

NUMERICAL AND VERBAL DECISION ANALYSIS AS PRACTICAL TOOLS PART II: GENERAL COMPARISON.

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In a previous paper, we described the application of two contending—or possibly complementary—approaches to decision analysis, verbal and numerical (Larichev et al. 1996). The effort was part of a research project intended in part to compare the approaches empirically and analytically.¹

Each case was addressed in a quasi-consulting mode, by proponents of one approach on their “home territory” so to speak. Russian decision analysts addressed a current Russian government problem of choosing between a land and sea route for transporting gas from the Yamal Peninsular in Western Siberia. American decision analysts reviewed a past US government decision on whether to permit an oil company to build an oil causeway into the Arctic Ocean off Alaska.

On the basis of practical experience in applying two quite different approaches to similar problems, including the above, attempt was made to compare the approaches more generally. There are two issues: general pros and cons of each approach; and circumstances under which one or the other is favored.

In undertaking such comparison, we should acknowledge that NDA has to date had many times the development effort and application than VDA. The potential for development of either approach sets limits of its applicability in practical tasks. Our consulting experience proved for us the great diversity of practical problems and the necessity to carefully take into account particularities of each problem for its successful solution.

Three groups of criteria for comparison are to be taken into consideration: methodological, institutional and personal.

Methodological criteria

Methodological considerations in characterizing an approach include: how major factors are to be measured; how good or bad people are psychologically in making such measurements; how options are treated or created; how feasible it is to obtain a desirable decision output; how great the cognitive and time burden is; how satisfactorily the major problems with informal analysis can be addressed.

¹ NSF Grant #DPP. [...]

Measurement of option evaluations on the criteria.

The two approaches differ very much in the kind of measurements used. NDA eventually obtains numbers. VDA uses only verbal measurements. Which kind of measurement correspond best to problem types, e.g. typified by the Arctic? How does the kind of the measurement depend on the degree of uncertainty ?

In experiments with 442 respondents Wallsten et al. (1993) found that 65% of respondents prefer to *give* the evaluations of probabilities in verbal form but 70% prefer to *receive* this information in quantitative form. This phenomenon has been called (Erev and Cohen, 1990) communication mode preference paradox (CMP). For example, an intelligence officer would prefer to *get* information from his subordinate officer in quantitative form, but to *give* his information to an upper level officer in verbal form.

There are real life examples. President Yeltsin's adviser, Dr. A.Livshitz, in preparing the most probable scenario of future development of Russian economy for 1996-1997, gave most of his evaluations of important parameters in verbal form. In 1981, the US National Security Council prepared a list of five possible operations against Libia for President Reagan, presenting the chances for the success in verbal form (Hamm, 1991).

Typical behavior of deciders at different levels in an organization sometimes contradicts the CMP paradox. In our own consulting work, we found Henry Kissinger and Henry Ford preferred to receive the findings of our quantitative decision analysis translated into a purely verbal form. The CMP paradox may be more typical for lay-people and for managers of middle level than for high level.

There are several reason for people to give and receive information in verbal form:

1. People use verbal communication much more easily than numerical. Quantitative probability theory appeared many thousand years the after development of language.
2. Words are perceived as more flexible and less precise, with more versatile communicative functions (Teigen, 1988), and therefore seem better suited to describe vague opinions and characterize imprecise beliefs. Erev and Cohen (1990) found that "forcing people to give numerical expressions for vague situations where they can only distinguish between a few levels of probability may result in misleading assessments".

But there are positive factors in the quantitative form of information:

1. People attach a degree of precision, authority and confidence to numerical statements that they do not ordinarily associate with verbal ones.
2. Numerical probabilities permit certain quantitative methods of information processing (e.g. Bayesian updating).

Experiments made over many years by Tom Wallsten and his colleagues demonstrated no essential differences between verbal and numerical representations of probabilities in the profit received by subjects in experimental games, or in the accuracy of their evaluations.

