2.9. COMPARISON OF DECISION ALTERNATIVES WITH REGARD TO RISK AND SAFETY CONSIDERATIONS: METHODOLOGICAL PROBLEMS

O. I. Larichev
VNIISI, USSR Academy of Sciences, Moscow

1. INTRODUCTION

The evolvement of large-scale technologies gave rise to a problem of choice between complex technological projects with regard to risk factors. The problem is quite specific and is commonly referred to as <u>risk analysis</u>. A partial case of this problem is the siting of a complex engineering system such as a nuclear power plant, a chemical factory, liquefied gas terminal, gas pipeline, and the like.

The problem of site selection with due account of the risk factor has been studied in many papers. IIASA approached it from the descriptive standpoint (how the choice is exercised) by conducting four case studies into the selection of sites for liquefied gas terminals.[1] Some papers[2] treated the problem from the normative standpoint. G. Ford et al[3] compared a number of methodological approaches to the nuclear power plant siting. The comparison ended with selection of the two best methodologies. In line with the latter and following the elimination of clearly unacceptable alternatives, the quantitative method of utility function construction was used to evaluate each alternative.

We believe the methodological specifics of the considered problem require some other approach. Further, we shall consider the distinguishing features of the problem of complex technological system siting.

2. SPECIFICS OF THE CONSIDERED PROBLEM

According to the descriptive research, subject to analysis is the multiple participants (many active groups) and multi-attribute problem. What is more, the multiple criteria estimates are highly uncertain and the opinions of the experts producing the estimates are often conflicting. The decision process as such comprises several steps resulting both in an acceptable decision or no decision at all.[1] Besides, there are the following specifics:

1) <u>Inhomogeneous Criteria</u>: Of course, there are many criteria characterizing the preferable alternatives for different decision choice participants. The additional complexity is that the criteria are inhomogeneous. They characterize economic, social, ecological, and organizational aspects of each decision alternative.

2) Criteria Estimates are in a Different Form: It is worth pointing out that because of the different nature of criteria, the criteria estimates are in different languages. Some of them may be quantitative (cost, distance estimates, etc.), others qualitative (environmental impact, earthquake probability). The lack of precise probabilistic estimates implies elicitation of the expert information only in the form of verbal event probability statements. What is more, the lack of necessary information sometimes results in relative rather than absolute criteria estimates. Thus, in comparing the gas pipeline alternatives with respect to the safety criterion, use was made only of qualitative methods,[4] i.e. which alternative is the safest for the population.

We believe that the primary language the estimate is formulated in is very important for all subsequent stages of alternative evaluation. Only the language customary for experts may ensure the measurement reliability. Of course, more often than not the measurements are conducted on strong quantitative scales. Nevertheless, the transition from the primary qualitative estimates to the secondary quantitative ones is methodologically incorrect as it engenders an unjustifiable arbitrariness.

3) Difficulty of Comparing Estimates by Some Criteria: Apart from the usual difficulties relating to comparing inhomogeneous estimates, there are additional complexities such as the comparison of the amount of electric power generated by a nuclear power plant and the number of casualties in case of accident. One can hardly imagine a manager capable of finding an explicit trade-off between the estimates by the above criteria. The assignment of criteria weights is psychologically incorrect.

4) Necessity of Accounting for Criteria Relating to Different Moments in Time: In making decisions on siting the complex technological systems, three groups of estimates must be taken into consideration:

   a) estimates of the area and place of location;
   b) estimates of the operating system's environmental impact;
   c) estimates of an accident's implications (highly unlikely, though).

The three groups of estimates relate, in effect, to different projects: the one under construction, a normally operating project, and a damaged one.

5) Difficulty of a Reliable Assessment of the Decision Implications: The book[1] convincingly shows that the expert estimates of probabilities of different events relating to the future can vary considerably (the probability of an aircraft hitting a liquefied gas terminal, probability of liquefied

gas-carriers colliding, etc.). The variance is probably due to the fact that people perceive poorly and assess very low probabilities.[5] The low probability estimates (10^{-4} and the like) are, therefore, hardly informative for accidents, both trivial and disastrous, which do take place from time to time. More informative is the matching comparison (quantitative and qualitative) of different safety control systems.

