METHODOLOGICAL ASPECTS OF PRACTICAL APPLICATIONS OF SYSTEMS ANALYSIS

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The ideas of the systemic integrated study of complex problems are gaining increasing recognition. Systems analysis can be regarded as a practical tool for implementation of these ideas. Many recently published textbooks and papers (e.g. [19] and [25]) deal with it or with its successful application in managerial environments (e.g. [18]). At the same time a fair number of publications appearing in the past decade indulge in criticizing some abortive systems analysis applications [9, 21]. The aim of this paper is to examine systems analysis procedures and postulates from the point of view of their relevance to a wide range of applied ill-structured problems [17].

SYSTEMS APPROACH

The words "system", "systems", "systemic", etc., are used in different expressions and combinations. In the pertinent literature, systems engineering [6], systems programming [3], systemic organizational design [28] and many similar terms are used along with the systems analysis notion. The main concept of system in its current meaning undoubtedly stems from the ideas of general systems theory [5] and cybernetics [27].

In the general framework of this overall systems approach, many different directions of study are feasible. For instance, one may regard it from the philosophical and methodological points of view. We do understand the importance and diversity of these various aspects of systems studies. But in this paper we will limit ourselves to consideration of just one of them, reflecting only the pragmatic side of systems analysis instructions.

The main concepts of systems approach are "system", "process", "input", "output", "feedback", "constraints", etc., [16]. These concepts have proved their validity in the analysis of systems of diverse nature. As for ourselves, we are going to look at them as they emerge in the study of the process of choice of a unique installation project or the process of compiling a departmental five-year plan, for instance. The analysis of these processes makes it possible to identify various systems dealing with similar problems (and the sub-systems they consist of), to establish their interdependence with different systems, and to identify their inputs (input information), outputs (decisions), feedbacks (decision analysis and verification) and constraints (resources, labour, etc.).

But what is the usual meaning of "systems approach" in this context? To answer this question, the existing recommendations as to how to tackle problems of a diverse nature in a "systemic" manner need to be examined. For instance, systems engineering recognizes [6] the following main stages of problem-solving: problem diagnosis and choice of objectives, enumeration or invention of options, their analysis, the search for the best option, and finally, solution presentation. Systems analysis and operations research usually distinguish five main stages of development of a similar scope: objective (or objectives) formations, search for the options consistent with the objectives established, evaluation of the resources needed for each option, model development, and the discovery of preference criteria suitable for the ultimate choice. In this context, the principal difference between systems analysis and operations research is that operations research relies on mathematical modelling, while systems analysis mainly uses logical models interrelating systems objectives, action options, environment and resources. The main stages of development referred to above may be compared to similar stages of managerial decision-making, which are [28]: establishing organization objectives, identifying the problems to be overcome to attain these objectives, analysing these problems and providing an ultimate diagnosis, searching for the solution, evaluating different options and choosing the best of them, discussing resulting conclusions with management and submitting them for final approval, finding the way to implement the decision taken, managing this implementation phase and validating the outcomes.

Similar stages of development are mentioned in various textbooks and papers - probably everywhere where authors endeavour to deal with complex problems in a systematic way (compare the general postulates for inventors looking for creative solutions to fundamentally novel problems [1]).

It is this precise structuring of research activities, this regard for objectives and the costs of their attainment, this identification and systematic evaluation of various options and this insistence on presenting the rationale for the choice that constitute the common features of the many papers dealing with systems approach. These ideas are of such a general nature that it is only fair to assume that many rationally minded people have used the similar structuring of their own complex problem solving processes for quite a long time.

Thus a systems approach to various problems primarily is manifested by the dissection of the system from its environment and by provision of an organized logical pattern of problem analysis. We can call this pattern the general systems approach schema. But in this regard, what makes the various modifications of the systems approach to dissimilar problems so different? First of all there is a difference in the way the analytical comparison of options is made. For instance, systems engineering makes use of standard evaluation techniques suitable for various classes of engineering systems (electronic circuitry, automatic control systems, etc.). Operations research relies heavily on several established techniques (mathematical programming, probability techniques, network analysis, etc.). As far as systems analysis is concerned, the main role is played by the "cost-effectiveness" analysis technique.

In dealing with a certain complex problem, our general systems approach schema is sometimes used without any reference to any special means of analytical comparison of options. This kind of approach has come to be immensely popular recently. It is now even hard to find a complex problem where a similar approach has not been recommended. Many attempts to directly apply the general systems schema to the solution of various problems are described elsewhere. For instance, one of the most detailed descriptions of this type is offered by Young [28]. He specifically analysed the process of a new hospital management system design. Meanwhile neither this nor any other similar presentation contains any conclusive proof that the general systems approach schema is a useful instrument of problem solving by itself. Of course, it is always useful to ponder the aims and objectives of your actions and to match them with the available resources, but there is nothing very new about it. In complex practical situations, similar postulates do not contribute very much. A meaningful demarcation of system borderlines is always a result of creative thinking. And the apparent general purposefulness of the established analysis pattern breaks down completely when confronted with the complex ill-structured problems of real life. Identification of objectives and problems often depends on the general idea of the solution, i.e. on the choice of certain options, whereas the decision rule itself depends on the available set of options.

