SYSTEMS ANALYSIS – WHAT, WHY AND HOW

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The New Approach to Urban Revival essentially involves the application of Systems techniques to problems of the city. The purpose of the workshop was to explore these techniques and to see how they might potentially be applied to problems of the urban environment. Systems analysis is essentially a viewpoint for defining problems, developing alternative solutions and evaluating these solutions. It is a broad point of view that explicitly considers a large number of interrelated factors relating to analysis and design problems.

Systems analysis procedures were originally applied to large-scale problems of defense and the space program, and have been applied in many diverse fields. These fields include: agriculture, law enforcement, medical care, transportation, environmental problems, housing, education, and many others. In many of these areas the attempts have been primitive, but they have showed that there is a great promise for systems techniques in dealing with large scale problems. The workshop was concerned with developing an understanding of the systems analysis process with special emphasis on the application of these techniques to the problems of urban areas. This paper will attempt to give some general definitions of systems analysis and to describe its methodology. A summary of the key features of the process and a checklist will also be given.

Definitions

System: a set of objects together with relationships between the objects and their attributes. Examples: solar system, circulatory system, computer system, urban systems.

Objects are the parts or components of a system, i.e., stars, heart, data storage, industry.

Attributes are properties or dimensions of the objects, i.e., temperature, location, size, income levels.

Relationships are those that tie the system together, for example: The gross national product is a function of government spending, industrial output and personal consumption etc. The characterization of relationships is a crucial part of systems analysis.

System can also be defined as: any combination of relationships combined in a purposeful way.

Systems Analysis: systems analysis is then simply the analysis of a system, or it can be defined in any of the following ways:

- a structured technique for handling large, complex problems to lead to an efficient allocation of resources to meet well defined goals and objectives.

- an inquiry to aid the decision maker to choose a course of action by systematically investigating his proper objectives, comparing quantitatively wherever possible the costs effectiveness and risks associated with the alternative policies or strategies for achieving them.

- a viewpoint from which to ask questions.

- a way of thinking

Operations Research: Generally, it denotes the mathematical techniques or tools that are associated with systems analysis. Systems analysis is more of a philosophy while operations research is the set of techniques used to analyze systems.

Subsystem: a system that is part of a larger system. This leads to a very important concept in systems philosophy namely the hierarchy of systems. Every system is a subsystem of another system. In systems analysis substantial effort should be made to look at your system and see how it affects higher and lower order systems. There should be a consistency between systems; goals, objectives, etc., should not conflict.

Why Systems?

The systems approach should be used because problems of society have become very large and complex. It is exceedingly difficult to deal with such problems by intuition or hunches. Systems analysis embodies a broad viewpoint that lends itself these types of problems. It is substantially different from conventional techniques, although it may not seem so at first to some people. There is nothing that is magic about the systems analysis process, but it generally has the benefit of providing a greater insight into the problems being studied. The structured and explicit nature of the systems approach is very helpful in bringing to light information that can be highly useful in a decision making context. The franchise hamburger restaurant can provide a good example of the systems approach. For the price of the franchise, the operator receives assistance in site selection, building design and construction, employee training, accounting practices, equipment design, advertising and standardized procedures for operating the restaurant. The franchise buys a hamburger selling system designed for a low cost profitable operation. Such a system can be much more effective and successful than conventional operations. The following section will discuss the general methodology of the systems approach.

Methodology

There is no orderly procedure or technique that can be used for all problems, for each problem requires special treatment. However, there are general principles and techniques that can be used. These will be briefly explained and their relationship given by the attached chart.

There are five basic activities in analysis that can serve a framework for a discussion of the methodology of systems analysis. These are: Formulate, Search, Explain, Evaluate and Interpret. In addition to these activities, the processes of program planning and implementation occur apart from the analysis. Each of these activities will be discussed briefly in the following sections.

