SOME THOUGHTS CONCERNING IMPLEMENTATION OF APPLIED SYSTEMS ANALYSIS IN WATER RESOURCES

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Some Thoughts Concerning Implementation of Applied Systems Analysis in Water Resources

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This paper is meant only for consideration of the problems--not to provide solutions for them.

The term 'systems analysis' was introduced by the RAND coorporation after World War II in connection with the selection and evaluation of weapon systems for development. Since that time tne main ideas of systems analysis have been broadly spread to different applied areas covering almost all kinds of mankind's activities. Nowadays systems analysis, or applied systems analysis (ASA), as H. Raiffa has mentioned in [1], is

> "an embracing rational approach to the resolution of complex problems...It is an umbrella term incorporating under its span such fields as: operations research and management sciences; cost effectiveness and cost benefit analysis; planning, programming and budgeting (PPB); decision analysis; many aspects of cybernetics, information and control systems, computer science, dynamic modelling, behavioral decision theory, and organization theory. Simply, ASA is a framework of thought designed to help decision-makers choose the desirable (or in some cases a 'best') course of action."

At the same time one should make a distinction between systems analysis and all above-mentioned techniques, say, cost effectiveness analysis. This distinction can perhaps be clarified by the following example.

Suppose a decision maker in the region R has decided to build a new reservoir. His objective (meeting the water demand of the region) as well as his alternatives (different possible places, capacity of the dam and so forth) are fairly clear and well-defined. If so, the situation is one for a cost-effectiveness analysis. Even if this situation would lead to a multidimensional problem, the decision maker could determine the best alternative.

Now, suppose the DM has a sum of money available and he wants to spend it for the long-range development of the region. First of all, he would need to investigate his goals (or goals of the people living in this region). Then he has to establish criteria and to look into the full range of alternatives--building new reservoirs, transfer of water from other regions, switching on dry technologies, increasing recreation possibilities by constructing more but smaller reservoirs, improvement quality of available water as well as ecological conditions, etc. Here, because the alternatives are so dissimilar, determining what the DM wants to do is the major problem; determining what it cost and how to attain it may become a comparatively minor one. This is exactly the situation for systems analysis. Now the question arises: what is the systems analyst able to do?

Many people think that the systems analyst armed with a model of the situation can arrive at the optimal course of action to recommend to the decision maker. But as Charles Hitch mentioned in [2], the systems analyst is

> "...faced by his fundamental difficulty. The future is uncertain. Nature is unpredictable, and the enemies and allies are even more so. He has no good general-purpose technique, neither maximizing expected somethings, nor *max-min*ing, nor gaming it, to reveal the preferred strategy. How can he find the optimal course of action to recommend to his decisionmaker?
>
> The simple answer is that he probably cannot. The same answer is also the beginning of wisdom in this business. There has been altogether too much obsession with optimizing on the part of operations researchers, and I include both grand optimizing and sub-optimizing. Most of our relations are so unpredictable that we do well to get the right sign and order of magnitude of first differentials. In most of our attempted optimizations we are kidding our customers or ourselves or both. If we can show our customer how to make a better decision than he would otherwise have made, we are doing well, and all that can reasonably be expected of us."

So now a new question arises: if the analyst with his model is not computing optimal solution, what is he about? R.D. Specht gives the following answer in [3]:

> "Computation is not his most important business. His functions are to define alternative objectives, to design alternative solutions, to discover the critical uncertainties, to recommend ways of reducing them, and to explore the implications of alternative courses of action. And computations help do these things."

In other words, following E.W. Quade [3] "systems analyst is the fellow who is likely to be forced to deal with problems in which difficulty lies precisely in deciding what ought to be done, not simply in how to do it."

The purpose of this paper is to show several sources of skepticism existing now in the decision maker's mind toward application of systems analysis. For doing that allows us to consider in the beginning the general approach being now used for systems analysis in water resources systems.

