of this work formulated six mathematical principles for comparative probabilities in the form of axioms representing the mathematical concept of the qualitative probabilities. The main experimental result obtained with adults and children above five is as follows: human comparisons follow completely the principles of the mathematical theory of the qualitative probabilities. The authors of this work conclude that the six principles provide a more reliable foundation for describing human behavior than the laws of the quantitative probability.

5.5.1.4 Qualitative measurements

We regard decision making in the unstructured problems as the domain of the human activity where quantitative (the more so, objective) means of measurement are not developed, and it is unlikely that they will appear in the future. Therefore, it is required to estimate the possibility of doing reliable qualitative measurements. Following R. Carnap, we turn to the methods of measuring physical magnitudes that were used before the advent of the reliable quantitative measurements. Before the invention of balances, for example, objects were compared in weight using two relationships — equivalence (E) and superiority (L), that is, people determined whether the objects are equal in weight or one is heavier than the other. There are four conditions to be satisfied by E and L [3]:

1.E is the equivalence relationship,
2.E and L must be mutually exclusive,
3.L is transitive, and
4.For two objects a and b either (i) a E b, or (ii) a L b, or (iii) b L a.

One can easily see that the above scheme enables one to carry out relatively simple comparisons of the objects in one quality (weight). It is required here that all objects be accessible to the measurement maker (expert).

Two more remarks are due. It is obvious that the thus-constructed absolute ordinal scale cannot have many values; otherwise, they will be poorly distinguishable by the measurement makers. To come to terms easier, it is required to identify commonly understandable and identically perceived points on the scale and explain their meaning in detail. Therefore, these scales must have detailed verbal definitions of the estimates (grades of quality). Moreover, these definitions focus on those estimates on the measurement scale that were emphasized by the persons constructing the scale (for example, they could be interested only in very heavy and very light objects). Thus, the estimates on the ordinal scale are defined both by the persons interested in one or another kind of measurement (in our case, it is the DM) and by the distinguishability of estimates, that is, the possibility of describing them verbally in a form understandable to the experts and the DMs.

There is no reason to question the fact that before the coming of the reliable methods of quantitative measurement of the physical magnitudes, they were already measured qualitatively. Today, these methods could seem primitive because we have much more reliable quantitative methods. Yet, there is no doubt that the pre-quantitative (qualitative) methods of measuring physical magnitudes did exist. When they were superseded by the quantitative methods, they were treated with negligence as something `unscientific' and obsolete. The progress of physics gave rise to the well-known statement that the science appears wherever the number (quantity) occurs. To our mind, these declarations refer mostly to the natural sciences, but in the sciences dealing with human behavior qualitative measurements were and will be the most reliable.

5.5.1.5 How to measure

For the conclusion, we could put the following requirements to human measurements in decision processes.

1. The measurements must be made in a language that is natural to DMs and their environment.
2. In the case of quantitative variables (criteria) it is preferable to use discrete scales with the evaluations representing some intervals meaningful for "measurement makers".
3. In the case of qualitative measurements the ordinal scales with verbal evaluations are the best way of measurement.
4. For the cases with big uncertainty the comparative verbal measurement (better, worse and so on) are the most correct way of receiving information from human beings.

In the general situation, one could take as the output of measurement process the discrete evaluations on criteria scales. Very often such evaluations have verbal labels or verbal descriptions.

5.5.2 Information elicitation for the construction of a decision rule

The next problem after the measurements is the construction of the decision rules for the evaluation of the alternatives. The problem for the DM is to construct the decision rules using the kind of criteria evaluations described above.

The operations performed by the DM in the process of constructing the DM's decision rules are to be psychologically correct. We shall differentiate between two types of measurements. We discussed above measurements of the main factors influencing the decision. We shall refer to them as the primary measurements. In some normative methods, the primary measurements suffice for reaching the final decision. In the method of the subjective expected utility, for example, the quantitative measurement of the utility and subjective probability allows one to calculate the expected utility of every alternative.

Yet, for a large majority of the normative methods this is insufficient, and some cognitive operations of the information elicitation are needed to construct a decision rule. We will call them the secondary measurements. For example, one needs to measure weights of criteria to decide whether the utility function is additive or multiplicative [16].