(Budescu and Wallsten, 1995; Erev and Cohen, 1990). One experiment (Erev and Cohen, 1990) consisted of two phases, each using a distinct group of subjects: experts giving probabilities of different events in basketball games and decider's ranking events using expert's assessments. Experts estimated the probabilities into two ways (verbal and numerical). Deciders could select the preferred mode of receiving expert assessment. They were paid for the right answers, corresponding to which events occurred. On average, the same amount of money was earned when deciders used the vague verbal expressions and when they used the precise numeric estimates. A finding was that the convenience of using verbal expressions outweighs a small loss in profit (1-4%) (Hamm, 1991).

Other experiments demonstrate that using numerical probabilities can actually lead to a decrease in profits and an increase in violations of the dominance rule (Erev et al., 1993).

Gonzalez-Vallejo and Wallsten (1992) found that subjects faced with binary choice decisions and the bids for lotteries based on events showed many fewer preference reversals using verbal than numerical expressions. Preference reversal is a well-known demonstration of inconsistency in human behavior (Tversky et al., 1988).

It has also been found that people reach agreement much faster using verbal communication. Because imprecise communications are not understood identically by everyone, they benefit society in certain situations by facilitating joint statements of position based on different presuppositions (as in the 1998 UN Security Council resolution on the use military sanctions against Iraq). An experiment demonstrates that the frequency of vague communication increases in a controlled social setting when its use is beneficial for the group (Erev et al., 1991).

In some experiments special attention was given to dependence between the mode of communication and degree of uncertainty (Erev and Cohen, 1990). Subjects evaluated the chances of winning for different basketball teams. The authors noted that in the case of an unknown team (big uncertainty), experts could differentiate only two levels of verbal uncertainty and give it in comparative form (e.g. "they may think that the home team will always perform better than visiting team"). The authors conclude: "Finally, forcing people to give numerical expressions for vague situations where they can only distinguish between a few levels of probability may result in misleading assessments" (p.17).

The above examples demonstrate the kind of measurements which can only be made using verbal evaluations. The comparative measurements are based on an ordinal scale with the relation: "more probable than".

Systematic studies by Huber and Huber (1987) show that lay-people (adult as well as children) use comparative probabilities much more often than numerical ones. They use them for the tasks of an objective nature (spinning a circular disc) as well as for the tasks of subjective nature (sport competitions, games). The authors formulate six mathematical principles of comparative probability. These principles are the most important axioms and lemmas of the mathematical concept of qualitative

probability. Let A, B, C ... represent events. For example, A may represent the event that a fair die shows 5 after being thrown, B the event that the die shows 2; $>$ means "more probable".

Principle 1 is transitivity: if $A > B$ and $B > C$, then $A > C$. Principle 4 is: $X \geq A$, the certain event X is at least as any event A, and so on. The main result for the experiments with children (from 5 years) and adults is they obey all 6 principles. The authors conclude that the six mathematical principles provide a more reliable theoretical base for comparative probability than numerical probability.

Comparative evaluations have been used in practical tasks of pipeline route selection (Oseredko et al., 1982; Larichev et al., 1995). But nevertheless, people often want to receive probabilities in numerical form, due to subjective factors expressed by CMP paradox.

Consideration of Alternatives

The two methods differ considerably in whether they force consideration of alternatives. The qualitative approach, through the ASTRIDA method [ref], seeks resolution of the decision problem by engendering a search for another alternative that has not previously been considered. As seen in the Yamal case, this alternative can be a new option developed by altering the negative features of one from that given initially, or, as in the Niakuk case, VDA can suggest an entirely new option for solving the problem. The quantitative approach, although it can consider new options, does not use their creation as a tool in the analysis. Someone looking for options could use the qualitative analysis to see where the largest disadvantages of the existing ones are and try to develop a third based on the observations. Here again, the quantitative approach does not force considerations of alternatives, but expresses differences between the options considered to numbers.

The quantitative approach may provide a clearer picture of compensating considerations of the options. Thus, the analysis may point out that one positive impact out-weighs a negative impact in another category. The qualitative approach has no way of considering this trade-off in numbers. The ability to point out trade-offs might in-and-of-itself not lead to new alternatives, but it could provide a way of considering compensatory effects that are not part of the project plan. For instance, an applicant could propose to replace wetland in the project area by creating wetland of equal or greater value in another area. The quantitative approach could aid in determining the equivalence of value.

Complexity reduction.

While decisions about oil and gas development in the Arctic are often portrayed as a simple battle between development and the environment, the choices are more complex.

