System Dynamics as a Realization of the Systems Approach

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Summary

The paper shows the connections between system dynamics and the systems approach. The basis is a comparison between features of the systems approach and features of classical system dynamics as applied in the Sprague Electronics Company study.

Introduction

System Dynamics (SD) analysis has been developed in the last fifteen years. A parallel intensive development of the systems approach has also taken place during this time. This paper argues the case that the systems approach creates a foundation for the ideas of system dynamics, and that a clear interpretation of system theory concepts is given by a SD analysis.

The association of these features of system dynamics with those of the systems approach is helpful in obtaining a better appreciation of the utility of both sets of ideas. The fundamental notion of the systems approach is the notion of system which we might define as follows:

system is any real or conceptual entity
consisting of interrelated components.

Features of General Systems Theory

The Systems Approach is a term which is not associated with a clearly defined body of knowledge or an agreed methodology. It represents rather the point of view of certain groups of people who consider it a useful tool for solving of problems posed by the increasing complexity of the real world, as ordered and shaped by human beings. This point of view can be recognized by means of the features discussed below.

Specification of a problem through a system and its goals.

There is a trend to solve problems by approaching them in a system manner (i.e. by describing the portion of reality of interest as a system). The wholeness property which is so frequently referred to as the basic feature of the systems concept means that attention is concentrated upon those components and interrelations which have an important effect on the desired behaviour of the system as a whole. In other works, the desired behaviour of a system, which is often called its objectives (goals, tasks) provides the start point.

An example of problem specification in the system dynamics context is sketched in the appendix to this paper.

The correct determination of system objectives is equivalent to the correct statement of the problem. To do this satisfactorily, it is necessary to consider the system objectives against the background of the super-system for which the system under study performs some desired function.

The proper establishment of objectives of the system under study requires the assessment of the suitability of these objectives. It is necessary to ask whether other needs should be taken into account in setting them. If the objectives of the system under study are not questioned, the resources assigned to building or testing systems may be completely wasted.

By placing so much emphasis on the objectives an advocate of the systems approach concentrates more on the 'outside' of the tested system than on the internal details of the system, and more on improving the behaviour of the system structure than on improvement of the system components.

Links with reality

On the whole the methods, conclusions and generalizations of the systems approach, are directly significant to the designing and testing of real systems. A basic difference, for example, from the approach of a mathematician - in both creating and testing of systems - is that achievements within the realm of abstract systems are sufficient for a mathematician, while the purpose of the systems approach is the search for applications to real systems. For instance, the solution of a set of equations is considered in a broader context and not merely as the solution of an abstract problem, e.g. as the derivation of an equilibrium description of an economic or technical real system. Generally, the nature of the system approach is problem-oriented rather than technique-oriented.

Interdisciplinary research and the unifying of various disciplines

The individual elements of a real system generally belong to many different conceptual systems, (e.g. biological, social and other systems) which are coupled by these elements into a single super-system. The analysis of a given system is associated with a need to recognize the similar properties among its various sub-systems. The unifying and synthetizing process of science is realized by the statement of laws that are valid for various fields encompassed by the common term of general system theory. This process consists of gaining knowledge and developing research methods by means of the solution, description, classification, reduction and interrelation of concrete problems by interdisciplinary teams. Interdisciplinary research is taken to mean in this context the synthesis of the work of specialists in various fields from the beginning of the study - as distinct from the synthesis of the final results.

The Methodology of the Systems Approach

The methodology of the systems approach includes the search for analogies, the building of models, and simulation techniques.

The real systems with which we have to deal are very complex and it is very difficult to define the nature of these systems. Thus it is not unexpected that we try to explain it by means of analogy between a known system and the system under study. The relations of equivalence between two systems are essential for such an analogy. This equivalence includes a certain set of factors which are the same for both systems and enables common conclusions concerning both systems to be drawn as far as these factors are concerned. In situations where the equivalence includes a set of factors that are significant for a property of the system under study in which we are interested we say that the analogy is good; otherwise - that the analogy is bad or superficial. To determine whether the analogy is good or bad is usually difficult particularly in case of more complex systems.

Due to the development of specialist theories which are very strongly associated with their particular fields, the analogue technique has been abandoned in physics. Instead the internal logic of theory is verified with respect to the formal principles of mathematics. The theory is then checked for the conformity with empirical data. Such an approach allows the speeding up of development of the field involved.

Social systems which include also the socio-economic systems are of great complexity and we have not been yet able to create theories which explain the phenomena specific to these systems and which are as useful as those in the technological field. Thus, the analogy search technique remains fully valid for social systems, but it is important to reject the bad analogies which are misleading and harmful. The rejection of bad analogies within the scope of system concept is effected by means of simulation of a model of the system.

Models provide a basis for the use of simulation techniques. The models should represent the system properties of interest to a degree which is accepted as satisfactory for the given scope of the test. The model structure should at the same time allow the performance of tests and their repetition under various operating conditions of the system.

System Dynamics as System Analysis

SD analysis has many features which tie in strongly with the system concept, and a discussion of an SD application to a real problem is a good example of such an interpretation.

