MODELS, THEORY & SYSTEMS ANALYSIS IN GEOGRAPHY

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Introduction

Every science has a goal, *i.e.* to understand and explain the real world phenomena. Although geography is 'short on theories and long on facts', yet development of theory seems to be vital both to satisfactory explanations and to the identification of geography as an independent field of study. Few would deny the fact that the last few decades have been one of the greatest periods of intellectual changes in the trends of geographic development. Most of these changes, the questioning of the past approaches, looking at old problems with new eyes, have been of a methodological nature involving, in virtually every instance, the substitution of quantitative approaches to problems formerly treated in descriptive ways. Today an apparently new perspective has been opened under the impact of so-called quantitative revolution. Statistical methods have been introduced to attain a desired level of objectivity, and search for models and theories and proceed apace. The works of Hartshorne (1939, 1959) may be considered the last in the chain of traditional writers in geography. The concepts of geography elucidated by Hartshorne and accepted by many practicing geographers began to come under attack from the early 1950s onwards.

Another factor that has encouraged this development has been the spread of quantification. A growing number of geographers became aware that mathematics and statistics could be applied to geographical problems. These provide precise tools to test theories and analyze data. The process of intellectual change led geographers to concentrate less and less on describing the differences between particular areas or places and more and more on the study of uniformities and the production of theories about the spacing of phenomena on the earth's surface. Such an emphasis on Nomothetic approach is in the right direction.

Besides, during the last few decades the focus has also changed to make the concept of the systems of much greater significance, along with that of models and theories. The search for generalizations based on the whole rather than on individual parts is, therefore, a complementary method of modern science known as systems analysis. Since all systems, whether physical or human or a combination of both, consist of a set of objects and the relationships binding these objects together into some organization, it is not surprising that the approach is especially useful in dealing with functional aggregates. Indeed, now the main focus of scientific enquiry has moved away from the study of objects or substances to the study of relationships and organizations. And, as all organizations are recognized as being particularly complex, systems analysis proves to be a particularly appropriate framework of study in geography. The systems approach is not a replacement for the analytic method, but it is an additional line of modern scientific enquiry designated to break down the barriers between inter-disciplinary enquiries. It represents one of the major current research frontiers in geography.

Models, theories and systems analysis provide important tools of explanation in geography in modern times.

Models

The practical problem that follows theory –building is how the related information can be presented. One significant and popular way is the employment of model building or analogue-theory[1] in geography. The quest for models is a recurrent theme in research and it has become very fashionable in geographic research (Harvey, 1969, 141). In general, model building is concerned with simplification, reduction, concretization, action, extension, globalization, theory formulation, theory testing, explanation, etc. The models link generalizations with theories.

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1. Analogy is the resemblance of relations between some phenomena of the real world in which geographer is interested.

Definition

The term 'model' is conventionally used in a number of different ways. In its simplest form a 'model' is the representation of reality in an idealized form. The process of model building is actually a process of idealization. The traditional reaction of man to the apparent complexity of the world around him has been for him to make a simplified and intellectual picture of the real world. The mind decomposes the real world into a series of simplified systems. The system is viewed from a certain scale; details that are too microscopic or too global are of no interest to us.

A model is thus a simplified structuring of reality that presents supposedly significant features of relationships in a generalized form. Models are highly subjective approximations in that they do not include all associated observations or measurements, but as such they are valuable in obscuring incidental detail and in allowing fundamental aspects of reality to appear. This selectivity means that models have varying degrees of probability and a limited range of conditions over which they apply. The most successful models possess a high probability of application and a wide range of conditions in which they seem appropriate. Indeed, the value of a model is often directly related to its level of abstraction. However, all models are constantly in need of improvement as new information or vistas of reality appear, and the more successfully the model was originally structured the more likely it seems that such improvements must involve the construction of a different model (Chorley & Hagget, 1967, 22). Scientific models are utilized to accommodate and relate the knowledge we have about different aspects of reality. They are used to reveal reality and more than this to serve as instruments for explaining the past and present, and for predicting and controlling the future.

According to another viewpoint, 'a model is a skeletal representation of a theory'. This implies that a theory may imply more than one model but a model cannot have many theories to be represented. Thus, we can say that models are of lower order than theories. Otherwise, there is no distinction between a theory and a model. The only distinction is that theory is abstract and model is concrete.

Thus,

- A model may be regarded as a formalized expression of a theory.
- A 'model' is a simplified structuring of reality that presents supposedly significant features or relationships in a generalized form.
- Models are highly subjective approximations as they do not include all associated observations and measurement, but as such they are valuable in obscuring incidental detail and in allowing fundamental aspects of reality to appear.

- This selectivity means that models have varying degrees of probability and limited range of conditions over which they apply.
- The most successful models possess a high probability of application and a wide range of conditions in which they seem appropriate.

However, all models are constantly in need of improvement as new information appears. Models are different from reality, as they are approximations of the reality. Therefore, they are called analogous. The term ‘true’ or ‘false’ cannot be applied in the explanation of models. Instead, the ones like ‘appropriate’, ‘stimulating’ or ‘significant’ should replace them.

Properties

The term ‘model’ is conveniently employed in a number of different ways. It is used as a noun implying a representation, as an adjective implying a degree of perfection, or as a verb implying to demonstrate or to show what something is like. In fact, models possess all these properties.

The most fundamental feature of models is that their construction has involved a highly selective attitude to information. Models can be viewed as selective approximations, which, by the elimination of incidental detail, allow some fundamental, relevant or interesting aspects of the real world to appear in some, generalized form. Thus, models can be thought of as selective pictures and a direct description of the logical characteristics of our knowledge of the external world shows that each of these pictures gives undue prominence to some features of our knowledge and obscures and distorts the other features that rival pictures emphasize. Each of them directs such a bright light on our part of the scene that it obscures other parts in a dark shadow. Only by being unfaithful in some respect can a model represent its original.

