THE ROLE OF SYSTEMS ANALYSIS IN GEOGRAPHY: EDUCATION OF A GEOGRAPHER, 1970.

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One of the key questions geographers have always asked is, "How do the various cultures of man relate to their environments?" In an effort to confront this question, geography and other social sciences, particularly anthropology, have put forth several explanations and conceptual schemes, which, however, have been found insufficient in many respects. But from this history of thought on the question of man-environment relationships has emerged the concept of the ecosystem.

Borrowed from the natural sciences, the concept of the ecosystem has been applied to geographical questions (usually only as a point of view), but with little or no understanding of the intricacies of the concept or of the illegitimacy of inappropriate usage of a natural science concept in the social sciences. Such studies are often merely organismic or ill-fitting analogies between the natural science concept and the social science phenomenon.

Criticism of the intellectual inconsistencies of such studies in the social sciences in general and efforts to stimulate scientific unity and inter-disciplinary communication led scientists in several fields of the natural and social science to develop "general systems theory"[1] to handle the multi-disciplinary employment of concepts originating independently in the various fields of science. From these efforts grew systems analysis, a methodological tool to utilize effectively the conceptual tools of general systems theory. Systems analysis, when properly understood and applied, can be a tool to accomplish high yielding and significant geographical research.

In general, a system is defined as "a set of objects (parts) together with relationships between the objects and their attributes (properties)."[2] In a system the performance of each part and its attributes depends to a greater or lesser extent on the performance of other parts: each stage of the relationships depends on the others likewise.

In delineating the meaning of "system," there is a dichotomy between "system" and "environment." For a given system, the environment is the set of all objects a change in whose attributes affects the system and also those objects whose attributes are changed by the behavior of the system." [3] That is, the environment influences, constrains and guides the system on its course through time and space and is influenced by the system in return. For example, a television (a system of electronic parts) may have as its environment a living room, a chair, and a viewer. The system together with its environment are part of a greater universe whose other components may or may not be of interest in a given context. In a larger sense, then, a "system" is an object of interest and its significant environment.

The ecosystem is the interaction of the biotic and abiotic, a system through which energy flows and in which materials circulate. To study an ecosystem (or any system) one must specify its universe, picking out only the essential variables and dichotomize this universe into "system" and "environment." To define this dichotomy, one must establish the system's boundaries, choosing the environment from those objects in the universe whose attributes are of most interest at the present scale of study. One can neglect those objects which do not play essential roles. Oftentimes the drawing of the boundaries of the significant environment is a matter of convenience or necessity, since the observer is limited by the tools available to the study and by the fineness of details which can be observed. There are, however, screening devices which can be used to simplify this procedure greatly. Having defined the dichotomy, the description and analysis of the objects and their inter-relationships can proceed.

In determining the man-environment ecosystem, therefore, it is not necessary to study the entire universe, but rather the system whose dominant is man and crucial interactions of man with his environment. This might in certain cases be construed to be Julian Steward's "cultural core" concept.[4]

The most important property exhibited by a system is whether it is an open system, that is, exchanging materials, energy, or information with its "environment" or a closed system with no import or export of energy in any form. In this respect, all subjects for geographic study must be considered open systems. The problem with some of the few studies of this nature which have been done in geography has been an insistence that the system studied must be closed to be handled easily . . . a problem which is simply one of misunderstanding the dichotomy between "system" and "environment." It is important that this difference be realized, as the properties of systems which are most useful from a geographical point of view are those which exist *only* for open systems.

One such property of geographical interest is adaptation, the ability of an open system to react to its "environment" in a way that is favorable, in some sense, to the continued operation of the system. Evolutionary theory is based on this notion of adaptation; it can find many applications in geography's studies of man-environment relationships.

Geography can use systems analysis to study many systems of interest to geographers (urban systems, traffic systems, diffusion systems, etc.), but the ecosystem in geography is the one with perhaps the longest history of geographical interest. In 1923, Barrows called geography "the science of *human ecology*" and urged geographers to view the problem of the "relationships existing between natural environments and the distribution and activities of man . . . from the standpoint of man's adjustments to the environment, rather than from that of environmental influence."[5]

Geography among all the social sciences is especially well-suited to study man's ecosystem. Amos Hawley called ecology basically a social science, one of behavioral interactions.[6] For geographers, culture is only a subsystem of man, culture being man's strategies for living.[7] Therefore, geography seems especially well-qualified to describe the environmental relations between the two parts of man's ecosystem, that is, the man-culture subsystem and the natural environment subsystem.

Since geography frequently studies systems, especially ecosystems, it is only natural that geography should also use systems analysis, the methodological tool which was designed to study systems. The goal of systems analysis is to search for the significant patterns in a system which have diagnostic validity. For geography this means a description of how two main subsystems, man's culture and his natural environment interact to form a spatial system.

There are several aids to analysis which the geographer can use: mathematical models, physical models such as scale models, and analogies to physical models, all of which have both their special advantages and their own limitations in expressing situations which reflect reality.