Program Planning: This activity involves the planning of the activity of the systems analysis group. It could include the development of a "problem portfolio, i.e., a list of problems that might possibly he analyzed. It would also include background studies, i.e., the gathering of background information of topics of potential interest. Such studies are useful since it enables a person to easily gain the necessary background for studies in new areas.

Program planning also includes the development of plans and proposals for an analysis. Such plans of attack should describe in some detail what is to be done, why it is to be done and how it will be done. It can be enhanced substantially through the preparation of task flow diagrams and schedules of work including deadlines and milestones. Careful planning of a project is a key to a good analysis of a problem and can make the rest of the effort relatively easy.

Formulation: This activity is basically one of problem definition. A problem should not be accepted as originally stated and a considerable effort should go into understanding and formulating the problem. A proper problem definition should consider the goals and objectives of the system as well as its inputs, outputs, variables, constraints, parameters and relationships. Questions that should be asked include: What are the functions that the system you are studying tries to perform? What is deficient in the status quo? What are the relevant factors to the problem (there very easily could be hundreds of them)? What are the higher and lower order systems? What resources do you have to study the problem with and to implement solutions with? Can you generalize the problem in a broad sense? All these questions can help to provide insight into the nature of a problem.

One should be very careful not to let statements of alternative solutions become part of a problem statement. For example, the problem statement – build a better mousetrap -- is a poor one since it mentions a solution -- the mousetrap. A better statement might be to develop an effective rodent control system. Then the mousetrap and other rodent control techniques could be considered as possible solutions to the problem.

Search: This phase involves such activities as finding facts and data, searching for relationships, and the assessment of relevant factors. Usually information and data will cost money and shouldn't be collected unless one is certain it is needed. It is important to maintain a proper perspective as to how the information will be used to avoid information overload.