Another important property is that models are structured, in the sense that the selected aspects of the ‘web of reality’ are exploited in terms of their connections. It is interesting that what is often termed a model by logicians is called a ‘structure’ by econometricians. This model feature leads immediately to the suggestive nature of models, in that a successful model contains suggestions for its own extension and generalizations. This implies, firstly, that the whole model structure has greater implications than a study of its individual parts might lead one to suppose, and, secondly, that predictions can be made about the real world from the model. Models have thus been termed 'speculative instruments', and a promising model as 'one with implication rich enough to suggest novel hypothesis and speculations in the primary field of investigation'. A good model is regarded as experimentally fertile, suggesting further questions, taking us beyond the phenomena from which we began, and tempting us to formulate hypotheses.

Because models are different from the real world they are analogies. The use of hardware models is an obvious example of the general aim of the model builder to reformulate some features of the real world into a more familiar, simplified, accessible, observable, easily formulated or controllable form, from which conclusions can be deduced, which, in turn, can be reapplied to the real world.

Uses

Once devised, the models are of tremendous utility for their users:

- Models simplify the otherwise complex relationships of the phenomena in the real world.
- Models represent the reality not only in simple but also in systematic /orderly manner.
- In geography, models are taken as generalizations, as they encourage the role of nomothetic approach in making observations.
- Models help in making prediction of trends.
- Models act like a bridge between the observational and theoretical levels.

Thus, models may be used to connect theory and experience, experience with imagination, theories with other theories, and imaginative creations with formal theory and so on.

Functions

Based on the various properties and uses of a model, its nine functions may be identified:

1. *Acquisitive/ Organizational*: The model provides a framework wherein the information may be defined, collected, ordered and manipulated. A model acquires the information that could be defined in its framework or provides a framework for defining certain kind of information.

2. *Psychological*: A model acts as a psychological device that facilitates complex interactions to be more easily visualized, i.e. a kind of picturing device (Chorley & Haggett, 1967, 24). This function enables some group of phenomena to be visualized and comprehended more easily that could otherwise not be because of its magnitude and complexity. A model helps to understand the reality in a simpler manner than otherwise it would have been.

3. *Logical*: A model explains the situation rationally, accounting for how a particular phenomenon comes about, or how a particular relationship among component parts works about.

4. *Normative*: The model represents reality in an idealized form, i.e with the help of certain norms, conditions, assumptions, etc. The normative function of a model allows broad comparisons to be made, by comparing some less known phenomena with more familiar ones.

5. *Systematic***:** A model functions like a system. The systematic function of a model stresses that the‘web of reality’ should be viewed in terms of inter-locking systems. This leads to the constructional function of the system.

6. *Constructional*: It means that a model provides a stepping-stone to the building of theories and laws. As a constructional device it helps in searching for geographic theory or the extension of the existing theory.

7. *Selective*: Model is a selective approximation, allowing some fundamental, relevant or interesting aspects of the real world to appear in some generalized form.

8. *Interpretative*: An important function of the model is to provide an interpretation of the theory in the sense that every sentence occurring in the theory is a meaningful statement.

9. *Cognitive***:** Finally there is the cognitive function of model, promoting the communication of scientific ideas.

Classification

Unfortunately, there is no common and firm classification for models. All are suggested typologies. This is mainly because of a number of meanings and functions of models, as understood differently by different scholars. The term 'model' has been used in such a wide variety of contexts that it is difficult to define even the broad types of usage without ambiguity. However, some general groupings /types include:

1. Apriori and Aposteriori Models;
2. Descriptive and Normative Models; and
3. Hardware and Software Models.

Apriori and Aposteriori Models: Two ways of the construction of a formal theory have been described. The first way begins with empirical observation from which a number of regularities of behaviour may be extracted. To explain these regularities a theory is proposed which may contain theoretical abstract concepts and eventually the theory may be given axiomatic treatment and may be verified. This theory may then be represented by some structured model, which can be used to facilitate deductions and simplify calculations. In this case the model developed in order to represent the theory is 'aposteriori'. On the other hand, the important form of the second route to theory construction lies through giving interpretation to a completely abstract calculus. In this case the model used is 'apriori'. This distinction is based on the type of procedure used in employing models in scientific explanations. In case the model is developed in advance in order to represent a theory/explanation, it becomes apriori. In such a situation the function of the model is simply to represent something that is already known, and the only arising question is that of the appropriateness of a model for a given purpose and this can be fully defined only if the appropriate theory is referred to. But, when the process is reversed, i.e. observations or theory precede a model, the model is the end result, an after product of explanations, it is aposteriori. However, apriori models are more common in geography.

Descriptive and Normative Models: The 'Descriptive' models are behavioural, i.e. they suggest how things exist in reality, whereas the 'Normative' models explain how they ought to be. The former are concerned with some stylistic description of reality and the latter with what might be expected to occur under certain stated conditions (Chorley, 1964). Descriptive models can be 'static', concentrating on equilibrium structural features, or 'dynamic', concentrating on processes and functions through time. Where the time element is particularly stressed 'historical' models result. Descriptive models may be concerned with the organization of empirical information, and be termed 'data', 'classificatory' (taxonomic), or 'experimental design' models. The 'Normative' models, on the other hand, often involve the use of a more familiar situation as a model for a less familiar one, either in a time (historical) or a spatial sense, and have a strongly predictive connotation.

Hardware and Software Models: The 'Hardware' models are based on the use of some hard/concrete material; e.g. physical, planning or defense project models. But, the non-physical, conceptual, symbolic or statistical models are categorized as 'Software' models. The simple regression model, as shown below, serves as an example:

$$Y = a + bX + e$$

Y=the dependent variable
X=the independent variable
a/b =two parameters to be estimated from the data
e = an error

Besides, the above general categorization of models, some specific typologies have also been presented by the scholars like Ackoff, Haggert and Chorley in 1960s. Of these the attempts of Chorley are most elaborate. In fact, Chorley devised two classifications. He regarded all models as being analogues of some kind, and suggested his first classification in 1964. In a later presentation (1967) Chorley revised and extended this classification system. This new classification incorporated all those types of models he discussed earlier and also included the ones that have been devised by his predecessors and fellow scholars. Hence, this classification is relatively the most extensive and complete. It consists of three major categories of models with a number of sub-types (Harvey, 1969, 155):

1. Natural Analogue System Model
    a) Historical Analogue
    b) Spatial Analogue
2. Physical System Model
    a) Hardware Model
        (i) Scale (Iconic)
        (ii) Analogue
    b) Mathematical Model
        (i) Deterministic
        (ii) Stochastic
    c) Experimental Design model
3. General System Model
    a) Synthetic
    b) Partial
    c) Black Box

The first group of models involves searching for analogous situations or events at different times or in different places, and drawing some conclusions. The second group of models corresponds to the more conventional notion of a model in the sciences. The third is a newer concept that treats the structure of a landscape as an assemblage of interacting parts, and attempts to represent the processes as such.