Analysis of the different normative techniques enables one to distinguish three groups of the information processing operations such as operations with criteria, operations with the estimates of the alternatives by criteria, and operations with the alternatives. Let us refer to an operation as elementary if it is not decomposable into simpler operations over to the objects of the same group, that is, to criteria, alternatives, and alternative estimates by criteria.

In the survey [26] the results of psychological experiments demonstrating the validity of different cognitive operations used in the decision methods were collected. Below is a group of the information processing operations which are admissible from the psychological point of view for the construction of a decision rule [26, 30].

1. Ordering criteria by importance.
2. Qualitative comparison of two estimates taken from two criteria scales.
3. Qualitative comparison of the probabilities of two alternatives.
4. Attribution of alternatives to decision classes.
5. Comparison of two alternatives viewed as a set of estimates by criteria and selection of the best one.
6. Comparison of two alternatives viewed as something whole and selection of the best one.
7. Determination of a satisfactory level by one criterion.

Let us note that the operations 4 and 5 are admissible in some limits defined by the parameters of a problem. For the operations 6 and 7 we do not have enough of the psychological research demonstrating the validity of the operations, it is a preliminary conclusion.

The admissible operations, reduce to qualitative comparisons (of the type "better", "worse", "approximately equal") of criteria, pairs of estimates on two criteria scales, holistic images of alternatives. Also, we may assign satisfactory values, exercise a simple decomposition of criteria, alternatives. Given a relatively small number of the criteria, we may compare two alternatives. With a not too big number of criteria, decision classes, and estimates on scales we may assign alternatives to the decision classes. All this together seems to be an essential constraint for a researcher working on the prescriptive [2] techniques. But psychologically valid methods give the reliable output. To avoid the gaps between normative and descriptive only a psychologically correct operation of the information elicitation are to be used.

5.5.3 Consistency test

One of the inherent characteristics of human behavior is proneness to error. In transmitting and processing information, people make errors. They make less and sometimes considerably less errors when using the psychologically valid information elicitation procedures, but all the same they do make errors. The latter may be caused by the distraction of human attention, a person's fatigue, or other reasons.

Errors are observed both in practice and in psychological experiments. They differ essentially from the human errors in psychometric experiments which are known to follow the Gauss law and have the greater probability for the greater deviations from the true value. The human errors in the procedures of the information processing are of a different nature. For example, our studies of the multicriteria classification demonstrated that in the problems of small dimension (which are simple for man) gross errors leading to many contradictions are rare — 1 or 2 out of 50 cases [25]. These errors are obvious. Errors of the same kind are met when comparing pairs of the estimates by the criteria, ranking criteria, etc. Stated differently, man can once and again commit essential errors. Therefore, the information elicited from man must be validated and not used uncontrollably.

In other words, an individual can make unavoidable errors from time to time. Hence, information obtained from a person must be subject to verification, rather than to be used uncontrollably.

How to check the information for consistency?

The efficient methods are so-called closed procedures [20, 30] under which the earlier collected information is subject to an indirect rather than direct test. The questioning procedure is built so that the questions are duplicated, but the duplication is exercised implicitly, through other questions logically associated with the former.

The following closed procedure was first suggested for the method ZAPROS [20]. Let there be Q criteria with ordinal scales and a small (2-5) number of estimates. It is required to order the estimates of all criteria, that is, to arrange them on the joint ordinal scale. To this purpose, it was suggested to perform pair-wise comparisons of the criteria scales.

All 0.5Q(Q-1) pairs of criteria were pair-wise compared, which enabled a rather reliable validation of the DMs' information. We note that as the number of criteria (hence, the complexity of the problem) increases, the potential amount of the redundant information generated by this comparison increases as well. A closed procedure of this type has been employed to advantage in the ZAPROS method.

Note that pinpointing a logical inconsistency should not lead, in general, to the automatic exclusion of an error but to the creation of the premises for a logical analysis.

The decision methods must incorporate means for checking the DM's information for consistency. No matter what method is used to elicit information from DMs, one must be aware of the possibility of occasional errors and of the stages of the DM training. In this connection, the procedures for checking the elicited information for consistency are required, as well as the methods for detecting and eliminating contradictions in the DM's information.

The need for consistency checks is not eliminated by the psychologically correct methods of the information elicitation from the DM’s. This checking is extremely important because it improves the efficiency of the training and compels the DMs to recognize their errors and work out a reasonable compromise.