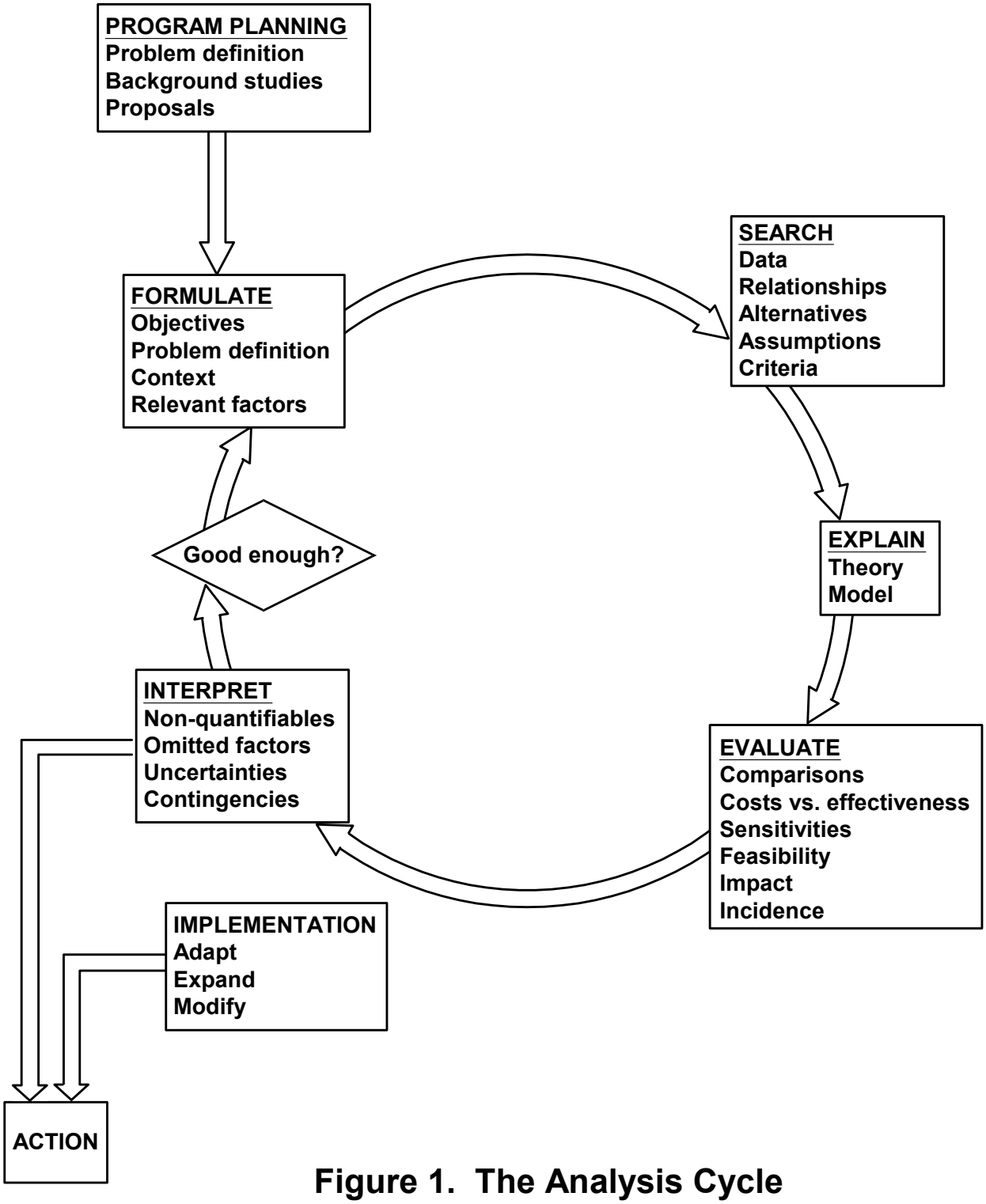

Figure 1. The Analysis Cycle

The development of alternatives is largely a creative art, but there are certain principles that may help. There should be a very large number of alternatives initially and they should vary widely in scope. By avoiding criticism in their development it is possible to develop a large quantity of alternatives. It is desirable to think in terms of unevaluated alternatives since a later phase of the analysis cycle will be used to give explicit rationale for their elimination. The premature elimination of alternatives is undesirable since it may often be done for poor reasons and potentially good alternatives may be lost. Alternatives may involve changes in technology, changes in policies, changes in procedures or changes in constraints. It is desirable to look at the extremes, and try to develop a continuum between them and to look for basic elements of a system and the forms they may take and recombine them in new ways.

Explanation: One of the central phases of analysis is to develop theories or models to aid in explanation of system behavior. A model is a small-scale version of the real world, a simplification. It is developed for some specific purpose and its form is based on this purpose, e.g., form follows function. Ideally the results of the model should closely match what would occur in the real world. Nevertheless it is only an indicator and the results should be carefully interpreted. Assumptions should be stated explicitly.

Models can be built in two ways, by contraction or by expansion. To build a model by contraction, you first attempt to find all the variables that may be important and systematically reduce the list until a model of reasonable size results. The method of expansion involves the building of initial models under simplifying assumptions. The assumptions are relaxed (e.g., constants become variables) and the model is expanded to the desired level of detail.

A model can be a useful tool of communication or an aid to understanding a process as well as a direct tool in the analysis.

Evaluation: Alternatives should be compared on the basis of their costs and their effectiveness. Both have to be considered for meaningful results. Both costs and effectiveness should be defined rather broadly, perhaps to include such things as social costs, and secondary benefits. The quality of the evaluation is enhanced if alternatives are compared in a consistent manner. One would be concerned with getting the greatest effectiveness for a given budget or a fixed level of gain for the least cost.

Evaluation should also include the assessment of sensitivities. This gives clues as to what further data should be collected or how strong the choice is. The feasibility of the alternatives should also be considered. This would include political, economic, social, technical and institutional feasibilities as well as the technical feasibility. The evaluation also should take note of the impact and incidence of costs and benefits and when the costs and benefits occur.