1. *Natural Analogue System Models*:

The natural models are simplified models to be used as a basis for further analysis and prediction by their translation into some similar natural circumstances. The explanations are sought from the natural world phenomena. This group of models involves searching for analogous situations or events at different times or in different places, and drawing conclusions. Accordingly, it has two major sub-types, viz. historical analogue and spatial analogue models.

Historical Analogue Models: The Historical Analogue Models represent analogous events at different times. An example of such a procedure is Rostow's schematic representation of the economic growth process that is derived from historical analysis and searching for analogies between different countries at different times. The model of Demographic Transition Theory serves another example.

Spatial Analogue Models: The Spatial Analogue models represent analogous situations at different places. A number of examples are available:

- The shift of highways being compared with the shift of rivers (by Bunge); or
- The growth and shrinkage of ice-crystals representing growth and shrinkage of market areas (by Christaller); or
- The study of Natural Cycle of Erosion of a river based on Human life cycle (by Davis).

2. *Physical System Models*

This group of models corresponds to the more conventional notion of a model in sciences. The relevant properties of real world are represented by the same properties in the model as well. They simply mean picturing the real world phenomena. Three sub-types have been identified, viz. Hardware, Mathematical and Experimental Design:

Hardware Models: As the term suggests, the Hardware Models use some concrete material, and may be scale models or simply analogue models. The Scale or Analogue, both the subtypes, means some kind of figurative representation.

> *Scale Models*: The Scale Models use the same material as in the real world phenomena, but with only change in scale. In Ackoff's classification such models have been designated as 'iconic'. Iconic or Scale models are generally three-dimensional models - made of same material but on different scale. For example, the globe is an iconic model of the earth.

Analogue Models: The Analogue Models have real - world properties represented by different properties (Ackoff, 1962). Besides the change in scale, the analogue models also involve a change in the materials used in building the model, e.g. an electric circuit being assumed as an analogue for traffic system. Ackoff (1962) calls them as 'Simulation Models'.

Mathematical Models: These models represent reality by some symbolic system, such as a system of mathematical equations or statistics. They have also been called as Symbolic Models (Ackoff, 1962). The mathematical models can further be classed according to the degree of probability associated with their prediction into 'Deterministic' and 'Stochastic'.

Deterministic Models: The model when used with certainty of the effect becomes deterministic. In this case, the outcome or results of the exercise are pre-conceived or are more of less sure to come true.

Stochastic Models: The laws of probability strictly govern this type of model, and there is doubt about the exact effect of a given cause.

Experimental Design Models: Such models involve some practical procedures, as in laboratory or in field. The models used in defence or planning are the experimental design models.

3. *General System Models*

This third category of models represents a newer concept of the times treating the structure of geographical landscape as an assemblage of interacting parts and attempting to represent the process as such. Three subtypes, viz. Synthetic, Partial and Black Box, are discussed below:

Synthetic System Models (i.e. in synthesis): Trying to bring the reality and its representation in perfect harmony or synthesis, such models simulate reality in a structured way, i.e. a perfect correspondence is expected between reality and the model used to represent it. Synthetic systems are artificially built to simulate reality in a structured way and, as Chorley points out, such models may be similar to experimental design models.

Partial System Models: The partial systems are concerned with workable relationships and attempt to derive results without complete knowledge of the internal workings of the system, i.e there may be some chance of correspondence between reality and its representation through the selected model.

Black Box System Models: The 'black box' approach attempts to derive results from a situation in which we have no knowledge of the internal workings of the system.

To conclude, the concept of models poses considerable methodological difficulty. There is a multiplicity of model types performing a multiplicity of functions associated with a multiplicity of definitions. Each particular model exhibits a different logical capacity for performing the function required of it. In fact, the type, nature, use, quality and significance of models – all depends on the types of theories to which they serve.

Theories

The quest for an explanation is a quest for a theory. The development of theory is at the heart of all explanations, and most writers doubt if observation or description can be theory-free. To state a fact entirely divorced from theoretical interpretations is not justified. Theories represent generalizations used for explanations. They can make precise predictions. The quantitative techniques can be used effectively if they are supported by carefully constructed theories.

Theories prove that there is 'some hidden order within chaos' and the geographers' task is to search for that order (rule or law). This order may be arrived at in two ways:

1. Empirically Inductive: i.e. induced empirically, or based on personal observations; proceeding for numerous particular instances to universal statements; moving from particular to general.

2. Theoretically Deductive: i.e. deduced theoretically; proceeding from some apriori universal premise to statements about particular sets of events or phenomena; i.e. proceding from general to particular.

In the latter case, the explanations are based on already established /existing theory (apriori), whereas in the former the explanations arrive at some theory, i.e formulation of a new or original theory (aposteriori).

However, the theories in either of ways are used for explanation and are the highest order generalizations.

Definition

A theory is defined as “a system of ideas explaining something”; or “a system of ideas based on general principles independent of the facts or phenomena to be explained”; or “a scientific statement or a group of scientific statements”. In order to understand the meaning of theory, the difference between a ‘simple’ and a ‘scientific’ statement needs to be made clear. Consider these two statements, for instance:

1. Delhi lies across the river Yamuna.
2. One finds the big cities generally located across the rivers in the world

Of the above two, the former is a ‘simple statement’, whereas the latter may be called a ‘scientific statement’, because the ‘scientific statements’ are based on generalizations, derived from a number of simple statements (facts).