5.5.4 Learning procedures

As was noted above, learning is a part of human behavior. It is one of the inherent properties of human behavior, and the trial-and-error approach is the most characteristic human feature. Learning involves the study of a multicriteria problem and gradual working out of the DM's policy (decision rule).

One can hardly expect that the needed information is just stored in human minds until elicited [52]. Despite the fact that such expectations were not made explicitly, they were implied. Indeed, in many decision methods people are required to give immediately all parameters of the decision rules. It can hardly be expected that at the initial stages of the decision making an individual can define sensibly and consistently the decision rule. It can be assumed that an experienced DM (especially, that who dealt previously with such a problem) has some elements of the policy such as a (possibly incomplete) list of criteria, comparative importance of some criteria and estimates, etc., but usually all this is specified in the course of the decision making where all tradeoffs are defined.

To allow the human ability of learning to manifest itself, the decision method must comprise special procedures for a gradual, rather than instantaneous, working out of the DM's policy. These procedures must allow the individuals to err and correct themselves, to work out partial compromises, and go on to the next ones. This process must allow the individuals to challenge their own decisions and return to the beginning.

5.5.5 Possibility to receive explanations

From a behavioral point of view, one of the requirements for any method is explainability of its results. The DM making a responsible decision would like to know why alternative A is superior to B and why both are superior to C. This requirement is quite legitimate. The stages of the information elicitation from the DM (measurements) and presentation of the final results are separated by the information’s transformation. Understandably, the DMs want to make sure that the assessments of alternatives are based, without any distortion, precisely on their own preferences. To meet this requirement, the decision method must be `transparent,' that is, allow one to find the one-to-one correspondence between the DM's information and the final evaluations of the alternatives.

The DMs must have an opportunity to check whether there is a correspondence between the resulting estimates of the alternatives, on the one hand, and their own preferences, on the other hand. This check allows the DMs to make sure that it is precisely their preferences that uniquely define the results of using this method. Consequently, the DM must get explanations from the method in an understandable language. Only after that DM can receive the feeling of power in the hands and would like to use the results of the analysis.

5.5.6 New decision methods adapted to human behavior

The requirements formulated above create the possibility to develop new decision methods adapted to known features of human behavior.

First, the statement of a multicriteria decision problem in an organization gives the chance to make a step forward from the usual satisfactory behavior. It was demonstrated in many practical cases of the multicriteria decision methods application: the choice of a pipeline route [34], the location of an airport [16].

Second, the utilization of the ways of measurements adapted to the human information processing system gives the possibility to justify the decision methods from the psychological point of view. Using the natural language strongly increases the chances of a successful practical implementation.

Third, new methods of the decision rules’ construction reduce the load on the human short-term memory and give the chances to reduce significantly the number of human errors, contradictions, biases.

Fourth, the special procedures for checking the information and eliminating the contradictions give the decision methods the new quality of the reliable tools.

Fifth, the process of a gradual development of a decision rule gives the DM the time for learning, for careful development of a compromise between the criteria.

Finally, the possibility to get an explanation increases the chances for a successful implementation of the multicriteria decision analysis.

5.6 PRACTICAL IMPORTANCE OF BEHAVIOR ISSUES

How important are the requirements given above for the practice? How big is the influence of the incorrect measurements and human errors on the possibility to get a practically valid output of a decision method? Are behavior issues important only for theoretical reasons or do they define the practical value of the decision analysis?

The partial answers to these questions are provided by the results of the comparison of three decision aiding methods implemented as decision support systems. One of them was the method of the Verbal Decision Analysis -ZAPROS, satisfying the requirements given above [21, 29].

5.6.1 The decision problem

The experimental study was done to compare three methods of the decision making [28]. The subjects were college students nearing graduation, which were in a job search process, facing opportunities similar to those given in the study.

Let us suppose that a college graduate has several offers (after interviews) and he (or she) is to make a decision. These jobs are very similar in quality (that is, every variant is acceptable, but of course, one variant is better upon one aspect and the other - on the other). So, the student has to present this task as a multicriteria problem and try to solve it with the help of an appropriate multicriteria method.