General Approach

A real existing *SYSTEM* is given in Figure 1. Due to its complexity, usually a *MODEL* of the system is used. The *MODEL* is being built by a modelling group (MG). In every case the *MODEL* is supposed to be relevant at least to the processes more interesting for the DM in the *SYSTEM*. And, of course, according to the contemporary requirements, the *MODEL* must be a quantitative one. Even if there are many qualitative factors one tries to put them into the *MODEL* in a quantitative way, because, as John Platt says in [4],

> "Today we preach that science is not science unless it is quantitative. We substitute correlation for causal studies, and physical equations for organic reasoning. Measurements and equations are supposed to sharpen thinking, but...they more often tend to make the thinking non-causal and fuzzy. The tend to become the object of scientific manipulation instread of auxiliary tests or crucial inferences,"

and later on:

> "You can catch pehnomena in a logical box or in a mathematical box. The logical box is coarse but strong. The mathematical box is fine grained but flimsy. The mathematical box is a beautiful way of wrapping up a problem, but it will not hold the phenomena unless they have been cought in a logical box to begin with."

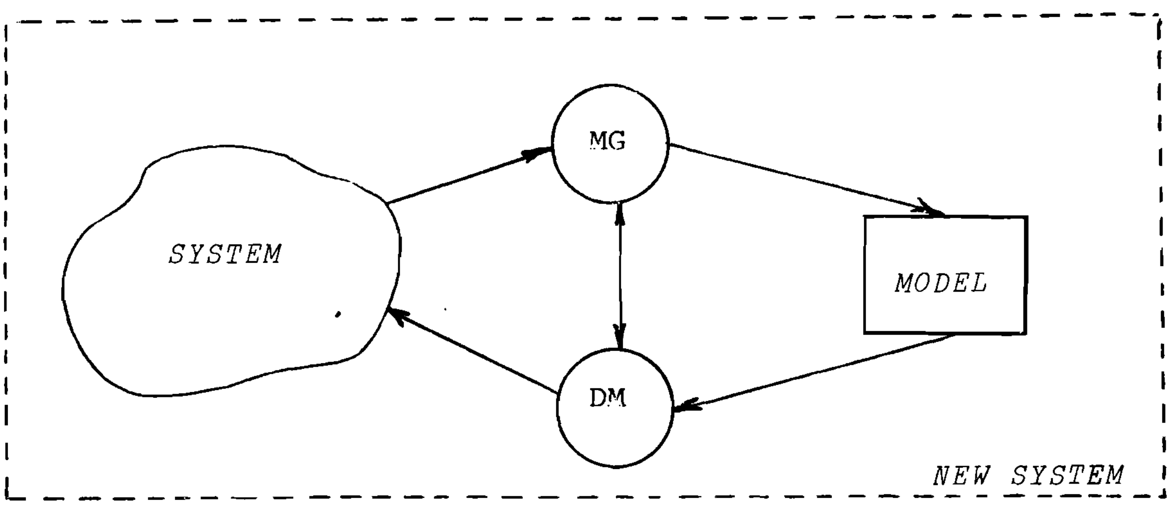

Figure 1.

As it can be seen in Figure 1, our attempts to improve the system's behaviour have increased the initial *SYSTEM* to a *NEW SYSTEM* that has an artificial element *MODEL* and two groups of people MG and DM. Each of these elements interacts dynamically with all others.

As far as the implementation of systems analysis is concerned, this structure, namely the *NEW SYSTEM*, causes many troubles and difficulties. Moreover, all sorts of errors, pitfalls and sources of skeptisicsm to systems analysis have arisen because one often forgets that he is dealing with the *NEW SYSTEM* and not with the *SYSTEM* itself. Some of these weaknesses of systems analysis concerning the elements of the *NEW SYSTEM* are discribed briefly below.