After searching out some relationship / order, we state it or express it in the form of scientific statements. The lowest order statements are ‘generalizations’ followed by ‘laws’ and ‘theories’ at higher order of explanation. Thus, the theories are the highest order scientific statements or the universal statements. They state some rule of action, behaviour, process or development.

If the form of explanation is empirically inductive, it generates original theories. But in the case of theoretically deduced explanations the process is reversed. In this situation, the theory already exists; only its testing or verification is required. Before the theory is tested and verified in real world situation, it is stated in the form of hypothesis[2]. At times, some new rule or law is also put to test before it gets universal acceptance to attain the status of a theory. At this stage it is only a hypothesis. A scientific hypothesis is a particular kind of proposition that if true, will be accorded the status of a scientific law. Assuming this definition of the term 'hypothesis', it appears that the difference between this term and the scientific law is simply a matter of confirmation. After confirmation it becomes a generalized statement or generalization.

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2. The literal meaning of hypothesis is 'anticipated outcome'.

Structure of a Formal Theory

The scientific theory has a formal structure, which basically includes its Calculus and Text.

CALCULUS	**TEXT**
TERMS STATEMENTS RULES	

The various words that constitute the specific vocabulary of a theory are its 'terms'. These terms are the Building Blocks of a theory. There are two types of 'terms', viz 'Axioms' and 'Derived Terms'.

The 'axioms' are the primitive terms that are basic, original and not derived, e.g. 'point' or 'line' in geometry; and 'river', 'plain', 'settlement', 'market', 'desert', 'road', etc. in geography.

The derived terms, on the other hand, need further definition, as they may have several connotations. They are formed from the primitive terms. The terms like 'distance', 'network', ‘region’, ‘space’, ‘long’, ‘short’, ‘high, ‘low’, ‘up’, ‘down’, etc. fall in this category. They are required to be defined and explained within some given context. Their meaning would change or vary in different contexts or references.

The original and derived terms combine together to make ‘statements’, the scientific sentences. Again, there are two types of statements, viz. ‘Axiomatic’ and ‘Derivative’.

The axiomatic statements are primitive statements. For example:

‘Delhi lies across the river Yamuna’

or

‘Thar Desert lies on the western margin of Indian Subcontinent’

The derivative statements are derived from axiomatic statements, and the explanations, at times, are sought from an existing theory. For example:

‘The important cities of the world lie across major rivers’

Or

‘The western margins of continents are deserts’

In addition to the primitive terms and axiomatic statements scientific theories also possess certain Rules or Laws that govern the formulation of the derivative sentences. At least five different types of laws may be formulated by geographers, such as: (i) Cross-Section; (ii) Equilibrium; (iii) Historical; (iv) Developmental; and (v) Statistical (Davies, 1972).

The axioms, statements and rules (laws) make up the ‘Calculus’ of a theory. But a theory is useful in empirical science only if it is given some interpretation with reference to empirical phenomena. Thus in Euclidean geometry, for instance, primitive terms such as ‘point’ and ‘line’ may be interpreted by ‘dots’ and ‘pencil lines’. By elaborating a formal structure we ensure the logical truth of the propositions contained in the theory. These propositions are linked to empirical phenomena by a set of interpretative sentences –called a ‘Text’. The text of a theory tells about its scope, i.e. where and how the theory should be applied and also its limitations in explanation. Thus, the text of a theory performs two important functions, viz:

1. It provides a translation from completely abstract theoretical language to the language of empirical observation. Without such a translation there is no possibility of empirical support for the theory. Or it identifies an abstract symbol with a particular class of real world phenomenon. For example, in a correlation-regression model 'X' and 'Y' represent the real world phenomena of Independent (e.g. 'rainfall') and Dependent (e.g. 'floods') variables respectively.
2. Another important function of the text of a theory is to identify the domain of objects and events to which theory can be applied. This domain may simply be defined by a set of spatial and temporal co-ordinates. Domain, in its simplest form is the field of application of theory. It is the section, aspects, reality that the theory adequately covers, including its limitations in application.

The theory itself is simply an abstract set of relata; the text states how and under what circumstances such an abstract system may be applied to actual events. The extent of domain of the theory varies according to the number of terms within it that have to be given a specific translation in terms of a specific subject matter.

A theory without a text and a well-defined domain is useless for prediction. To a greater or lesser degree theories are provided with appropriate texts. No text can be absolutely perfect, but undoubtedly the provision of a text for theoretical structures accounts for their greater predictive success.

Thus, a theory with a complete calculus and text is a Formal Theory. But most theories, particularly in social sciences like geography, are incomplete.

Types of Theories

It has already been suggested that it is comparatively rare for theories in either the natural or social sciences to be stated in a completely formal manner. In some cases this may simply be because sufficient information is not available for such a formal statement to be made. This raises, therefore, the problem of how theories are in fact stated, how far such theories can be partially formalized, and what criteria we need to employ in distinguishing speculative fantasies from scientific theory. In fact, in a continuum of theoretical formulations, at the one end of which lies the pure formal theory and at the other end lies the purely verbal speculative statement. Thus, there is a whole range of theories in between.

Here an attempt is made for a brief classification of theoretical structures according to their degree of formulation, i.e. based on the degree of precision, and the extent to which the theories are structurally complete or incomplete (Harvey, 1967, 96-100). There are four main types and these range from completely formal Type-I theories, through the Type-II theories and Type-III theories which involve pre-supposition and quasi-deduction respectively, to the more nebulous Type-IV theories, which scarcely conform in any respect to the standards of scientific theory:

Type I: Deductively Complete Theories
Type II: Theories with Systematic Presupposition
1. Elliptical Formulation
2. Common Sense Presupposition

Type III: Quasi – Deductive Theories
1. Inductive systematization
2. Incomplete Deductive Elaboration
3. Theories With Relative Primitives

Type IV: Non – Formal Theories
Verbal Explanations
Pseudo-theories/ Speculative statements

Type I: Deductively Complete Theories: Such theories possess completely formal structures. Their axioms are fully specified. All steps in the deductive elaboration are fully stated. For example, a textbook in Euclidian[3] Geometry exhibits this kind of structure. The probability theories and the theorems in geometry fall in this category. They are perfect, but do not have empirical content, as it is not actually required. In other words, they have perfect calculus, but the text is missing.