Because development takes place on public land in both Russia and the United States, several interests are usually involved. Each interest group may have a particularly distinct concern or stake - or even more than one. Development, primarily a consideration of economic interests, may include the company carrying out the activity, the local or regional government, or the federal government. All may have an interest in seeing the

development take place but with enough differences among them, e.g., taxes versus profits, that they cannot be considered the same. The complexity can arise from defining those differences as aspects of the same national interest. Similarly, the environment is not a single thing. Development may improve some aspects of the environment, while negatively affecting another. Finally, within the US, the battle often takes to a legal forum. Delay is a tactic, and the creation of complexity may be a way of increasing delay.

The qualitative approach eliminates much of the complexity by reducing the question down to the bare essential of differences. In the Yamal pipeline case, this difference came down to a trade-off between environmental impacts and cost. The qualitative approach can reduce several factors down to numbers, as was the case in reducing uncertainty down to a dollar value, but it does not try to equate everything to dollars. This approach has the advantage of clearly highlighting the main differences.

The quantitative method does not so much reduce the complexity per se, but brings to bear a common denominator. A chief issue between the two methods is whether the numbers created under the quantitative approach are "real:" do they truly reflect psychological states, that is states in which numerical intervals are equidistant and values placed on different impacts in fact follow a common scale and are thus comparable?

Providing desirable decision output.

NDA gives finally the value of utility to each alternative. After that it is possible not only to nominate the best alternative but also to define the difference in utility between the alternatives. It means that the output of NDA methods is rich enough to give decider the basis for detail evaluations and comparison of any options. By using VDA one is trying to construct a binary relation between the alternatives. Two options could be in a relation of dominance, equivalence and incomparability. In the latter case they cannot be compared on the base of psychologically valid operations of information elicitation, and VDA cannot give recommendations to decider. In such difficult cases, VDA approach would define the direction of search for new, promising alternative as it was in the Yamal and Niakuk cases above--an attractive possibility. But a decision method itself (or computer) cannot invent new options. Only human beings (decider or experts) could find or develop new ideas and implement them in the form of new decision option.

This means that it is possible also to expand so-called CMP paradox (Erev and Cohen, 1990) to decision output: some deciders could want to receive the analysis with numerical evaluations. It corresponds to the output of NDA approach.

How exact is exact enough?

In experiments at Texas A and M University, student subjects (Larichev et al., 1995) solved the same experimental tasks using three different decision support systems. Two of them were based on Multiple Attribute Utility Theory (MAU) and represented NDA approach. One was a VDA

system (ZAPROS) (Larichev and Moshkovich, 1995). ZAPROS is a decision support system for constructing a partial order (not all options are comparable) over the set of options. It does not require conversion of qualitative measures into quantitative form. The relations among alternatives are close to those based on ordinal dominance

The systems Logical Decision (Smith and Speiser ,1991) and DECAID (Pitz,1987) have the same ideas and differ only in technical details. Both are easy to implement , but vary slightly in the way in which they elicited attribute weights and estimates of attribute values. The most popular elicitation procedures (direct graphical estimation versus tradeoffs with "mid-Points ") were used in these two systems.

Experimental results show that ordinal relationships between task parameters are much more stable with qualitative than quantitative measures. Results from DECAID and LD are much less coincident with each other than with results obtained through ZAPROS. It means that quantitative methods are very sensitive to small errors in decision makers and experts answers. The question arises :how exact could be a decision maker in the condition of uncertainty ? It is well known that the exactness of physical measurements depends on the exactness of the instrument used. The same is true for human measurements. When it is difficult to assume that the decision maker is able to give exact valid numerical estimations of different parameters ,it may be better to use ordinal and often verbal judgments with the appropriate logical analysis of possible inconsistencies.

Mitigating uncertainty.

One unanimously accepted goal for decision method application is reducing the confusing effect of an uncertainty (Brown 1990). The approaches deal with uncertainty in very different ways. The VDA, at least in the Yamal case, looks at the cost of reducing uncertainty. That is, it transforms it into a monetary figure: how much will reducing uncertainty to an acceptable amount cost? Even if decision-makers do not decide to pay for that reduction, it is not an unknown. A public debate can be pursued in which the cost of uncertainty carries a concrete figure.