I. The *MODEL*

Over the past twenty years almost all water related scientific literature has been based on investigation and presentation of models for particular events (rainfall-runoff models, different kinds of water quality models, optimization models for single and multi-purpose reservoirs, etc.). Presumably, the assumption for doing this is that these models are general enough to be linked together in one model no matter what system dealt with. However, the linkage has often been forgotten and the worst issue of such an approach is that people of the MG have become more interested in the *MODEL* than in the *SYSTEM* itself. This mode of thinking (and action) makes the DM uncertain about the practical significance of the *MODEL*'s results when they have to be applied to the real water resource system.

The processes of water resources systems have almost always been divided into two parts: management of the system (from an organizational point of view) and control of the technological processes. In many countries there is a passion for investigating the managerial processes, e.g. what kind of administrative structure to be created, how to shift people in the new structure, and so on. This matter is, of course, a very important one, but the MG must not forget the technological processes on the lower levels. Furthermore, the lower levels' activity, to some extent, do not practically depend on the organization and the shifting of people on the upper levels.

Another aspect which confuses the DM when he has to accept a decision offered by the *MODEL* is that many "soft" elements (e.g. political, sociological, legal, etc.) are not considered enough. From the DM's point of view, these are often the most important elements concerning the *SYSTEM*'s management and control, because water resources systems are closely connected with almost all other natural, economical and political systems.

As far as the *MODEL* is concerned, many sources of skepticism have also arisen toward optimization. First of all, many people considered using optimizations models as an attribute of the *MODEL*. In other words, if we are given a set of parameters and a subset of them has to be chosen, then the optimization technique should be applied by all means. Such an attitude may stem from the human desire for everything to be done in the best way possible. However, we are now able to optimize in a small number of situations, not because the available models are not scientific enough, but because they are far from being practical for real vast situations. Consequently, this leads to standardizing and trying to put a great diversity of real problems into one or a few kinds of optimization models.

Besides that, a single objective approach has been predominating for a long time, in spite of the fact that real problems in water resources systems have many noncomensurable goals. Moreover, many of these goals are qualitative. What we need now is an approach for multiobjective optimization under the condition that there are noncomensurable goals with both qualitative and quantitative natures.

II. Interaction between MG and DM

It is supposed that MG and DM are keeping each other in contact during the *SYSTEM*'s investigation. Nevertheless, one can encounter the following situation.

The DM assigns the problem to the MG, supplying it with initial information and goals to be attained. Receiving them, the MG often forgets the DM's existence and goes on with the investigations until the final results are obtained. Then comes the big surprize. After examining the results, the DM tells the MG that he does not want these results; he wants something else which was not mentioned and actually had not been investigated. In other situations the DM is offered 100 or 200 pages of formulae which he does not believe, because he simply does not understand them.

In this context special difficulties arise when the DM is implementing the optimization results for a long period of time (five or ten years) obtained by the *MODEL*. Suppose the *MODEL*'s results are far from those the DM thinks they have to be. He himself, of course, could not afford to wait five years and then to say: "I am terribly sorry. I was wrong. I should not have accepted this decision the MG offered me." In order to prevent such a situation, the DM and the MG should work closely, and furthermore, the DM should be convinced by the MG gradually during their dialogue.

III. The *SYSTEM*

There are two key aspects of the *SYSTEM* which the DM has to allow for when he is trying to implement the results obtained from the *MODEL*, namely: staff which is capable enough to operate and to manage the *SYSTEM* on different hierarchical levels, and technical devices which have to meet the requirements of the contemporary models. For example, suppose an excellent *MODEL* has been built by the MG after incredible efforts. The model was run on a computer and the results (for instance, the ratio of the amount of water which has to be distributed to users A and B, [Figure 2]) have been obtained. This result is sent to the manual operator of the gate. Because everybody is an innovator, the operater computes the mean value, fixes the gate on it and does not pay any attention to the results.