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3. Euclid was a famous mathematician of Alexandria in ancient times; his treatises on geometry are famous.

Type II: Theories with Systematic Presupposition: They involve the reference to another set of theories. Such theories may or may not be deductively complete. These have two subtypes:

Elliptical Formulations, which are deduced completely, but proof is not given; and
Common Sense Presupposition, in which the deductive part of theory is missing, because it is technically difficult to give deduct and proof.

Type III: Quasi – Deductive Theories: They may be regarded as incomplete theories. Because the primitive terms of the theory, the deductive elaborations of it, do not conform to the standards of formal theory. The terms or theorems have not been derived properly and completely; and have been substituted in various forms. Accordingly, three sub-types may be distinguished:

(1) *Inductive systematization*: i.e. the theory substituted by assumptions.

(2) *Incomplete Deductive Elaboration*: where certain steps have been left out, because they appear too complicated for explicit deductive procedures to be employed.

(3) *Theories With Relative Primitives*: In this case the theories do not make use of original primitive terms or axioms; instead use only derived (parallel) terms or theorems.

Type IV: Non – Formal Theories: They may be regarded as statements made with theoretical intensions, but for which no theoretical language has been developed. They are verbal explanations, ranging in sophistication from carefully thought–out system of linked statements to the kind of ‘explanation sketch’. Historians frequently use such theories. They are also called as

Verbal Explanations, where systematic explanation is given but without rigorously having calculus or text, or Pseudo-theories /_Speculative statements, where no systematic relative statements are made or which cannot identify calculus or text.

The discipline having Type-I theories is considered as the most advanced. In geography, the theory building has reached, at the maximum, at Type-II level. However, the most common in geography are Type-III. In practice geographical theory varies a great deal in its degree of formulation. Given the nature of geographic concepts the development of formal theory in geography appears to be a very restricted possibility. For the most part we must at best rest content with varying degrees of partial formulation. In most cases the systematic pre-supposition or the quasi-deduction involved are not of the 'harmless' variety in which a full proof or full theory is available but not stated.

The Basic Postulates

An explicitly developed scientific theory requires a number of axiomatic statements from which the theorems can be derived. To achieve this empirical status these axiomatic statements (containing primitive terms) require translation to either observable classes of events or to theoretical concepts from which the behaviour of observable classes of events can be derived. The concepts that correspond to the axioms of the theory are called its basic postulates.

Such concepts and principles (or the postulates) that have been used or may be used by geographers in theory building can be classified into two, viz.:

1. Derivative Concepts, and
2. Indigenous Concepts

<u>Derivative Concepts</u>: The use of derivative concepts involves the "consumption" of some theoretical structure from another discipline. A number of such concepts have entered in geography from other disciplines,as economics, psychology, sociology, geometry, physics, chemistry, biology, etc.

(a) ‘Economic Concepts’ have frequently been used as the foundation for geographic theory. Economics has, perhaps, been the most successful of the social sciences in developing formal theory (even if the empirical status of that theory is open to doubt). Many of the postulates and theorems of economics have been absorbed into geographic theory. In particular, the location theory, which has been “especially concerned with the development of the theoretical – deductive method in geography”, can be related to economic postulates. Out of many such cases, Central Place theory by Christaller has been described as the one relatively well-developed branch of theoretical economic geography, using economic geographical laws. The fundamental spatial concept – ‘the range of a good’ is basically derived from economics. Similarly, Losch (1954) treated the location of settlement as part of the general location problem and, grounding his analysis firmly on ‘Chamberliman economic theory’, gave a more powerful theoretical foundation for the settlement theories of Christaller. Dacey (1965) has provided a geometric version of a probabilistic central-place system. The articulation of a theoretical structure in this may again be traced back to the basic economic postulation. All the above examples are just few out of many to demonstrate how geographical theory may be derived from the basic postulates of economics.

(b) Psychological and sociological postulates have also been introduced in the construction of geographical theory. Human geographers (e.g. Bruhnes, Sauer, Wolpert) have long recognized that geographical patterns are the end – product ‘of a large number of individual decisions made at different times for often very different reasons’ and that it was necessary to employ some psychological notions in explaining those patterns. Traditional notions regarding the importance of individual and group behaviour in the creation of geographic patterns can be sharpened by reference to the psychological literature. Psychological postulates, particularly behavioural ones, have been employed directly by geographers with profit. The use of sociological postulates in human geography is equally as widespread as that of psychological. For instance, the concepts of fertility, mortality, migration, etc. all have a deep grounding in sociology.

(c) The relationship between geography and geometry is of special relevance. As a branch of mathematics, Geometry provides an abstract language for discussing sets of relationships.

Geography maps many of its problems into this abstract language. The various forms of geometry appear to be a peculiarly appropriate language for theorizing about spatial relationships, about morphometry, and about spatial pattern. From this language we may derive the 'morphological laws' that help to explain geographical distributions.

(d) Of all the derivative postulates, the physical postulates are of tremendous significance to research in geography, and especially physical geography. These postulates have been mainly derived from the sciences like physics, chemistry and biology. Much of the studies on desert erosion, coastal erosion, glacial erosion, make direct use of the basic postulates and known relationships of physics. Similarly, works in meteorology are related to the postulates of physics, while work on soil formation, weathering processes, and so on, refers to the concepts of chemistry and biology. In fact, any work on process in physical geography can be related, directly or indirectly, to the postulates of the various physical sciences. The Davisian system in geomorphology needs a special mention here.