The NDA approach can estimate the amount of uncertainty, but decision-maker has to be able to think in numerical terms to provide an estimate. The payoff is that the analysis can derive a single estimate of uncertainty to go with the single estimate of utility, and the uncertainty can be graphically presented.

Under the NDA, we can evaluate how much money it is worth spending on research to reduce the uncertainty, using the well-known “value-of-information” paradigm, which is cognitively difficult to replicate informally or qualitatively. It is based on reducing the probability of a costly error.

Time spent and cognitive burden on decider.

From a practical point of view it is important to minimize time needed and cognitive burden. In applying NDA to new live case similar to Niakuk, eliciting input for two options, in which 30 consequences were distinguished, from a project manager with a biology bachelor's and unfamiliar with the approach, took about 4 hours. She had been concerned about diverting time from a crunch she was in, to participate in the exercise. But afterwards she said that the process of elicitation, with immediate computer feedback on action implications for permitting helped her do (and probably improve) thinking she would have to do anyway, on the way to making a recommendation on the permit. She did not find the answering to be cognitively uncomfortable.

In Yamal case decider spent less than one hour answering the questions needed to compare two initial options. So the time burden was still less than NDA. The questions were posed in natural language and decider really was not conscious that a decision method have been used.

Institutional criteria

Institutional criteria include: how communications in and between organizations can be improved ; how easy it is to use the approach; how big are educational requirements for members of an organization ; how big is institutional acceptance of an approach; what is the effect of cultural differences.

.Improvement of the communication

Both approaches may be improvements over the often confused discussions surrounding oil and gas development in the Arctic. Achieving greater clarity does, to some extent, provide improved communication.

VDA approach is more directly connected with communication because the sentences taken from the language used by decider and active groups compose the verbal quality grades on the criteria scales. VDA approach is adapted to the reality of ways of information exchange existing in organization and between the organizations. It does not require from decider or expert any preliminary knowledge of decision methods, but makes method “invisible “an user, a tool completely natural for the user.

From the other hand , NDA approach can present its findings in graphically interesting forms because of its numerical base. Our research did not specifically attempt to measure improvements in communication, but conversations with regulators in other agencies who participate with the CoE in the permitting process claimed that the NDA improved their understanding of CoE's position, and how their own might differ from it.

Ease of Use

Similarly, VDA is easier to use because it employs natural language. The NDA required the decision-makers to get used to it. Setting the scale (the meaning of the '100'

impact) took considerable discussion and making a judgment along that scale did not come "naturally." These difficulties were encountered even with decision-makers who had a scientific background and were comfortable with numbers. One might well ask whether the difficulties might be even greater for people without this kind of background. Given that the remote villages of Alaska are finding ways to become more involved in important decision-making, it would seem important that the analysis method used be accessible to them. Accessibility is a combination of education and ease of use. How much more education would be needed for a decision-maker before the NDA "made sense" or was "easy to use?" With the NDA, after the decision-makers had used it once, they picked up modifications very rapidly. Thus, the VDA may be most appropriate where a decision analyst does not have a large amount of time to work with the decision-maker. NDA may be easier to work with as the length of time available increases.

Educational requirements.

During practical work, attention must be given to the initial knowledge of decision analysis typical for the members of an organization. Due to recent education or special courses in decision analysis, key participants in the decision process may have enough knowledge of NDA. that its application of NDA on any practical problem looks natural. But typically this cannot be assumed and VDA the only practical possibility for a consultant to use. Even when some members of an organization have studied some days operational research or decision analysis, they feel themselves in more comfortable and confident using the language accepted in the organization. That is why the analysis for both approaches typically begins with the qualitative description of the problem.

Cultural differences.

It is necessary to stress the cultural differences influencing the applicability of different approaches. For American culture numerical evaluations are more typical and acceptable than for Russian one. For example, the use in cases of difficult public of so-called contingent valuation, which requires "to put a price tag on goods not traded in any market place" (Fischhoff, 1996). The requirements to apply cost-benefit analysis for all significant federal actions produces favorable conditions for NDA and other quantitative analytical work for American analysts. That is why NDA is accepted more widely in US than in Russia or Europe.