Four criteria are used as the focus of the study: salary, job location, job position (type of work involved), and prospects (career development and promotion opportunities). The following alternatives were used:

FIRM	SALARY	JOB LOCATION	POSITION	PROSPECTS
a1	$30 000	Very attractive	Good enough	Moderate
a2	$35 000	Unattractive	Almost ideal	Moderate
a3	$40 000	Adequate	Good enough	Almost none
a4	$35 000	Adequate	Not appropriate	Good
a5	$40 000	Unattractive	Good enough	Moderate

It is easy to note that in this case there are three possible estimates upon the scale of each criterion. The greater the salary the more attractive an alternative would be to a rational subject. Thus, we have four criteria with three possible values each and the values of each criterion are rank-ordered from the most to the least preferable one.

It is evident, that there are no dominated alternatives. Therefore, the comparison of these alternatives required some value function, which would take into account the advantages and disadvantages of each alternative upon each criterion.

5.6.2 Two decision support systems based on numerical measurements

Two decision support systems based on the Multiattribute Utility Theory ("MAUT") [16, 17] were used for the solution of the problem given above. These systems are LOGICAL DECISION [44] and DECAID [36]. The third DSS was one based on the Verbal Decision Analysis (see below).

Both decision support systems LOGICAL DECISION and DECAID were used to solve this task. Both systems implement ideas from multiattribute utility theory, providing possibilities for the construction of an additive utility function for the case of the risky decisions, and an additive value function for a decision making under certainty. In our study, we used only additive value functions.

The value function obtained from both systems would therefore have the linear additive form of the weighted sum of the criteria estimates. The coefficients of importance for the criteria (the weights of importance) are used.

Both systems are easy to use, have a flexible dialogue and graphical tools to elicit the decision maker's preferences.

The main difference in the systems (besides interface) is the way of the determination of the numerical values for the evaluations upon separate criteria. In DECAID a pure graphical (direct) estimation is used (a point on the line of the size 1). In LOGICAL DECISION there is a possibility to use a special function for the criterion values. To determine the parameters of this function it is enough to mark the "middle" value for the criterion (sure thing for a lottery with 50% possibility for the best and the worst estimates).

The criteria weights are also defined in a different manner in these two systems. In LOGICAL DECISION criteria weights are defined on the basis of the trade-offs in a rather traditional way [17]. In DECAID weights are elicited directly (in a graphical way - point on a line), though the system provides also the possibility to make trade-offs, but after that the result is presented as points on the lines.

Taking into account the commonness of the approach implemented in both systems and also the similarity of the information, received from the DM in the process of the task solution, one could suppose that the attempt to solve the above described task with the help of these systems must lead to very close results.

5.6.3 Decision support system ZAPROS

The third DSS is one from the family of Verbal Decision Analysis [29]. Only verbal measurements are used on all stages of this method. ZAPROS uses ranking rather than rating information, but the additive overall value rule is correct if there is an additive value function. In ZAPROS the additive rule does not provide the summation of the verbal estimates, but rather the means of obtaining a pair-wise compensation between the components of the two alternatives.

For the preference elicitation from the subjects the following procedure was used.

Subjects were asked to compare several specially formed alternatives by pairs. For each pair two alternatives differed on evaluation according to two criteria only (one evaluation was best for each alternative) and had equal evaluations (best or worst) on other criteria.

For the task presented above it was necessary for the subjects to compare the pairs of the alternatives different on each pair of the four criteria. The example of a typical question is:

"What do you prefer: the firm giving salary $ 40 000 with an adequate location or the firm giving salary $35 000 with a very attractive location? Please, take into account that on the criteria "Position" and "Prospects" both firms are good".

Comparing these alternatives, subjects were to choose one of the following responses:

1. alternative 1 is more preferable than alternative 2;
2. alternative 2 is more preferable than alternative 1;
3. alternatives 1 and 2 are equally preferable.

The implementation of a such simple system for the comparison of the pairs of the alternatives gives us a possibility for a simple check of the received comparisons on the basis of transitivity.

The method provides a verification of the received comparisons for the transitivity and allows to change some of the responses on the request of the user to eliminate the intransitivity. It also guarantees that the comparison of each pair of the alternatives from this set is supported by at least two responses of the user.

Let us note that such a way of the preference elicitation is psychologically valid (see above). The received information allows one to build joint ordinal scale combining all evaluations on the separate criteria scales. The joint ordinal scale provides the possibility for the construction of a partial ranking for every given set of the alternatives.