Indigenous Concepts: There are plenty of 'concepts' and 'principles' developed by geographers that could function as postulates for theory. But few have been developed in indigenous manner. In fact, we have not sufficient experience of theory – construction in geography to discuss indigenous postulates with any certainty. But, on the basis of the limited experience we possess in this direction, together with some apriori notions regarding the nature of geographical enquiry, some clues may be provided as to the nature of such indigenous postulates. One of such postulates, and the one that served as the central concept of geography for a long time is 'the concept of region'. This has been repeatedly used to explain the areal differentiation of earth's surface and the human spatial organization. The region is not the only concept of this type. Some other concepts well may form a set of indigenous postulates for the development of geographic theory. These concepts are often related to what are often called 'spatial processes' – or rather sets of spatial relationships. These concepts have essentially to do with 'location', 'distance', 'pattern' and 'morphology'.

'Systems' Analysis

All around us, we find every phenomenon, every event and every feature assigned to a system, e.g. economy is a system, politics is a system, nature is a system, and even an individual human being is also a (biological) system in himself. Each part of the system or each individual over the earth is significant not only in terms of functions it is performing independently, but also in terms of its relationships with others; and unless and until these individuals are studied together they can not form a system. Hence, it is within the framework of the systems that we are studying each and every component of the world or the Earth. The system's approach can be suggested as a way or a method of comprehending the world as a whole.

The modern emphasis on system as an explicit item for analysis may be seen as a part of a general change in emphasis from the study of very simple situations in which the interactions are few, to situations in which there are interactions between very large numbers of variables. The interest in these complex systems has grown very rapidly in the 20th century. Given the multivariate nature of most geographic problems, it is hardly surprising that systems analysis provides an appealing framework for discussing these problems. In geography, the awareness towards the use of system's approach has developed because of the realization that:

1. Firstly, the earth's surface (world) is made up of different types of areas, regions, or places; and these, besides having an individual significance, also are part of a 'whole' as conceived by Ritter (in his *Erdkunde*) and Humboldt (in his *Cosmos*); and
2. Secondly, these parts or sub-parts are not only inter-related with each other, they also form independent sub-systems of their own.

Definition

"A system is a functioning whole with various sub-systems interlinked with each other". The 'system', contrary to chaos, is the name of an order. In other words, it is 'the way, sequence in which the various components or phenomena are organized into a whole, into a totality." There is a whole range of systems from microscopic to micro, meso and macro systems. Various examples of system can be cited, as climate, water system, plant ecology, human society, economy, etc. (Harvey, 1967, 447-459).

The characteristics of a System may be summarized as follows:

1. A system has an order of or sequence of functions;
2. Although each part of a system plays an individual role in the system's operation, no part is entirely independent of others.
3. A change in the operation of one part will have significant repercussions throughout the system.
4. Systems are generally open-ended.
5. Accordingly a system has some inputs and some outputs:
6. The system is not a juxtaposition of various elements; it is rather a functioning whole.
7. There is always some stimulus (or driving force) behind the functioning of a system.
8. Systems are generally at balance or at equilibrium.
9. Malfunctioning of one part disturbs the balance of whole system.
10. Within macro systems there are micro systems (the sub systems)

A system is not merely the assemblage of various components; rather it is the functioning of those components together and independently as well. The 'whole' is greater than the parts. Any little change leads to the various corresponding changes in the whole system. For instance, continuous flow of smoke and gases from the factories and mills have greatly increased the amount of carbon dioxide in the atmosphere; and this increase has disturbed the ecological balance of CO_2 already present in the atmosphere. As a result there is decrease in the total amount of rainfall, increase in the temperature, etc., which in turn affects crop production.

Essential Features of a System

The essential features of a system define its basic functional characteristics in terms of its environment, behaviour, state of existence, information and organisation. All are interrelated (Harvey, 1967, 455-459).

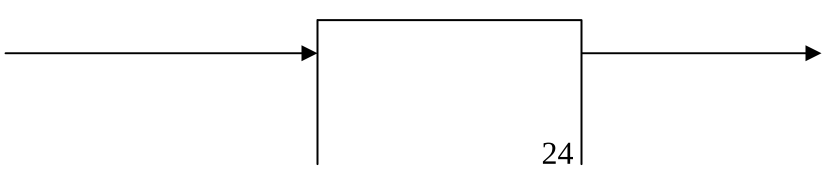
Environment of a System

The environment of a system is the whole of which the system is only a part. For example, the economy constitutes the environment of a firm; or a farm system has its environment in the biosphere. The changes in this environment bring about direct changes in the values of the elements contained in the system under examination. Environment changes from system to system, even of the same time, because it is not the time more considered here, rather it is the manner or way in which the elements (relevant) are combined and functioning together.

This flexible approach to the concept of environment in systems analysis is particularly useful to geography, because it has made considerable use of the notion of the environment. It is useful at this juncture to clarify the usual meaning of the terms ‘open’ and ‘closed’ systems. The open system interacts with the environment. It means then an open system is not isolated from its environment, but exchanges materials or energies with it. A closed system, on the other hand, operates without any kind of exchange with the environment.

The Behaviour of a System

When we speak of the ‘behaviour’ of some system we are simply referring to flows, stimuli, and responses, inputs and outputs, and the likes. We can examine both the internal behaviour of some system or its transactions with the environment. A study of the internal behaviour accounts for a study of functional ‘laws’ that connect behaviour in various parts of the system. Most analyses of behaviour tend to concentrate on the latter aspect. For instance, a system has one or more of its elements related to some aspect of the environment, and the environment undergoes a change. Then, at least one element in the whole system is affected and the effects are transmitted throughout the system until all connected elements in the system are affected. This constitutes a simple stimulus – response, or input-output system without feedback to environment.



STIMULUS (INPUT) SYSTEM RESPONSE (OUTPUT)

Fig. 1: Behaviour of a System

In other words, the behaviour of a system is described by its flows that connect the inputs (stimulus) with the outputs (responses) (Fig.1). The simplest example of this is provided by input-output analysis of economics, in which a vector of final demands (e.g. derived from imports, home consumption, or however) is related to a vector of final outputs in various sectors in the economy.

The State of a System

In general the state of a system may be thought of as the values which the variables take on within the system at any particular point of time. Now it is possible for the variables to take on a large number of values, so that the term ‘state’ is often used in a more restricted sense to refer any well defined condition or property that can be recognized if it occurs again. It is therefore useful to differentiate between the **transient** and **transitional** states and the various types of **equilibrium** states, which have distinctive properties.