Institutional Acceptance of the Methodologies

One measure of the success of NDA approach described in the Niakuk case was in the CoE's continuing interest in its development and use. Initially, CoE decision-makers appeared more comfortable with the VDA, but became more accepting of the NDA as they used it. Two instances of non-acceptance did arise, however, during the course of research. In one instance, a person with whom the research team was interested in working declined to do so because he felt that the decision he was called upon to make

was his sole responsibility. In another instance, an oil and gas interest group decided not to be involved because of their concerns that the methods would create a dollar figure for environmental change that might be used as a damage figure in legal proceedings.

In the case of VDA application in Yamal case there were no question of acceptance because the approach itself was “invisible” for decider and experts. They participated in professional discussions answering the consultants questions posed in natural and understandable language.

The possibility to apply a decision analysis for a practical task depends strongly from the attitude of decider. First of all ,he has to be interested in final results which could improve his position in the organization or in the relation to other organizations. Very often he needs the results to increase the possibility of explanation for the future decision or to increase his personal power. But sometimes decider is afraid of possibility to involve a consultant into sensitive questions connected with analysis of problem

Personal criteria .

Personal criteria include: how big are educational requirements to decider; how possible to provide to decider the possibility for learning in the process of decision method application ; how professional habits of a consultant influence the selection of an approach

Educational level of a decision maker

. decider is to be enough educated to know how to obtain the valuable output from the analysis and to know how to use a consultants help. It is the question of practical experience and intellectual ability of decider. Such qualities are presupposition for the utilization of any analytical technique.

Personal education in decision analysis helps to decider to accept the approach of NDA.

VDA methods do not require from an user a special knowledge in decision analysis. VDA approach is especially needed in the situations when a decision is taken in new circumstances or in conditions of high uncertainty.

Professional habits of a consultant.

The consultants working in different countries often use quite different analytic techniques in the process of analysis. It is evident that French consultant use ELECTRE methods (Roy,1985) much more often than AHP methods (Saaty,19xx). VDA methods are used by Russian consultants. MUA and AHP are the most popular decision analysis methods in US.

The existence of different schools in decision research defines in great degree the toolbox and professional habit of a consultant. There are positive and negative consequences of this situation .

As the positive one it is possible to stress the professional habits developed by the consultant in dealing with one kind of analytic technique. Decision analysis is a combination of art and science. To develop an art of successful application of a decision analytic technique one is to practice it.

The negative consequences of the consultants attachment to one kind of analytic technique are :

-limitation of number of possible analytic tools which could be successfully used for different kind of practical problems ;

-utilization of the analytic technique for the cases when quite different approach could be more efficient .

To big extent the negative consequences are defined by the contemporary state -of -art in decision analysis. This field of research lacks comparative studies of the conditions for application of different analytic techniques. It was stressed above the difficulties in undertaken such studies . But the maturity of research field is reflected in its ability to classify tools and tasks.

Possibility of learning for decider

It is difficult to expect that decider has preliminary formed preferences in his head. By solving new problem an experienced decider may have some ideas and professional habits . But final decision rule is usually developed in the process of problem solution . That is why an analytic technique has to provide to decider a possibility to learn in the process of construction of decision rule. Errors are an inevitable part of human behavior. decider has to have the possibility of making errors in decision process , watch the consequences and receive a feedback.

VDA methods provide such possibility for decider. For example, in ASTRIDA method (see above) decider could make contradictory comparisons of reference alternatives. The information about the contradiction is given to him back for the analysis . The methods ZAPROS and ORCLASS (Larichev and Moshkovich, 1994, 1995) provide the same opportunities. NDA approach give same possibilities of learning by asking qualitative comparisons before quantitative ones . But there are not special procedures for finding and eliminating contradictions which really provide the possibility of learning for decider.

Conclusion.

The last 30-40 years of experience in applying decision analytic techniques demonstrated that there are no universal tools for any kind of problem. Similar decision problems are solved successfully by analysts from different countries using quite different tools.

The usual line of research is to use laboratory studies to develop and to evaluate some tools for the real world (Fischhoff,1996). The research presented in this paper had opposite direction : to study an applicability of tools for the real world and to find some statements of problems for the laboratory research.