In general, the situation looks like this: logical structuring and systematization of the various stages of complex-choice problem solving might be quite expedient for some managers and consultants. But they do not offer a blank cheque for problem solving. Young claims that systems approach offers itself as an engineering technique. Unfortunately, it has still a long way to go before it reaches this stage of maturity. To be considered a constructive means of problem solving, it has to develop some specific set of analytical tools, some specific techniques for the evaluation and comparison of options.

Evidently systems approach application, even at the level it is currently capable of, may be beneficial. The damage stems from its excessive over-evaluation, from the resulting fetishism, and from the fact that it has become the vogue of research. Unfortunately there is now a tendency to use the term "system" indiscriminately. To quote Gvishiani [7]: "The term 'system analysis' has become very fashionable and in this capacity is tagged on every managerial action which has proved to be successful."

This fetishism becomes exceptionally dangerous when not engineering systems, but rather social (transport, urban, managerial and so on) ones are being dealt with.

This reliance on the omnipotence of systems approach makes certain scientists quite confident that knowledge of the general pattern of investigation alone is sufficient to successfully deal with the various problems arising from different ways of life. However, in different systems even the concept of rationality is vastly different. For instance, rationality criteria valid for health services might not be so in public transit systems.

Thus, the pragmatic potential of the general schemata of systems approach (i.e. the list of the stages of a typical research inquiry) is relatively moderate. But at the same time, the didactic impact of systems analysis ideas is extremely important. These ideas should find their place in the curriculum of universities, vocational schools and just ordinary schools. The ideas of a systemic, consecutive and consistent, multistage approach to complex problem solving may be quite beneficial for intelligence shaping and development.

OPTIONS COMPARISON TECHNIQUES

Recognition of the existence of the general systems approach schema makes it possible to consider systems analysis as a combination of this schemata along with the correct specific options comparison technique. But what technique are we referring to?

Systems analysis is generally considered a tool for dealing with ill-structured problems where qualitative, uncertain and ill-defined aspects prevail. To see what distinguishes these problems from others, we may compare them to the problems dealt with typically in the general framework of operations research [26]. This options comparison is organized in the following manner: first, one has to develop a mathematical model that objectively reflects the principal features of the problem being investigated. Then one has to define a proper criterion that represents in an unambiguous and explicit manner the requirements to be met. The best choice then corresponds to the optimal value of the criterion. However, in this case the problems are well structured.

In contrast, in ill-structured problems the lack of data needed for the development of an objective model is typically assumed. It is precisely because of this insufficiency of objective data that we are unable to weave different aspects of the problem together into a single integrated model. Instead we are forced to consider them on their own as separate evaluation criteria, and the problem itself turns out to be a multicriterial one. The data needed for matching the different criteria and for options evaluation in accordance with the different criteria should be provided by a decision-maker (DM) and his experts. As is correctly noted in [23], systems analysis is tailor-made for those problems where the trade-off between different criteria is made on a judgemental basis.

Of the different modes of options comparison in the systems analysis framework, the most important is the "cost-effectiveness" technique. It provides specific models of cost and effectiveness evaluation, and relates to each option several values obtained through their use. The ultimate decision rule (i.e. trade-off between the cost and effectiveness values) in certain cases employs the value judgement data of the DM. Three main approaches to cost-effectiveness aggregation have been singled out. The first requires minimizing the cost of the options, with an effectiveness no lower than a certain level (i.e. to choose the "cheapest" alternative providing a predetermined benefit). The second approach demands the maximization of effectiveness while keeping the cost no higher than prescribed (this is a case of budget constraints), and the third demands the maximum ratio of effectiveness to costs.

The rationale of the first two approaches is quite obvious. In essence, they reduce one of the criteria to a role of a constraint because it would be absurd to demand the simultaneous maximization of effectiveness and minimization of the cost. As to the third approach, Hewston and Ogawa [8] warn against the liberal mechanistic use of it, since one may obtain the same value of ratio for quite different combinations of effectiveness and cost values.

The first attempts to apply the "cost-effectiveness" technique were made within the domain of a military systems analysis [25]. The problems with which one had to deal there were of the borderline type between well- and ill-structured ones. These problems also provided the opportunity to develop objective cost and effectiveness models. Unfortunately further attempts to follow a similar pattern when dealing with genuinely ill-structured problems found these opportunities to be lacking. As a result, multiattribute or multicriteria choice models emerge, allowing each option to be represented by an entire vector of evaluation results.