Thus, this rank-ordering may be used for the comparison of the initial five alternatives because in our task the additive value function is supposed to be the right one and the criteria were formed to be preferentially independent. This algorithm does not guarantee the comparison of all alternatives because for some pairs of the alternatives ZAPROS gives only the incomparability relation.

5.6.4 The comparison of three decision support systems

Each subject from the group used all three DSS for the solution of the problem presented above. The difference in the outputs of the methods consisted in following: some pairs of the alternatives have not been compared with the ZAPROS method. Simple method of the preferences elicitation used by ZAPROS gave no possibility (in general case) to compare all given alternatives. ZAPROS gave only a partial ranking of the alternatives.

In contrast to it, two other methods give the complete ranking for the given alternatives. Also, LOGICAL DECISION and DECAID gave numerical values of the utility for all alternatives.

The results of the experiment were analyzed in a different form: the ranking of the given alternatives, the ranking of the specially formed alternatives used in ZAPROS, the ranking of the criteria weights and so on.

First of all, it was found that the correlation between the outputs of LOGICAL DECISION and DECAID was very low. The ANOVA test demonstrated that for the group of subjects the outputs of LOGICAL DECISION and DECAID have not been statistically significant in the measurements of the criteria weights and the ranking of the alternatives.

The following results were very interesting: the outputs of the pairs LOGICAL DECISION-ZAPROS and DECAID-ZAPROS were correlated and were significantly correlated. It means that only for the alternatives compared by ZAPROS the relations were essentially the same.

It is possible to give the following explanation of the results.

The alternatives that could be ordered by ZAPROS are in the relations closed to the ordinal dominance. Such relations are more stable. Moreover, they were constructed in a very reliable way: verbal measurements psychologically correct way of preference elicitation, a possibility to check information and eliminate contradictions.

Two complete orders constructed by LOGICAL DECISION and DECAID were based on the numerical measurements and the weighted sum of the alternatives estimations by criteria. The difference in the utility (even small) defined the final order of the alternatives. The errors (even small) made by people while performing numerical (primary and secondary) measurements resulted in quite different orders of the alternatives.

5.7 CONCLUSIONS

The fact that a DM can not perform some cognitive operations in a reliable way is very important. It is the starting point for the development of a new decision theory where behavioral issues play at least the same role as the mathematical ones.

This new theory is needed not only for the decision analysis. The economists still believe in the myth of the existence of a *rational person* who behaves like a robot in the mathematical models of economics. But the facts demonstrate that consumers’ behavior is far from rational [10]. The same is true for investor's decisions.

Behavioral issues are very important for political science [7]. We witness many errors made by leading political figures in different countries. Some such errors are difficult to explain. But a lot of them could be explained by the behavior factors. To describe how politicians make decisions, to help them choose the better strategies one must take into account knowledge about human behavior.

The reason of gaps between prescriptive and descriptive is basically the lack of the joint work between psychologists and sociologists engaged in the behavior research and mathematicians developing normative methods. The members of different research communities have different goals that generally do not coincide. Only joint multidisciplinary work could change the situation.

The understanding of the importance of research directed to the elimination of the gap between normative and descriptive is constantly increasing.

It is a good sign, the sign of the formation of a new image for the decision theory. New multidisciplinary research will give the important theoretical and practical results.

REFERENCES

[1] Bettman, I., P. Kakkar: Effects of information presentation format on consumer information acquisition strategies. Journal of Consumer Research, 3(1977).

[2] Brown, R., A. Vary: "Towards a research agenda for prescriptive decision science: the normative tempered by the descriptive." In: O. Huber, J. Mumpower, J. van der Pligt, P. Koele (Eds.) *Current Themes in Psychological Decision Research*, North-Holland Amsterdam 1992.

[3] Carnap, R.: *Philisophical Foundation Of Physics*., Basic Books Inc. Publishers London 1969.

[4] Currim, I. S., R. K. Sarin: Prospect versus utility, Management Science, 35, 1(1989)22-41.

[5] Dolbear, F. I., L. B. Lave: Inconsistent behavior in lottery choice experiments, Behavior Science, 12,1(1967).

[6] Dror, Y.: *Public Policy Making Reexamined*, Transaction Publishers, Oxford. 1989.