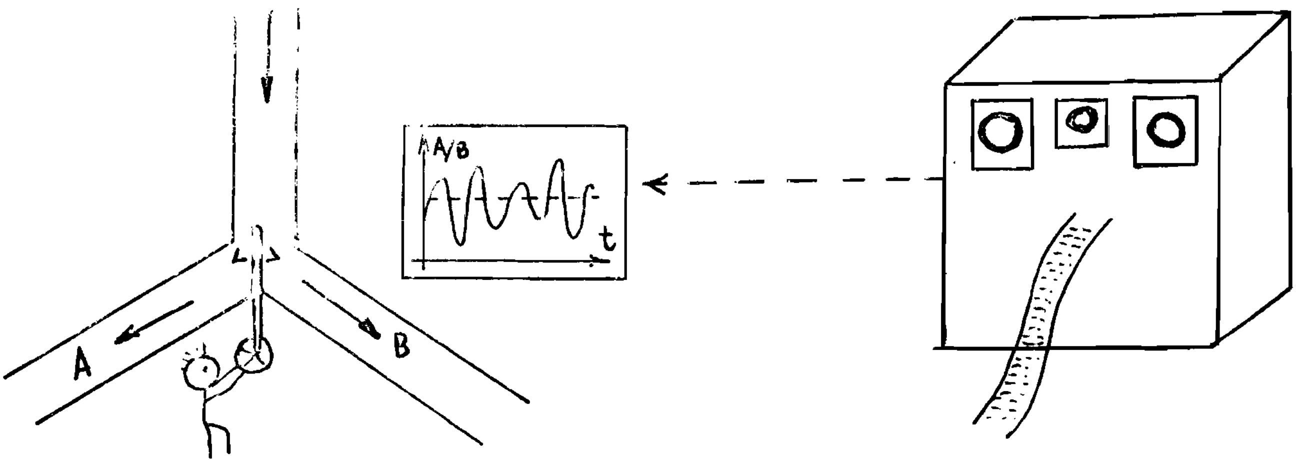

Figure 2.

Between the *SYSTEM* and the *MODEL* there is another very important relationship connected to data collection, data analysis and data planning.

The term data collection refers to activity which has to be accomplished in order to reconstruct past events in the *SYSTEM*. By analyzing these data, the MG is trying to predict the future behavior of the *SYSTEM* which is supposed to be the same as the behaviour of the *MODEL*. For in doing this, either the theory of probability and mathematical statistics or sensitivity analysis could be applied.

For the time being the first approach predominates because it is believed that it gives "final recommendation" for values of the *SYSTEM*'s (or *MODEL*'s) parameters.

As far as the DM is concerned, the second approach is more convenient, i.e. to deal with the uncertainties, exploring their limits and calculating in terms of the range of uncertainty. Introducing an optimistic or upper bound estimate, and a pessimistic or lower bound estimate, the DM will keep asking himself "would the output of the model be acceptable if the worst (or best) possible happened." Carrying several numbers of the parameters through all calculations can increase the work load greatly. If this can be done, then the DM will be more certain in himself because he could see the whole "decision area" and make a more rational decisions.

There is one more problem concerning data, namely, data planning. It arises from the fact that we have to allow for our future attempts to investigate and to model our systems having all data we probably need. It is worthwhile to spend more time on thinking what our system would be in the future, what kind of data would be needed and to plan their collection now.

The preceeding pages are a brief overview of the problems the DM encounters when he has to make a decision in water resources systems. No claim is made for completeness of all difficulties in systems analysis. Many of them are unpredictable because, as E.S. Quade has mentioned in [3],

> "system analysis is not, like statistics or physical chemistry, say, a body of knowledge and skills that can be acquired largely without becoming involved in particular applications."

References

[1] IIASA Background Information, 1974.

[2] Hitch, C.J. "Uncertainties in Operations Research." Operations Research, 8, July-Agusut 1960.

[3] Systems Analysis and Policy Planning. edited by E.S. Quade and W.I. Boucher, American Elsevier Publishing Company, Inc. New York, 1968.

[4] Platt, J.R. "Strong Inference," Science, 146, No. 3642, 1964.

[5] Weinberg, G.M. An Introduction to General Systems Thinking. John Wiley & Sons, New York, 1974.