At present, there is a variety of different multiattribute evaluation and comparison techniques that are often referred to *as* decision-making techniques. In all of them, these are experts (sometimes DMs) who evaluate the options in accordance with different criteria. What makes them different is the ways they transform these evaluation results in an integrated utility evaluation. These techniques may be classified as follows:

In the first group (direct techniques), one can stipulate those techniques which a priori assign the dependence of option integrated utility value to partial evaluation values. This dependence is chosen in the form of a weighted sum of partial evaluation results, with the weights representing the relative importance of different aspects or attributes [4]. Decision trees [20] may serve as another example of direct technique. In accordance with this technique, one has to consider each decision (for instance, to build a plant according to policy A or B, to construct its shops according to technological design or D, etc.) one after another, generating different options for the final choice from the different sequences. After that, an appropriate rule makes it possible to calculate for each option its success probability, which is to be multiplied by the option utility (in a monetary form).

The techniques of the second group (compensation techniques [15]) compensate differences in the partial evaluation of a pair of options, and thus make it possible to find which of the two is preferable. This approach is conceptually the simplest. According to it, one simply has to list all the advantages and shortcomings of every option, discard all the advantages or disadvantages common to each, and study only those which make the options different.

The main instrument of the techniques of the third group (incomparability threshold techniques [22]) is the binary relation among different options showing which of the two options being considered is preferable (by a majority of criteria). By checking this relation, we can sort every option pair according to its comparability (when either option may be preferable to the other, or may be indifferent) or incomparability and by varying the basic relation may obtain a number of comparable pairs.

The fourth group (axiomatic techniques [10]) can be said to comprise those which from the outset postulate several properties of utility function representing the integrated preferences of the DM. Information obtained from the DM in this case is used mainly to check the validity of these assumptions, among which the most popular is the assumption of independence.

In the instance when at least a partial model of the problem under consideration is available and may be programmed for a computer, one may adopt one of the techniques of the fifth group (man-machine decision systems) [13]. Here the desired interrelations between different criteria are revealed through man-machine interactions.

Existing decision-making techniques are reviewed in detail in the survey [11].

Although the focal element of each of the techniques mentioned above is the use of information obtained from DM and his experts, more often than not the crucial question of how to acquire this information is largely overlooked and at times completely neglected. Sometimes DMs are immediately asked to select a choice model, an aggregation technique which may be sooner asked than done, sometimes they have to provide direct estimates or offer value judgements on multiattribute comparison, and sometimes to assess numerically judgemental probabilities.

Of course, different problems require consideration of different sets of options. For the problem where an alternative dominating all other (or nearly all), criteria exists, and where one has simply to identify the best possible choice, every existing decision-making technique is equally valid and will lead to the correct result. Unfortunately however, there are plenty of problems of a far more complicated nature, and for them decision-making is a long way from being that simple. But how to choose a proper decision-making technique for a realistically complex problem?

In my opinion, this choice should be based on the extent to which the requirements for information from the DM inherent in the technique harmonize with the existing accessibility and reliability of this information. To be able to do this, one has to use the results of specific psychometric studies (e.g. see [24]) and to classify different tasks in accordance with their complexity for the DM. This will provide one with a solid foundation for a rough comparison of different groups of decision-making techniques. However, even now one may assume that comparability threshold and trade-off techniques are more reliable than others. Of course, whenever possible (i.e. whenever a partial model of the process under scrutiny is available), it is desirable to select most of those man-machine decision-making techniques which do not demand direct multiattribute option comparison. Axiomatic and certain direct techniques should be used with the utmost prudence, as they are the most demanding as regards the difficulty which a DM would have when trying to provide the necessary judgemental information. That is why the practical feasibility of these techniques is uncertain.

FEASIBLE RESEARCH DIRECTIONS

In practical systems analysis applications, the general systems approach schema and option comparison techniques merge in an integrated whole. It is no coincidence that both the advocates [18] and most ardent opponents [9] of systems analysis alike have firmly linked it to the "cost-effectiveness" technique. Therefore, the further improvement of analytical tools of option evaluation and comparison is of vital importance for future applications of systems analysis.

To successfully deal with ill-structured problems, one first has to master the sophisticated art of problem analysis of identifying objectives and means, and of comprehending the inner mechanics of the processes involved. The only way to acquire this mastery is through case studies. Nonetheless, at the same time new ways of multiattribute options comparison have to be developed. And in our opinion, they have to be based on considerations of existing abilities to obtain information from the DM and his experts, and to check it [12, 14]. These techniques should become a convenient vehicle for expressing their preferences.

Analytical tools making the task of managers faced with a complicated decision-making problem easier have been changing rapidly in recent decades. Systems analysis should not be regarded as something already finite. It is being developed parallel to the necessity of dealing with increasingly complicated situations. But even now it may certainly provide real assistance to those confronted with difficult practical problems and who are well versed in the art of problem analysis, and help them to improve the quality of their decision-making.

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