[7] Dror, Y.: Basic Consepts in Advanced Policy Sciences., In: S. Nagel (Ed.) *Encyclopedia of Policy Studies*, Marcel Dekker, New York 1994.

[8] Erev, I., B. Cohen: Verbal versus numerical probabilities: efficiency, biases, and the preference paradox, Organizational Behavior and Human Decision Processes, 45(1990)1-18.

[9] Ericsson, K.A., W. Kintsch: Long-term working memory, Psychological Review, 102(1995)211-245.

[10] Foxall, G.R.: *Consumer Choice*. Kent, Maidstone 1983.

[11] Huber, B., O. Huber: Development of the concept of comparative subjective probability, Journal of Experimental Child Psychology, 44 (1987)304-316.

[12] Humphreys, P. C.: "Application of multiattribute utility theory", In: H. Jungermann, G. De Zeeuw (eds.), *Decision making and change in human affairs,* Reidel, Dordrech 1977.

[13] Gonzalez-Vallejo, C., T. Wallsten: The effects of communication mode on preference reversal and decision quality, Journal of Experimental Psychology: learning, memory and cognition, 18 (1992)855-864.

[14] Kahneman, D., P. Slovic, A. Tversky (eds.): *Judgement Under Uncertainty: Heuristics And Biases.*, Cambridge University Press, Cambridge 1982.

[15] Kahneman, D., A. Tversky: Prospect theory: an analysis of decisions under risk., Econometrica, 47(1979)263-291.

[16] Keeney, R. L., H. Raiffa: *Decisions With Multiple Objectives: Preferences And Value Tradeoffs*, Wiley, New York 1976.

[17] Keeney, R. L.: *Siting energy facilities*: Academic Press, New York 1980.

[18] Korhonen, P., J. Wallenius, "Behavior Issues in MCDM: Neglected Research Questions", In: J. Climaco (eds.) *Multicriteria Analysis*, Springer, Berlin 1997, pp. 412-422.

[19] Korhonen, P., O. Larichev, H. Moshkovich, A. Mechitov, J. Wallenius: Choice behavior in a computer-aided multiattribute decision task, Journal of Multi-criteria Decision Analysis, 6(1997)233-246.

[20] Larichev, O. I., Yu. A. Zuev, L. S. Gnedenko: “Method ZAPROS (CLosed Procedures near Reference Situations) for the analysis of variants of complex decisions”, In: S. V. Emelyanov (eds.), *Multicriteria Choice for the Solution of Ill-structured Problems*, Moscow: VNIISI Proceedings, N 5 (in Russian), 1978, pp. 83-97.

[21] Larichev, O. I.: *A method for evaluating R&D proposals in large research organizations*, Collaborative paper CP-82-75, Laxenburg, Austria: IIASA 1982.

[22] Larichev, O. I.: *Objective models and Subjective Decisions*: Nauka (in Russian), Moscow 1987.

[23] Larichev, O. I., O. A. Polyakov, A. D. Nikiforov: Multicriteria linear programming problems (Analytical Survey), Journal of Economical Psychology, 8(1987)387-407.

[24] Larichev, O. I., E. M. Furems, “Multicriteria Packing Problems.”, In: Y. Sawaragi, K. Inoue, H. Nakayama (eds.), *Toward Interactive and Intelligent Decision Suppport Systems*, Springer, Berlin, 1987, pp. 218-226.

[25] Larichev, O. I., H. M. Moshkovich, S. B. Rebrik: Systematic research into human behavior in multiattribute object classification problems, Acta Psychologica, 68(1988)171-182.

[26] Larichev, O. I.: Cognitive validity in design of decision-aiding techniques, Journal of Multi-criteria Decision Analysis, 1, 3(1992)127-138.

[27] Larichev, O. I., R. Brown, L. Andreeva, and N. Flanders: “Categorical Decision Analysis for Environmental Management: a Siberian Gas Distribution Case.”, In: Caverni J. P., Bar-Hillel M., Barron F. N. and Jungermann H. (eds.), *Contributions to Decision Research*. North-Holland, Amsterdam, 1995, pp. 255-279.

[28] Larichev, O. I., D. L. Olson, H. M. Moshkovich, A. I. Mechitov: Numerical vs. cardinal measurements in multiattribute decision making: how exact is exact enough? Organizational Behavior and Human Decision Processes, 64, 1 (1995)9-21.