Often the most useful method in systems analysis, however, will be that in which the simulation of real conditions is mathematical in nature since mathematics is a language proven capable of handling interrelated components with relative ease. To analyze a system mathematically, several requirements must be fulfilled at least in part: (1) The relationship must be known explicitly; (2) The important attributes must be quantifiable and few enough to list; (3) Given the set of relationships, the type of behavior induced must be known. There are several widely used mathematical approaches available to the analyst: besides the standard definition of the system by families of differential equations, there is also information theory, game theory, decision theory, stochastic models, graph theory, and others. Whatever form the mathematical model takes, it always consists of sets of equations whose solutions explain or predict changes in the state of the system over time.

The advantages to be gained by abstracting the real situation into a mathematical model are numerous. The mere mathematization of a system may mean a more thorough analysis of the situtation than would perhaps have been required for a mere qualitative description. More especially, mathematical analysis can aid in clarifying the concepts involved, can examine the independence or non-independence of variables, can suggest in the derivation of new propositions additional ways of testing the theory empirically. Most importantly, it can, through appreciation of similarities or isomorphisms, lead to the discovery of unsuspected connections, and unifications.

All too often, geographers despair at the thought of making mathematical models, (or any other, in fact), primarily through lack of understanding the complexities of such endeavors. By way of example of how really uncomplicated such mathematical analysis should be, I would like to present here Kenneth Watt's typical four steps in a systems research program.[8] The first step is to measure and list the important variables and the possible causal pathways, and then to sample to measure the relative dependency of the variables. A second step involves sampling the data, regression analysis, analysis of variance and the use of other appropriate statistical tools to determine which variables should be retained in the systems model because they make a statistically significant contribution to the variance of the dependent variables. The next step is to describe the system by translating the data into mathematical equations and then to test the suitability of various models and the fit of the parameter values to the model. The final step is to simulate the optimal conditions of the system. The simulated studies are performed to show how the system can be manipulated to produce an optimal result. Strategies are evaluated by reading the mathematical model into a computer so the computer can explore the consequences of the various strategies and find an optimal result. For geographers, the interest might be to test how closely the optimum of the models reflects reality determined by a culture.

In the actual application of systems analysis to geography (or to any of the other social sciences), one distinction must be made which does not occur when handling physical or purely biological systems: man the thinker is involved as the dominant. Ethno-ecology is the study of how men view their environment, the image upon which depends their social behavior. Social behavior must be dealt with as an important ecological factor, a part of the ecosystem of man. This concept proposes that environmental perception theory should be incorporated to better discern man's ecological relationships.

The delineation of the ecosystem for a particular culture must be derived from the way the people studied conceive of, and therefore use, their environment. This approach takes into account those cultural factors which cannot be due to the natural environment (at least as a response to the present natural environment) but which do come to bear on man's environmental behavior. Perception (actually "conception") is the key to behavior which discloses the nature of the cutural factors which enter into all man-environment interactions. Instead of studying an objective ecosystem, a "cognitized" ecosystem should be studied.

The difficulty of actually defining the "cognitized" ecosystem can be overcome through an awareness of developments in social psychology and related fields These fields deal with social behavior based on statistical evidence from which statistical or mass models have been built, models which can be altered to suit the purpose of a geographical study. Polls and surveys seem to be good predictors of human behavior (due to the "regular irrationality" of human behavior) and may be yet another resource available to aid the geographer in determining the behavior parameter of his system. Finally, the Monte Carlo and other random models have been used in other studies and may be of advantage in testing models developed in systems analysis.

Given that geography can use systems analysis in its work, the question arises, "Why is consideration of geographical problems in an ecosystem by systems analysis better or even more useful than other approaches to geographic research?" The answer lies in the limitations of other methods. The landscape approach often produces little more than descriptions of the evidence that man has interacted with his environment; for too long this school has produced meat with no real skeleton. The environmental perception geographers as well as past ecosystem geographers can show "how" these interactions have occurred and continue to occur. Systems analysis geographers have the added leverage of being able to make models of some predictive value, models which can sketch the changing picture of the "real" world as *all* the various parameters of man's interactions change. They have systems analysis which Boulding calls " the skeleton of science" upon which to hang the meat of geography.[9]

The most important advantage of the systems approach in geography over the other approaches is the extent to which systems analysis lends itself to the performance of cross-cultural and trans-environmental studies. For years geography has sought the mechanisms of man-environment interactions by using various conceptual methods (the landscape school, the environmental perception school) and various theoretical approaches (determinism, possibilism), but with only limited results. These schemes, could only be applied to individual cultures or environments with any precision. They could only list the characteristics of each culture or environment in the vain hope that someday, when enough studies had been collected, the similarities and differences would form themselves into a pattern. Systems analysis was created for just the kind of cross-study comparisons which geographers have desired for so long.

Systems analysis is a methodology of universal application, a tool which can facilitate cross-cultural and trans-environmental studies through the systematic comparison of the families of differential equations (or the equations of other models, as the case may be) which describe the models of man-environment relationships in various cultures and environments.

Because systems analysis can accomplish for geography cross-cultural and trans-environmental studies, it promises to be the tool from which significant studies will come. These studies will do more than the older schools could achieve: they can strengthen geography as a discipline, can give it a theoretical framework, and finally, can allow geography to make valuable contributions to man's knowledge of himself.

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