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Current Methodological Problems of Systems Analysis and Its Application

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1. Historical background of systems analysis

Part of the basic thesis of the workshop sponsors is that the smooth stage of systems analysis development is over and there are signs of current difficulties in its application to practical problems.

To better understand the current state-of-the-art of systems analysis methodology one has to trace the history of its origins and development.

Undoubtedly, systems analysis originated as a means of handling certain military and engineering problems as described in the well-known book *Analysis for Military Decision* by E. S. Quade.[1] The majority of these problems resembled those in operational research. The objective description of the core of the problems was considered quite possible. The methodological features of the operational research approach may be easily traced using the example of the well-known "cost-efficiency" method, considered by many as an integral part of systems analysis. Originally cost-efficiency models were developed just like models in operational research (transportation problems, assignment problems and the like). It was supposed that a researcher was able to define objectively the existing features of a problem and to reflect them in the model, and that the studied phenomena lacked "behavioural freedom". The difference in the approach to synthesizing the cost and efficiency estimates boiled down to the consideration of the decision-maker's opinion. Complex as they may be, the problems first subjected to systems analysis were, in our opinion, at the interface of well- and ill-structured ones. These problems, however, required an independent methodology of systems analysis comprising the known stages of the systems approach, i.e. to define goals; find alternative ways of achieving them; develop a model integrating the goals, means and parameters of the system; find the rules to select the best alternative[2] as well as a cost-effective method for comparing alternative methods of accomplishing the goals. It is worth pointing out that Quade distinguished quantitative differences rather than qualitative ones between operational research and systems analysis.

2. New applications

Great difficulties were encountered in extending the methodology to ill-structured problems wherein the qualitative, poorly defined, aspects tend to dominate. In our opinion, the major features of these systems are as follows:

The impossibility of constructing objective models of the investigated system.

In fact, the majority of ill-structured problems lack an objective, scientifically based model integrating the system parameters in a unified whole. Consider, for example, the problem of R & D project estimation. Here we find that the quality of the project depends on such factors as the scientific skill of researchers, the value of the end result of the completed scientific tasks, cost of the project etc. However, one cannot say there is only one correct mathematical relationship between these factors which defines the general utility of the project. There can be many relationships, as well as factors, and the choice is made by the decision-maker according to his experience, intuition and world outlook. Another decision-maker may prefer some other model. It is noteworthy that the factors included in the model are very difficult to measure quantitatively.

Thus, we are now in the world of subjective models. The lack of objective, scientifically valid, relationships make us regard the system's parameters as criteria for evaluation of alternative solutions. The problems acquire a multi-attribute nature.

H. Rittel and M. M. Webber in their interesting paper[3] write about "wicked" problems with many possible approaches to their definition, where the goals are influenced by the method of approval

adopted. There is a great variety of such problems, e.g. development of tourism in a country or region, allocation of resources for basic research, selection of manuscripts for publishing in a publishing house. One could say that all strategic problems have features of wicked ill-structured problems. It is quite understandable that the original methodology of systems analysis was not fully able to cope with the peculiarities of such ill-structured problems; giving rise to many new problems which are exemplified in the application of the PPB system to civil problems. I. R. Hoos in the excellent book "Systems Analysis in Public Policy; a critique"[4] writes about unsuccessful attempts to use quantitative indicators and to construct "cost-effective" models.

Systems analysis in its primary form implied from the beginning that there would be a sequential analysis of the problem, from the goals to the means. Experience shows that this systems approach is not a universal solution to all problems. As a constructive tool for comparing alternatives, systems analysis implies using the "cost-efficiency" method. Now it is clear that the construction of "cost efficiency" models for many problems is characterized by a great degree of subjectiveness and can be done in various ways.

It is also clear that the methods used in comparing alternatives greatly influences the entire systems analysis methodology with respect to its applicability.

3. Modern key methodological problems: practical view

Systems analysis in the 1970s differs undoubtedly from that in the 1960s; the problem analysis is more flexible, improved multicriteria methods are applied to compare the alternatives.