‘Equilibrium’ refers to a system that maintains some kind of balance instead of being in a ‘transient’ or ever-changing state. ‘Homeostasis’ implies that the balance is at a fixed point or level. A ‘steady state’ is an equilibrium that does not depend on a fixed point or level. ‘Morphogenesis, is the process that leads to changes in a system’s form, structure, or state, so that it comes to exist at a new and more complex level of equilibrium.

Normally, we can recognize two kinds or categories of equilibrium, viz. *stable* and *dynamic*. The stable equilibrium includes both homeostasis and steady states, as defined above. In a homeostatic social system there is always activity, but it does not alter (change) the balance between the system’s components. A social system that was in a steady state would be equally stable, but it would also change – in an orderly way. Dynamic equilibrium refers to the process by which a slight disturbance engenders constant change throughout the system.

Organization and Information in System

The twin concepts of *organization* and *information* are exceedingly important in systems analysis. They provide the necessary concepts for discussing certain aspects of behaviour of systems in a general or objective way. The concept of ‘organization’ can best be examined by way of an example. Consider a system, containing ‘n’ elements, that behaves in such a way that if we know the value of one element in the system we can predict the values of all the others. Such a system is highly organized. Consider a similar system in which even though we know the values of ‘1-to-n’ elements, we still cannot predict the value of the ‘nth’ element. Such a system is disorganized. ‘Information’ may be regarded as ‘the measure of the amount of organization’ (as opposed to randomness) in the system.

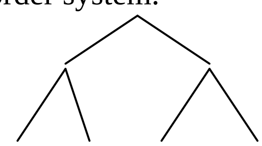
The term ‘entrophy’ and ‘negentrophy’ are closely related to the organization and information in the system. Entrophy (a measure of unavailable energy) is often referred to as a measure of disorder or disorganization. Basically it is an expression for the degree to which energy has been unable to perform the work. It states “systems can only proceed to a state of increased disorder”. Negative entrophy or Negentrophy, on the other hand, is a measure of order. These two concepts are perhaps best illustrated by an inanimate example. If we put sugar in coffee, there will be an increase in entrophy, since the sugar crystals, which would otherwise have held their shapes indefinitely, will dissolve. If we heat the coffee, entrophy will increase further, since the increase in heat motion will dissolve the sugar faster. Any closed system tends to increase its entrophy in this way, and will finally approach the inert (inactive) state of maximum entrophy. An open system, on the other hand, can maintain a fairly low level of entrophy, by interacting with its environment. As a result, it will tend to develop a more complex structure.

It is useful to think of entrophy and negentrophy when studying socio-economic systems because it makes us ask how organized they are. Whereas entrophy brings disorder, negentrophy is thought to be bringing order.

Structure of a System

Structure of a system refers to the arrangement of various component parts (elements) in it. This structure is composed essentially of the 'elements' and the 'links' between elements.

Element is the basic unit of a system. The definition of an element depends on the scale at which we conceive of the system. The international monetary system, e.g., may be conceptualized as containing countries as elements; an economy may be thought of as being made up of firms and organizations; organizations themselves may be thought of as systems made up of departments; a department may be viewed as a system made up of individual people; each person may be regarded as a biological system, and so on. In substantive terms, therefore, we face the problem that systems may be embedded in systems, and that what we choose to regard as an element at one level of analysis may itself constitute a system at a lower level of analysis. The only way for the problem to be solved is to simply group elements into a 'hierarchy' of 'classes' with each higher-order class forming an element in a higher order system.



The links within the elements provide the other component in the structure of a system. Generally the five forms of relationships can be defined (Figs. 2 to 6).

(i) <u>Cause and Effect Relationship</u>: Also known as 'Series' relationship, it is the simplest and is the characteristic of elements connected by an irreversible link.

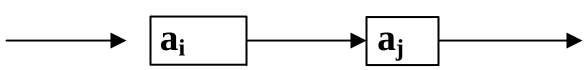


Fig..2: Cause and Effect Relationship

For example, rainfall affects the rate of soil erosion but soil erosion apparently has no effect on rainfall.

(ii) <u>Parallel Relationship</u> : It is similar to multiple-effect structures in that both a_i and a_j are affected by some other element 'a_k' . In other words, for both the sets of elements there is common cause or stimulus to function. Taking the same example as in the previous case, the rainfall is the cause of soil erosion on the hill slopes and also of the increased runoff in the streams.

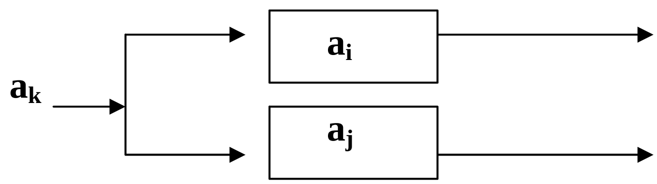


Fig..3: Parallel Relationship

(iii) Feedback Relationship: It is a kind of link that has newly been introduced into analytic structures. It describes a situation in which one element influences itself. For instance, if crop- production of a year is not up to the desired level of production, then there will be a kind of feedback to the stimulus, i.e. to improve the ways and means of production. Then the whole system of the crop-production will either modify itself or will be discarded.

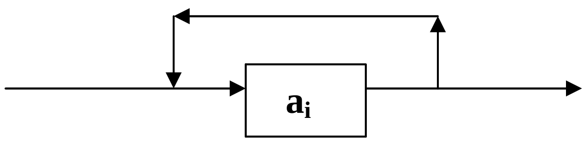


Fig. 4: Feedback Relationship

Feedback in a system is essentially a way whereby the output is used to control its working so that it may achieve its desired goal. It is a self-steering mechanism.

(iv) Simple Compound Relationship: Where a set of components is affected by two ways, i.e. by feedback and also because of the influences from other set of components, working simultaneously.