To make “ science good for the real world “ (Fischhoff,1966) the decision analysis research community is to collect practical experience by solving practical tasks. The comparison of decision analytic technique has to become a common practice .From time to time we witness a “struggle for the field “ between the authors of different decision analytic tools . But field is big enough to locate the variety of useful tools .It is more interesting but more complex to find a correspondence between a task and a tool. But to do it one is to study the field carefully, to understand it by solving complex practical tasks and to match the tasks and the tools .

References

(Alphabetize)

- . Flanders NF, Brown RV, Larichev OI, Andre'eva E. Justifying Public Decisions in Arctic Oil and Gas Development: US and Russian Approaches. *Arctic*. In press.
- . Brown RV, Flanders NE, Larichev OI. Decision Science for Regulating the Arctic Environment. *Arctic Research of the US*. Jan 1997.
- . Brown, R.V. and Pratt, J.W. Normative validity of graphical aids for designing and using estimation studies. Zeckhauser R, Keeney RL, Sebenius J (Eds.). In *Wise Choices* Symposium in honor of Howard Raiffa. Wiley. 1996.
- . Andre'eva E, Larichev OI, Flanders NE, Brown RV. Complexity and uncertainty in Arctic Resource decisions: the example of the Yamal Pipeline. *Polar Geography and Geology*, 19:22-15, 1996.
- . Larichev, O.I., Brown, R.V., Andreyeva, E., Flanders, N.E. Categorical decision analysis for environmental management: A Siberian Gas Distribution Case. In *Contributions to Decision Making I*. Eds. Caverni JP, Bar-Hillel Maya, Barron FH, Jungermann H. North Holland-Elsevier. 255-286, 1995.
- Hamm R." Selection of Verbal Probabilities Solution for Some Problems of Verbal Probability Expression", *OBHDP* ,48,pp 193-223,1991.
- Huber B., Huber O. "Development of the Concept of Comparative Subjective Probability", *Journal of Experimental Child Psychology*,44,304-316,1987.
- Rapport A., Wallsten T., Erev I.,Cohen B. "Revision of opinion with Verbally and Numerically Expressed Uncertainties", *Acta Psychologica* ,74,pp.61-79,1990.
- Gonzalez-Vallejo C., Wallsten T. "The Effects of Probability Mode on Preference Reversal", Working paper of Department of Psychology ,University of North Carolina,
- Erev I. Cohen B. "Verbal versus Numerical Probabilities: Efficiency, Biases, and the Preference Paradox",*OBHDP*,45,pp1-18,1990.
- Wallsten T., Budescu D., Zwick R. "Comparing the calibration and coherence numerical and verbal probability judgments ",*Management Science*,39,pp.176-190,1993.
- Brown R. "Assessment Uncertainty Technology for Making and Defending Risky Decisions", *Journal of Behavioral Decision Making* ,v.3,213-228,1990.
- Budescu D., Wallsten T. "Processing linguistic probabilities :General Principles and empirical evidence", *The Psychology of Learning and Motivation*,v.32,Academic Press,1995.
- Larichev O., Olson D., Moshkovich H., Mechitov A. "Numerical vs. Cardinal Measurements in Multiattribute Decision Making :How Exact is Enough ?",*OBHDP*,64,N.1,pp 9-21,1995.

Larichev O., Brown R., Andreyeva E., Flanders N. (1995) "Categorical decision analysis for environmental management :a Siberian gas distributing case", in :J.-P.Caverni, M.Bar-Hillel,

F.H.Barron, H.Jungermann (Eds.) *Contribution to Decision Making*, North Holland.

Teigen K. "The language of uncertainty ",*Acta Psychologica*,68,27-38,1988.

Erev I., Wallsten T., Neal M. " Vagueness, Ambiguity, and the cost of mutual understanding "*Psychological Science* ,v.2 ,N.5,sep.1991.

Oseredko Y., Larichev O., Mechitov A. "Main Gas Pipeline Route Selection Problems, Taking into Consideration Risk and Uncertainty Factors", In: H.Kunreuther, E.Ley (Eds). *The Risk Analysis Controversy*. Springer - Verlags, Berlin, 1982.

Larichev O.,Moshkovich H. "An Approach to Ordinal Classification Problems "*International Journal of Operational Research* ,v.1, N 3, pp.375-385,1994.