In modern systems analysis one can distinguish three directions. The first one is not connected directly with decision making. It is directed at the investigation of the entire problem or its parts in order to establish a basis for decision-making.

Although such projects are mostly undertaken on the instructions of the decision-maker, his policy preferences are hardly, if at all, taken into account in the course of investigation. Such applications of systems analysis can be called system studies. System studies of ill-structured problems may include detailed verbal descriptions of all the system attributes identified, of all possible decision estimation criteria, of forecasts with respect to the system and to changes in the environment, and so on. Some problems may be approached with mathematical models.

The second direction of systems analysis relates to decision-making situations, where no decision-maker or a group of decision-makers can be identified; for example, where it is necessary to solve a social problem, touching upon the interests of a large group of people, but where there is no organization responsible for handling this problem. Thus, there is a decision-making problem but no decision-maker whose preferences could serve as a basis for a decision rule.

The third direction concerns the estimation of the decision alternatives and the selection of the best alternative.

Since the decision in ill-structured problems should be developed on the basis of the decision-makers preferences, research is carried out not only on the decision-makers instructions but also with his direct participation. In such cases systems analysis can be viewed as a synthesis of the systems approach, methods of multi-criteria alternative estimation and decision-maker's experience, preferences, intuition. In applying systems analysis in its present state to practical problems one encounters, in our opinion, the following major main methodological problems:

1. The difficulty of measuring the qualitative concepts characteristic of ill-structured systems.

Today, the qualitative concepts are mostly brought in line with numerical, quantitative scales. A lot of methods used for measuring the decision-maker and expert preferences employ lotteries, number scales etc. Such measurements can often distort the actual human preferences. At present there are no techniques for quantitative measurement of many subjective criteria of decision estimation such as, for example, scientific quality, organizational prestige, and so on. It is well-known, however, that ordinal scales had been used for many physical variables (heat, length) until quantitative scales were developed. Nevertheless, at present we lack any reliable method for quantitative measurement of variables in ill-structured problems. Consequently, ordinal scales with verbal labels of quality de-

grees must be used. These scales make it possible to get equivalent descriptions of ill-structured problems in natural language.[5]

Great skill must be used in employing natural language in this way so as to preserve pithy and qualitative descriptions at every stage of decision-making.

2. Development of decision rules in ill-structured problems.

Since the alternative estimation models have to account for the decision-maker's preferences, one must be able to identify these preferences and utilize them in decision rule construction. In this case the main problems are connected with the psychology of decision-making.

Recent investigations[6] show, that a number of limitations inherent in the human cognitive apparatus sharply reduce its possibility to cope with information and the reliability of this information. For example, we know, that due to the limited capacity of short-term memory people have to resort to a number of heuristic methods for the analysis of multidimensional information.

The major techniques are:

(i) dropping of a number of criteria;

(ii) neglect of small differences in the estimations by one criterion;

(iii) successive consideration of the criteria.

These devices are very important for the human being since they help him to cope with complex problems. On the other hand, however, the same methods lead to contradictions and errors.[7]

One of the major current problems of systems analysis methodology is how to enhance and extend human capacity so as to process multidimensional information in a reliable and non-controversial manner.

We are trying in our investigations to develop special decision making techniques[5] which would take into account the data processing capabilities of a man and extend them.

3. The problem of applying the systems approach to the analysis of ill-structured systems.

The application of the systems approach to real life complex situations of decision-making is only possible by an interactive approval, examining many ways of moving from changing goals to changing means in order to find a single (or several) "solvable" representation of the problem for a decision-maker.

4. Current trends in systems analysis

The current state-of-the-art of systems analysis makes a complex picture. Problems continue to be studied (and sometimes successfully) with objective cost-effectiveness models, similar to the approaches used in the earliest applications of systems analysis. As the boundaries between various types of problems are fuzzy, there are continuing attempts to build objective models for problems where inadequate, objective information must be supplemented through subjective judgement. Very often, due to the lack of any data source, the consulting analyst "patches the holes" on the basis of his own knowledge of relationships between the system parameters. In complex models this "patching" affects the final results in an unpredictable manner. The developed models to a great extent reflect the belief of their creators that the world is arranged in that way, and not some other way.