Interpretation: Results of the analysis should be interpreted in light of factors that were not directly considered. Results should not be accepted blindly, but consideration should be given to non-quantifiables, omitted factors, uncertainties, and contingencies. These things might have a significant effect on eventual success. Uncertainty should be treated explicitly to determine its effect upon the best choice. Likewise, one should consider how his recommended solution will act under unusual circumstances which are possible but not probable, i.e., contingencies. Confidence in a choice may be increased by a break-even analysis, i.e., how far can you be off before the recommendations changes.

Implementation: The final phase of the analysis process is one of implementation. In many ways this phase is inherent in the other activities of the analysis. Solutions that cannot be implemented are of very little value. Implementation is aided by careful planning and an understanding of the mechanisms for implementation. In this phase as well as all other phases of an analysis careful planning is vitally important. This phase also involves the modification and adaptation of results to new conditions and circumstances. It also involves updating of data, reevaluation of procedures and techniques, expansion of results to other uses and applications and other activities.

Summary

The key elements of systems analysis can be summarized in the following statements:

Systems Analysis explicitly looks at

- The System.
- The setting of the system; how it relates to other systems.
- The Goals and Objectives, what are you trying to do? Why?
- Interrelationships -- how do the elements of a system affect each other?
- Technology and Creativity - innovate, open your mind up, try something different and new.
- Costs and Effects, defined broadly, how they are related, tradeoffs.
- Uncertainty. Don't ignore it, assess it and try to get around it.
- Contingencies -- Will your answers work well under many possible circumstances?

Check List

To aid in the performance of analysis or problem solving, a check list of questions will be given which may aid in maintaining the systems viewpoint and help avoid bias or error. They could be used either in making an analysis or in examining someone else's recommendations, plans or analysis. They come partially from Quade (2) and from class discussion.

1) What is the purpose of the analysis?
2) Who is doing the analysis and is he qualified to do it?
3) What decision is the analysis concerned with?
4) Who must make the decision?
5) When must or should the decisions be made?
6) Does the analysis ignore any related factors that should be considered jointly with the problems in the analysis?
7) Have a large number of alternatives been developed and do they represent diverse and extreme solutions as well as intermediate actions?
8) Are all the recommended actions considered in the analysis feasible technically, economically, politically and socially?
9) Does the analysis ignore any consequence of the decision that should be considered in making the decision?
10) Are the assumptions explicitly stated?
11) What is the basis for the preliminary elimination of inferior alternatives in the analysis?

12) Do the criteria appear reasonable?
13) Does the systems analyst fully disclose his subjective judgments?
14) Are the results of the analysis presented in a useful form?
15) Are the limitations of the analysis as well as its good features, pointed out clearly and candidly?
16) Does the analysis provide some relatively simple rules for computation or for any scheme that the decision maker can use to eliminate inferior actions himself?
17) Are the conclusions intuitively satisfying?
18) If there are special cases in which the conclusions are known, are these conclusions consistent with the general ones?
19) Is the significant problem being considered, or is a related problem really the significant one?
20) Does the analysis allow for uncertainties?
21) What contingencies allow for uncertainties?
22) Are enemy or competitor reactions explicitly taken into account?
23) Is the model adequate, logical and reasonable?
24) Does the study give consideration to other possible models?
25) Are the recommendations made with full recognition of the uncertainties involved?
26) Have the goals and objectives been considered throughout the analysis?
27) How sensitive is the final recommendations to assumptions and the way the analysis has been done?

References

1) Hall, A.D., "A Methodology for Systems Engineering," D. Van Nostrand and Co., Princeton, NJ, 1962.
2) Quade, E.S., ed., "An Appreciation of Analysis for Military Decisions," Rand-McNally, Chicago, IL, 1967.
3) English, J.M., ed., "Cost Effectiveness -- Economic Evaluation of Engineered Systems," Wiley, New York, 1968.
4) Morse, P.M., and Bacon, L.W., eds., "Operations Research for Public Systems," MIT Press, Cambridge, MA, 1967.
5) "Systems Engineering -- Applied to Five Major Social Problems of our Time," *Consulting Engineer*, March 1968.