6) Difficulty of Harmonizing Conflicting Estimates: Of course, harmonizing opinions of different active groups is a complicated process. Even if all of them strive toward an acceptable decision, the alternative estimates of individual criteria and on the whole may vary considerably.

3. REQUIREMENTS TO DECISION TECHNIQUES

The above specifics make it possible to formulate several requirements on evaluating technological system siting alternatives. First, practice shows the desirability of approaching the choice problem from a more general standpoint: not to be confined to comparing the available alternatives, but to look for new ones and compare (sometimes modify) them with the existing alternatives. In other words, it is a consistent specification of requirements for the complex project siting by analyzing the available alternatives, determining the range of alternative estimates, searching for new sites (if necessary), etc.

Second, each active group must be able to verify any estimate. Hence, the latter must be easily understood and formulated in an adequate language.

Clearly, the axiomatic techniques based on quantitative scales, comparison of all criteria, and construction of the decision-maker's utility function do not meet the requirements.

4. THE SUGGESTED METHODOLOGICAL APPROACH

The first characteristic of the suggested approach is the search for a dominant alternative. The psychological research[7] indicates that in selecting the best alternatives, the decision-maker first pinpoints a preferable alternative and then tries to substantiate its superiority over the others.

It is possible to develop a normative method also oriented toward the search for domination. In comparing the decision alternatives, one has first of all to remove the inferior ones. Then, in the course of a pair-wise comparison, one looks for superiority of one alternative over the other.

There is, as a rule, a small number of decision alternatives (not more than 10). The suggested approach implies a pair-wise comparison of project siting alternatives. The three aforementioned groups of estimates (those of site, of environmental impact, and of accident implications) are not compared with one another. The estimates of only two alternatives in each of the three groups are subject to comparison. The purpose of comparison is to determine which alternative is preferable and by what criteria group. With this in mind, use is made of the compensation techniques and the improvement of some estimates of some estimates at the expense of others. The second feature of the approach is that the decision alternatives are not viewed as fixed and invariable, but rather as a type of alternative with possible modifications within the limits of the type. The point is that in designing certain projects (industrial buildings,[6] gas pipelines,[4] cities), it is possible to improve some criterion estimates at the expense of others. Thus, with additional investments we may improve the quality of a nuclear plant site. By installing a new power line, we may place the plant farther from settlements, etc. In case the alternatives are incomparable, it makes sense to define requirements to an alternative which is superior to the two available alternatives by all criteria. Account must be taken of the opinions of different active groups. The decision-maker's job boils down to a search for the required alternative and to demonstrating the lack of an opportunity for developing one.

The pair-wise comparison may end up in the selection of an alternative acceptable to all active groups or in a lack of accord between the active groups if no best alternative can be found. In the latter case, however, there arises a host of requirements for the project design and the desirable site which is in effect a guide to future actions.

We employed this approach in comparing the alternative routes of a gas pipeline.[4]

At the preliminary stage of research, three variants of pipeline route have been selected: maritime, median, and piedmont. The comparison of variant was made on criteria given in the table.

Of the parties involved in the actual pipeline selection procedures, four major participants can be singled out. First, there is the customer organization which determines the design task and performs pipeline maintenance; secondly, the organization that designs the pipeline; thirdly, any project has to be agreed upon with the regional authorities which represent the interests of the local population; and finally, the route selection is influenced by the contractor who will actually construct the pipeline.

When comparing the routes, each participant in the selection process is primarily concerned with a definite subset of the given criteria. For example, the project organization draws attention to criteria C, C1, C2, IN, R, and S; regional authorities are concerned with criteria RP, IN, S, R, and C2; and the customer is naturally interested in criteria C, M, R, and S.

Finally, the contractor gives primary consideration to criteria T_{min} and S.

The selection procedures adopted are as follows. The project organization analyzes all possible pipeline routes. Using the initial basic outlines, the route direction in each version is then specified as that minimizing the presented costs. Then the project organization selects a version and transfers this proposal together with information about all the other versions to the customer and then to the regional authorities for approval. The contractor's representatives also take part in these discussions. In this example, the project organization preferred the maritime version. When considering the various versions, the regional authorities pointed out the comparison between the far superior evaluations of the median version on criteria C2, RP, and R and the "best" evaluations of the maritime version on criteria IN and S. During the analysis, the regional authorities asked the customer and the project organization to find new technical solutions to improve the evaluations of the median version on criteria IN and S in order to bring them nearer to the maritime version evaluation. As a result of investigations towards this end, the project organization suggested the possibility of cutting down the guarding zone, combined with an increase in reliability effected by increasing the thickness of the pipe wall. It was found that with such an improvement the number of buildings requiring demolition would be considerably reduced and the presented costs of the median and maritime versions would become closer, despite the increase in the amount of metal required and in the cost of the pipeline. In the table, evaluations of the versions after incorporating this improvement are given.