The well-known example of SD application in the Sprague Electric Company (Forrester, 1961) was concerned with finding a problem solution for the producer who was unsatisfied with the performance of his production lines. This problem was basically one of the amplitude of production change against time being greater than that of the random order changes. This meant that the system had amplified the external disturbances.

The model that was built was a conceptual system. It represented the functional elements that were significant for the production process as well as the interrelations between those elements, which could be observed in the real system. The model behaviour was equivalent to a problem description by means of a system which had the properties characterising the problem under consideration (i.e. the gain in the production flow with respect to the order flow).

The model was constructed in the form of a mathematical model. It allowed the performance of simulation tests of the behaviour of the production process with respect to various disturbances, e.g. random changes of order amounts, generated by the environment.

The tests of the model showed that the structure and the magnitudes of parameters in the producer's system had been so selected that their changes would not lead to the problem solution, that is a satisfactory reduction in the gains or the introduction of attentuation where gain had occurred. Therefore, the scope of research was widened to explain the causes of the disturbance amplification. The system was considered as a sub-system of a super-system that is a customer-producer system consisting of two sub-systems: customer's sub-system and producer's sub-system.

The simulation of customer-producer system behaviour showed that significant improvement of system performance could be achieved by changing certain parts of the structure of the producer's sub-system. Next, appropriately selected changes in the system's parameters were introduced into the producer's sub-system. This enabled the system to be improved to an even greater extent. The result was that the external disturbances that were picked up by the producer's sub-system could be attentuated.

The customer's and producer's sub-systems included the sub-systems of lower order, e.g. production, sales, accounting and other sub-systems. This indicates how many specialists of various branches had to participate in the building of the model. Interdisciplinary teams of this type consist of two basic groups: managers of the organisation under test and research workers in the field of SD analysis.

References

Forrester J.W., Industrial Dynamics, M.I.T., 1961.

APPENDIX

The author feels that some comments upon specification of a problem through a system and its goals may be interesting to a reader.

Let us start by defining more closely what we understand by problem specification. The notion of a problem is associated in a natural way with the questions: what?, why? and where?. The general answer to these questions we interpret as follows :-

what? - the description of symptons we are concerned with;

why? - indication of the causes of the worrying symptons and of expected advantages that might result from their removal;

where? - indication of an area, its elements, interrelations, and so on connected with the worrying symptoms.

As the reference point for general consideration concerning the answer to the above questions in the context of system dynamics, we take the Sprague Electronics case.

What?

We aim to formulate a description of the worrying symptoms supplied by managers in the form of a time sequence of values of variables we are interested in. In the Sprague Electronics case these are the production and employment time sequences.

Why?

In studying the problem of any organisation we should start with the definition of the main goal of this organisation. For business organisations we find it as a rule to be a profit. The main goal creates a base to justify the expected results of solving the problem and in consequence make it possible to decide if the problem is worth undertaking.

The analysis of the influence of the worrying symptoms upon the main goal achievement is often omitted. Managers as a rule provide information about the symptons only and define the task as their removal. In most cases the analyst agrees to undertake that task without considering whether it is justifiable. He assumes that the manager's experience plus certain premises of a general nature are enough guarantee that removal of the indicated symptoms is of significant value for the achievement of the main goal. However, we should be aware that this agreement is the equivalent to undertaking a risk that can only be justified on a subjective basis. Such an attitude, in the opinion of the author, underlay the omission of the consideration of the main goal in the Sprague Electronics case description.

Where?

Business organisations achieve their main goals, e.g. profit by performing a useful function and receiving a suitable reward. The supply of electronics components is that function in Sprague Electronics case. In consequence of the elimination of the profit question from our considerations we get the supply of components as the main goal. Thereby we concentrate our mind on Sprague Electronics interactions with its customers, i.e. on the Sprague Electronics customer's super-system.

What is the goal of that super-system? The supply of the final electronic equipment to their purchasers. This supply depends both on customers and the activity of Sprague Electronics. It is, therefore, necessary to consider the reactions of customers under different conditions. What would happen if the components supplied do not correspond to customers needs with respect to quality, price, delivery? He would buy them from another producer. In consequence of this answer we add other producers to complete our super-system.

It is relatively easy to have the customers aggregated as it is of no concern to Sprague Electronics from which one it gets orders. The producers were aggregated by Forrester too, as he found that their actions are based on similar rules. This aggregation brings us back, however, to the question: what would happen if supplied components do not correspond to customer needs? According to Forrester the customer would manufacture components himself in such a case. We are not going to deny that such an explanation might be enough in relation to the Sprague Electronics case. However, in the more general case the creaton of components manufacturing by customer is equal to creation of the new producer of components who would compete with Sprague Electronics. In consequence then we have to deal with the "Sprague Electronics - competitor-customer" super-system.

In calling attention to the definition of system boundaries based as previously on examination of the goals of the system under test and of its super-system, we are lead to results which are similar to those gained upon the basis of direct search for the factors significant to the model reproducing the worrying symptoms. These two ways of thinking do not compete but complement each other.

It seems appropriate to finish the appendix with a more general note. Namely, we should not acknowledge the problem specification as complete until we finish building and validating a model which explains the causes of worrying symptoms and which create the basis for new policy design. Up to this time the questions: what?, why? and where? are still relevant.