Larichev O., Moshkovich H."ZAPROS- LM -a method and system for ordering multiattribute alternatives ". *European Journal of Operations Research* , 1995, vol.82, 503-221.

Erev I.,Bornstein G.,Wallsten T. "The Negative Effect of Probability Assessments on Decision Quality", *OBHDP* 55, 87-94,1993.

Larichev O.I. "Science and Art of Decision Making ", Nauka Publisher,1979 (in Russian).

Raiffa H. "Art and Science of Negotiation ",Harvard Univ. Press, 1982.

KeeneyR., Raiffa H. "Decisions with Multiple Objectives : Preference and Value Tradeoffs ", Wiley,New York,1976.

Howard et al., (Decision analysis text book)

Brown et al., *Decision Analysis for the Manager*, Holt, 1974.

Brown RV, Flanders NF, Larichev OI, Andre'eva E. Decision aids for land-use permitting: an Alaskan oil case. *SPUdecider95 Conference*. In preparation.

Roy B. "Methodologie Multicritere d'Aide a la Decision ", *Economica*, Paris 1985 (in French).

von Winterfeldt, D. and Edwards, W. *Decision analysis and behavioral research*. New York: Cambridge University Press, 1986.

Watson, S.R. and Buede, D.M. *Decision synthesis: The principles and practice of decision analysis*. New York: Cambridge University Press, 1987.

Larichev O.I. "Objective models and Subjective Decisions ", Nauka Publisher,1987 (in Russian).

Timmermans D. "Decision aids for bounded rationalists (an evaluation study of multiattribute decision support in individual and group settings)",Dissertation, Groningen University, The Netherlands, 1991.

Buede D.M. and Chisser R.W. "Providing an analytic structure for key system design choices", Journal of Multi-Criteria Decision Analysis,v1,N1,1992,pp17-27.

Olson D. "Review of empirical studies in multiobjective mathematical programming :subject learning and response to nonlinear utility ",Decision Sciences,v.23,N1, 1992,pp1-20

Brown, R.V., and Ulvila, J.W. *Selecting analytic approaches for decision situations* (Revised Edition). *Volume I: An overview of the methodology. Volume II: Case studies. Volume III: Appendices* (Technical Report 77-7-25). McLean, VA: Decisions and Designs, Inc., December 1977. (NTIS No. AD A047965 (Vol. I); AD A047880 (Vol. II); AD A048228 (Vol. III))

Brown, R.V. The Role of Statistical Decision Theory in Decision Aiding: Measuring Decision Effectiveness in the Light of Outcomes. In Freeman PR, Smith AFM (Eds) *Aspects of Uncertainty: A Tribute to Dennis Lindley*. Wiley, 1994.

Howard, R.A., and Matheson, J.E. (eds.) *Readings on the Principles and Applications of Decision Analysis*, Vols. I and II. Menlo Park, CA: Strategic Decisions Group, 1983.

Larichev O.I. "Cognitive validity in design of decision-aiding techniques", Journal of Multi-Criteria Decision analysis, V1,N3,pp127-138.,1992.

Larichev O.I., Moshkovich H. "Qualitative methods of decision Making ", Physmathlit Pulisher,1996(in Russian),1996.

Andreyeva E., Larichev O., Flanders N., Brown R. "Complexity and Uncertainty in Arctic Resource Decisions: the Example of the Yamal Pipeline"

Fischhoff B. "The Real World :What Good is it ?", Organizational Behavior and Human Decision Processes, v 65,n 3,pp.232-248,1996.

Gonzalez-Vallejo C. and Wallsten T. "The effects of communication mode on preference reversal and decision quality ",Journal of Experimental Psychology: Learning ,Memory and Cognition, 18,pp855-864,1992.

Moshkovich H. (1991) Qualitative methods in multiattribute decision making .,*Proceeding of 13 Research Conference on Subjective Probability, Utility and Decision Making*, University of Fribourg, Switzerland.

Tversky A., Sattach S., Slovic P. "Contingent weighting in judgment and choice",
Psychological Review ,95,pp.371-384,1988.

Saaty, T.L. *The Analytic Hierarchy Process*. New York: McGraw-Hill, 1980.

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