Sometimes the qualitative dependences between model parameters are quite explicit but it is difficult (or impossible) to determine the exact strength of these dependences. By filling the gap the consultant also strongly affects the result.

The resulting pseudo-objective models are unacceptable for decision-makers as they are not based on the executives' experience, intuition, preferences. As a result the model builders often do not exert any influence on decision-making.

Though the well-known and popular definitions of systems analysis emphasize its direct orientation towards decision-making, the same term (systems analysis) has often been associated in recent years with the development of mathematical models with a view toward creating "banks" of models with potential use in decision-making. A realization of the fact that the application of systems analysis represents a combination of "art" and scientific analysis, was used actually as an excuse for the "separation" of the analytical aid from the "art" and its further study. This approach has resulted in the emergence of a great number of mathematical models; but there is little evidence relating to their

practical application. We believe that practical problems possess characteristic features which can be reflected only by a model built specially for the problem. Many models (e.g. so-called global models) contain a lot of assumptions and premises of their creators intermixed with certain objective dependences. Hence, application of such models in decision-making is simply dangerous.

The experience gained from unsuccessful applications of systems analysis to problems with a subjective structure brought about two directions of research. The first one "policy analysis" is concerned with solution of public policy problems. The research conducted along these lines place a strong emphasis on the art of problem analysis, problems of organizational mechanism of decision implementation, etc. As an example of interesting research conducted in this field, we shall mention the article by H. Rittel and M. M. Webber.[3]

The second direction is connected with systematization of the experience of applying systems analysis, identifying standard mistakes and miscalculations. It is worth mentioning E. S. Quade and G. Majone's book *Pitfalls of Analysis*[6] recently published by the International Institute for Applied Systems Analysis. The book attempts to systematize the unsuccessful approaches to problem analysis, model formulation, consultant-decision-maker interrelationships, etc.

For all this, extremely little attention has been paid to improving the methods and procedures for the analytical comparison of alternative decisions. As usual, one encounters in the literature, descriptions of cases of applying the "cost-effectiveness" techniques to such problems as storage of radioactive waste, construction of atomic power stations, though these problems undoubtedly involve various subjective and objective factors. An impression is gained that the authors of these papers have overlooked popular critical articles and books.[4, 9] Actually, major research in the methods of comparing complex decision alternatives are conducted at present by specialist decision analysts and not by systems analysts.

5. On the crises in systems analysis

One symptom of a crisis in systems analysis is doubt as to its capability to solve complex practical problems. This doubt follows from several causes. One cause arises from unsuccessful attempts to evaluate decision alternatives using pseudo-objective models. Another cause follows from attempts to use the systems approach as a universal and constructive method for solving ill-structured problems. In addition the abundance of useless mathematical models (developed in the name of systems analysis) does not at all increase the attraction of systems analysis.

All these causes are linked to a considerable extent with the aspiration (sometimes subconscious) to convert systems analysis to an "exact science" like operations research. The main potential value of systems analysis arises just from the differences which distinguish systems analysis from operations research.*

From our point of view the most valuable thing that system analysis has introduced into the methodology of complex problem solving consists in the understanding of the fact that subjective judgement must be accompanied by deep analysis. The methods of this analysis can, and must, change and improve. We have defined above the three major directions of improvement of these methods.

It must always be remembered that the application of systems analysis is a combination of art and science, where art prevails. The logical analysis of a problem is an art; the search of the ways to construct alternative estimation rules is an art. As this art improves new techniques and methods emerge that can be scientifically proved and their application area mapped. The methodology of systems analysis should not be regarded as something rigid but as a tool for the analysis of complex problems changing both under the influence of the researcher-analysts. Let us hope that these changes will take us to new and perfect methods.

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* «Operations Research» is used here in the narrow sense of mathematical model building. (Ed.)

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