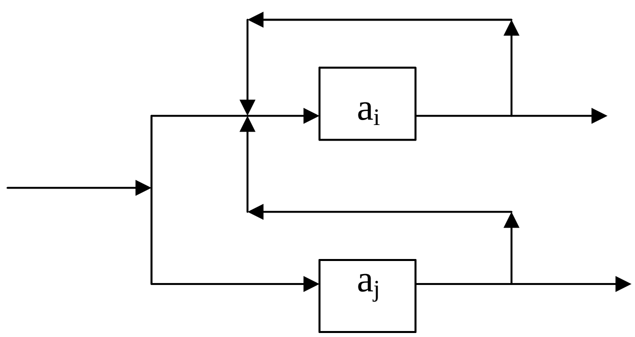


Fig. 5: Simple Compound Relationship

The present Indian Society can be an example cited here, because today it is not only changing and modifying its norms and values by discarding certain old ones but also adopting certain characteristics of the western society. It is all for the betterment of human beings.

(v) Complex Compound Relationship: i.e. where there are influences and changes from all sides and within each and every component, modifying and influencing each other.

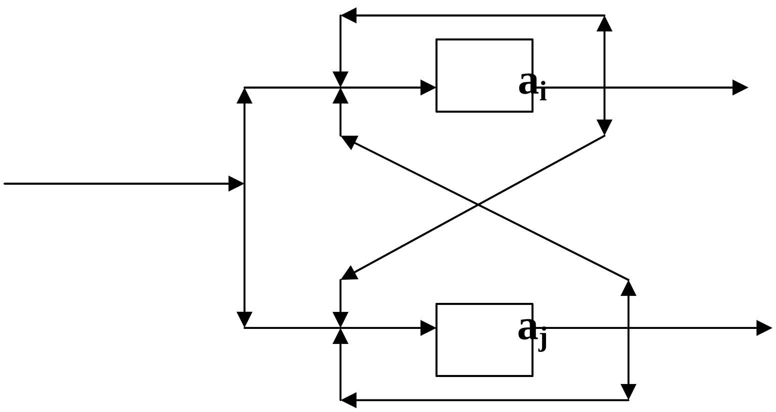


Fig. 6: Complex Compound Relationship

In this system, there are influences and changes from all sides and within each and every component –modifying and influencing each other. Our environment, consisting of physical and cultural environment, may be cited as an example here. Such systems are very difficult to interpret.

All the above five types of links form a kind of ‘wiring system’ connecting the elements in various ways.

Types of Systems

There are various ways in which we could classify systems. We would differentiate between open and closed systems; between man-made and natural systems; and so on. Rather than to attempt an exhaustive classification of systems, the attention has been concentrated upon those types of systems which have something new to tell us regarding the analysis of complex interactions. Most that is new in systems analysis has to do with systems which are homeostatic, self-regulatory, adaptive, and particularly with systems that incorporate some form of feedback.

(a) *Homeostatic System*: It is the system that maintains a constant operating environment in the face of random external fluctuations. Such systems resist any alteration in the environmental conditions and exhibit a gradual return to equilibrium or steady-state behaviour after such an alteration. The displacement of a spring, e.g. , will be followed by a series of oscillations until eventually the spring returns to a stationary state. Human body itself is a homeostatic system, i.e. it maintains its equilibrium at about 98.2 degrees Celsius. Generally the homeostatic systems refer to open-systems' analysis, and are associated with the important concept of steady-state - a concept which has a great significance in the study of fluvial and other geomorphological processes.

(b) *Adaptive System*: It is similar to homeostatic system in many respects, but possesses some special characteristics. An adaptive system is one for which there exists for each possible input a set of one or more preferred states, or preferred outputs. The adaptive character of the system means that if the system is not initially in a preferred state, the system will so act as to alter its state until one of the preferred ones is achieved." The study of such systems provides a mode of approach to systems that are usually throught of as 'goal-seeking'. Such systems clearly rely upon feedback mechanisms of some kind in order to achieve the preferred state. 'Wheat-production' of a country can be taken as an example. Suppose a nation has set the goal for the production of wheat during a certain plan year. If the required figures are not achieved in that year, in the next year more sophisticated and advanced techniques will be used and something more will be done in order to increase the production of the wheat up to the desired level, i.e. there is a kind of feedback to the system.

(c) *Dynamic System*: It may be regarded as a separate class of systems. Both homeostatic and adaptive systems show a change of state over time as they move towards steady or preferred state. In a truly dynamic system, however, feedback operates to keep the state of the system changing through a sequence of unrepeated states usually termed as the 'trajectory' or 'line of behaviour' of the system. Feedback may, for example, cause new preferred states to be identified. Economic growth models, such as the circulation and cumulative causation models, may be regarded as dynamic systems.

(d) *Controlled System*: In this kind of system, the operator has some level of control over the inputs. Such controlled systems are, of course, of great interest in systems engineering and cybernetics (the study of communication and control mechanisms in machines and living beings). Systems control theory provides a good deal of insight into the behaviour of systems, and is not irrelevant to the application of geography to substantive problems. Particularly in the field of planning, government of both national and local levels, controls some of the inputs into the economic systems and manipulates (handles, manages) these in order to try and achieve some desired level of output. Monetary or budgetary policy are thus used to stimulate house demand, while at the local level the investment in roads, utilities, public housing and so on which is controlled by local government, provides an important means for varying the inputs in order to achieve certain goals (outputs).

In most situations we have control over certain inputs while others are impossible or too expensive to manipulate. In seeking to maximize agricultural input, for example, we may be able to control water input by irrigation, but we must do so in a situation where other aspects of the biosphere remain uncontrolled. Partial controlling systems are thus of great interest.

Thus, Systems' analysis is capable of dealing with the structural characteristics and the behaviour of complex interacting phenomena, and systems concept therefore provides an appropriate conceptual framework for handling substantive geographical problems.

In conclusion it is worthwhile to stress that there is no single path to scientific understanding. All scientists search for order in the real world, whatever their disciplinary perspective is in organizing the search. For this, model building, theory formation and the use of systems approach serve as important tools of explanation and cannot be dispensed with lightly.

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