With these improvements, all the participants in the selection process chose the median version as the most acceptable, and so this version was selected.

The example given above is typical in gas pipeline route selection. Each active participant in the procedure is at first guided by his own subset of criteria, working through from the more to the less important ones. This is characteristic of a satisfactory decision search according to Simon. We must point out that usually no single version is superior on all criteria; it is almost always necessary to look for a compromise. A typical feature of an actual comparison process is a series of attempts to revise some of the versions, in order to improve their assessments on particular criteria.

5. CONCLUSION

We believe that the successful selection of a project site depends on the following factors:

1) understanding by all active groups of the necessity to solve the problem the technological project is being built for (e.g., additional power supply);

2) opportunity for all active groups to elicit information about all feasible alternative ways to solve the problem; a joint selection of one of the ways is desirable;

3) opportunity for the joint assessment and comparison of the project sites;

4) development of a convenient and effective tool for comparing the alternatives; a man-machine collective decision support system best serves the purpose.

TABLE

	Criterion	Designation	Order of Preference		
			Maritime	Median	Piedmont
1	Presented costs (million roubles)	C	8,9	9,5	10,8
1A	Cost of laying the main route (million roubles)	C1	31	40	46
1B	Cost of laying prospective pipeline branches to consumer (million roubles)	C2	9,5	5	5
2	Construction time	T_{min}	Second best	Best	Worst
3	Convenience of maintenance	M	Inferior	By far the best	Inferior
4	Reliability of maintenance	R	Best	Inferior	By far the worst
5	Influence on the environment	IN	Best	Inferior	By far the worst
6	Connection with regional development plans	RP	Second best	By far the best	Worst
7	Construction conditions	B	Second best	Best	By far the best
8	Population Safety	S	Best	Inferior	Inferior

REFERENCES

1. Kunreuther, H., Linnerooth, J. et al. Risk Analysis and Decision Processes, Springer-Verlag, 1983.

2. Keeney, R. L. Siting Energy Facilities, Academic Press, 1980.

3. Ford, C. K.; Keeney, R. L. and Kirkwood, C. W. "Evaluating Methodologies: a Procedure and Application to Nuclear Power Plant Siting Methodologies," Management Science, Vol. 25, No. 1, 1979.

4. Larichev, O. I. et al. "Main Gas Pipeline Route Selection Problems, Taking into Consideration Risk and Uncertainty Factors," in: H. Kunreuther (ed.) The Risk Analysis Controversy, Springer-Verlag, 1983.

5. Kahneman, D.; Slovic, P. and Tversky, A. (eds.) Judgement under Uncertainty: Heuristics and Biases, Cambridge University Press, 198.

6. Larichev, O. I. et al. "The Interactive Procedure of Industrial Building Projects Choice," in: Proceedings of Multicriteria Objects Estimations, VNIISI Proceedings, No. 9, 1984.

7. Montgomery, H. and Svenson, O. "A Think Aloud Study of Dominance Structuring in Decision Processes," in: R. Tleitz (ed.) Aspiration Levels in Bargaining and Economic Decision Making, Berlin: Springer-Verlag, 1983.

Larichev O. Comparison of decision alternatives with regard to risk and safety considerations: methodological problems // Issues and Trends in Risk Research / Ed. by B. Segerstale, G. Kromer. — No. WP-88-034. International Institute for Applied Systems Analysis, 1988. — Pp. 189–196.

```
@InBook{Larichev_1988,
  title =         "Comparison of decision alternatives with regard to
                   risk and safety considerations: methodological problems",
  booktitle =     "Issues and Trends in Risk Research",
  author =        "Larichev, O.",
  editor =        "Segerstale, B. and Kromer, G.",
  publisher =     "International Institute for Applied Systems Analysis",
  number =        "WP-88-34",
  year =          "1988",
  pages =         "189-196",
}
```