[29] Larichev, O. I., H. M. Moshkovich: ZAPROS-LM-A method and system for rank-ordering of multiattribute alternatives.., European Journal of Operations Research, 82 (1995)503-521.

[30] Larichev, O. I., H. M. Moshkovich: *Verbal Decision Analysis For Unstructured Problems.*, Kluwer Academic Publishers, Boston 1997.

[31] Lindblom, C. H.: The science of mudding through, Public Administration Review, 19(1959)155-169.

[32] Montgomery, H., O. Svenson: “A think-aloud study of dominance structuring in decision processes”, In: H. Montgomery, O. Svenson (eds.), *Process and Structure on Human Decision Making*, J. Wiley and Sons, Chichester 1989, pp. 135-150.

[33] Nikiforov, A. D., S. B. Rebrik, L. P. Sheptalova: “Experimental study of stability of preferences in some decision making tasks”, In: S.V.Emeljanov, O.I.Larichev (eds.) *Procedures for evaluation of multicriteria objects*.., VNIISI Proceedings, N 9 (in Russian), 1984, pp. 69-80.

[34] Oseredko, Y. S., O. I. Larichev, and A. I. Mechitov: “Main Gas Pipeline Route Selection Problem.”, In: H. Kunreuther and E. Ley (*Eds.*) *Risk Analysis Controversy: An Institutional Perspective*, Springer, Berlin 1982, pp. 91-101.

[35] Payne, J. W., J. R. Bettman, E. Coupey, E. J. Johnson: “A constructive process view of decision making :multiple strategies in judgment and choice”, In: O. Huber, J. Mumpower, J van der Pligt, P. Koele (*Eds.*), *Current Themes in Psycological Decision Research,* North Holland, Amsterdam 1993, pp. 107-142.

[36] Pitz, G.F.: *DECAID Computer Program*. Carbondale, IL, Univ. Of Southern Illinois 1987.

[37] Raiffa, H.: *Decision analysis. Readings,* Addison –Wesley, Menlo Park, California 1968.

[38] Russo, J. E., L. D. Rosen: An eye fixation analysis of multiattribute choice, Memory and Cognition., 3(1975)267-276.

[39] Savage, L.J. *The foundation of statistics.* Wiley, New York 1954.

[40] Simon, H., A. Newell: Heuristic problem solving: the next advance in operations research., Operations Research, 6(1958).

[41] Simon, H. A.: *The New Science of Management Decision*, Harper and Row Publ., New York 1960.

[42] Simon, H.A.: “Computational Theories Of Cognition.”, In: W.O’Donohue, R.F. Kitchener (eds.), *The Philosophy Of Psychology*., England, Sage Publications, London 1996.

[43] Slovic, P., A. Tversky: Who accepts Savage's axiom? Behavioral Science, 19(1974)368-373.

[44] Smith, G. R., F. Speiser: *Logical Decision: Multi-Measure Decision Analysis Software.* Golden, CO: PDQ Printing, 1991.

[45] Solso, R. L.: *Cognitive Psychology,* Allyn and Bacon, Inc., Boston 1988.

[46] Steuer, R. E.: *Multiple Criteria Optimization: Theory, Computation, and Application,* J. Wiley and Sons, New York 1986.

[47] Tversky, A., Intransitivity of preferences, Psychological Review, 76 (1969)31-48.

[48] Von Neumann, J., O. Morgenstern: *Theory Of Games And Economic Behavior*. Princeton University Press, Priceton 1947.

[49] Wagner, H. M.: *Principles of Operations Research*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey 1969.

[50] Wallsten, T., D. Budescu, R. Zwick: Comparing the calibration and coherence numerical and verbal probability judgments, Management Science, 39(1993)176-190.

[51] von Winterfeldt, D., G.W. Fischer: “Multiattribute utility theory: Models and assessment procedures”, In: D. Wendt, C. Vlek (eds.) *Utility, probability and human decision making,,* Reidel, Dordrecht 1975.

[52] von Winterfeldt, D., W. Edwards: *Decision Analysis and Behavioral Research,* Cambridge University Press, Cambridge 1986.

[53] Wu, G.: Editing and Prospect Theory: Ordinal Independence and Outcome Cancellation, *Working Paper of Harvard Business School*, 1993.

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