GEOGRAPHIA POLONICA 37, 1977

# FOUNDATIONS OF THE MODEL OF SPATIAL SYSTEM OF TOWNS

ZBYSZKO CHOJNICKI

## INTRODUCTION

This study is to present the foundations of a model of the spatial system of towns. In order to accomplish this task, the model and the systems methodologies are integrated. In the model methodology, reality is idealized so as to identify the factors and relations that are significant and to cut out those of secondary importance. In following such a research procedure, which by way of abstraction, eliminates subsidiary effects on the studied object, and thus makes certain research assumptions, we are led to the construction of a model. The resulting models are idealized and hence abstract representations of reality formulated as sets of modelling assumptions. The objects thus characterized — spatial systems devoid of certain real features — are called ideal types or abstract phenomena.[1]

The proposed modelling strategy is to identify the fundamental features of the spatial system of towns through what is called the systems approach or the systems methodology. One important feature of this methodology is that the studied object, say a town or a set of towns, is treated as a specific system.

The systems methodology is not uniform in character. Its origin can be traced to several trends and concepts which were later integrated into an independent discipline tentatively called systems theory. But at present that theory is in fact scarcely more than a loose collection of notions and directives.[2]

Attempts to approach the town, or a collection of towns, as a system have been made before. Geographic literature gives ample evidence of comparisons of the town to the organism as a systematic analogy. It was L. Bertalanffy's general systems theory that most significantly promoted the systems approach to the problems of towns in western geographic literature.[3]

---

[1] Thus conceived, the model method is very realistic and is a consequence of the methodological directions employed by Marx. See the studies by J. Topolski, *Założenia metodologiczne "Kapitału" Marksa* (The methodological assumptions of Marx' "Capital"), Warszawa 1970; L. Nowak, *U podstaw marksistowskiej metodologii nauk* (Foundations of the Marxist methodology of science), 1971; and the collection of essays edited by J. Kmita, *Elementy marksistowskiej metodologii humanistyki* (Elements of the Marxist methodology of the human sciences), Poznań 1973.

[2] Cf. V. N. Sadovskiy, Ogólna teoria systemów jako metateoria (General systems theory as metatheory), *Prakseologia*, 2 (46) 1973, pp. 23–46, and A. I. Uyemov, Systemy i badania systemowe (Systems and systems research), in: *Problemy metodologii badań systemowych*, Warszawa 1973.

[3] L. von Bertalanffy, The theory of open systems in physics and biology, *Science*, 111, 1950, pp. 23–29; General system theory, *General Systems*, 1, 1956, pp. 1–10; General system theory: a critical review, *General Systems*, 7, 1962, pp. 1–20.

This is no place for a full discussion of the otherwise scanty geographic studies in this respect, but let us draw attention to certain fundamental difficulties and dangers that may turn up in adopting the systems approach to the study of distribution of towns in terms of Bertalanffy's conceptual framework. This latter is essentially organic in its character thus leading to a number of faulty analogies between the organic model of the system and the town, or the system of towns or settlement system.

The organic model of systems ignores a number of structural and developmental characteristics of towns, such as cultural systems, which, in reality, are concrete products of social activity and fulfill definite socio-economic functions. What is primarily meant here is the specific character of those systems as wholes which, rather than being organic, constitute conceptually isolated portions of reality of different degrees of differentiation and integration. Nor do those systems retain their structural interdependences, since the changes that take place in them are not cyclical in character and include radical transformations of the structures themselves and the appearance of new elements.[4]

Different in their consequences are attempts to employ cybernetic models in studies of settlement systems (and, more broadly, in economic geography). Such approaches operate with the conceptual framework of cybernetics and information theory (feedback, entropy etc.) and have already had a number of interesting applications which can be treated as attempts to develop new instruments for analytical purposes.[5] If systems methodology is to be more extensively applied in geographic-economic studies of towns, adequate conceptual system models must be developed first. These must be more than simple adaptations of system models in other domains. Rather, they must be sets of assumptions concerning the geographic-economic study of towns using the notions and methods of systems theory so as to conform fully with the specific requirements of the field of research, i.e. of economic geography.

The primary prerequisite for the construction of such models is the formulation of a basic model of a spatial system of towns thus defining the properties of towns as a system. Before we furnish such a basic theoretical foundation let us briefly discuss the meaning of the notion of system in its form and substance.

## SYSTEM: ITS FORM AND SUBSTANCE

The term "system" is charged with much ambiguity, which is due to the many attempts to use it for the description of various types of objects.

To dodge this danger we must restrict ourselves to the formal features of the object designated by the term "system" only. In contrast to the various substance-oriented notions of system, this can be called a formal or relational system. The underlying idea of the definition of system is the existence of a set

[4] Cf. P. Haggett, Locational analysis in human geography, London 1965; D. R. Stoddart, Organism and ecosystem as geographical models, in: R. G. Chorley, P. Haggett (eds.), *Models in Geography*, London 1967, pp. 511–548 and G. B. Mc Loughlin, *Urban and regional planning: a system approach*, London 1969.

[5] Tentative applications of this type are made in the following studies: B. J. L. Berry, Cities as systems within systems of cities, *Papers and Proceedings of the RSA*, 10, 1964, pp. 147–163; J. V. Medvedkow, Concept of entropy in settlement pattern analysis, *Papers and Proceedings of the RSA*. 18, 1967, pp. 165–168; O. Wärneryd, *Interdependence in urban systems*, Göteborg 1968.



of elements and the relations between them; it is upon these that further conditions of substantial character are imposed.[6]

A system in the formal (set-theoretical) meaning is a certain pattern of elements of a definite set which are connected with one another and with elements that do not belong to that set by definite relations. Formally then it can be defined as follows:

$$S = \langle X_i, R_i, R_{ij} \rangle,$$

where

$X_i = \langle a_{i1}, a_{i2}, ..., a_{in} \rangle$ is the set of elements or the subset of the system;

$R_i = \langle r_{i1}, r_{i2}, ..., r_{in} \rangle$ is the set of relations in the broad sense — including both the functions and properties of the elements — which exist in the set $X_i$;

$R_{ij} = \langle r_{ij0}, r_{ij1}, r_{ij2}, ..., r_{ijn} \rangle$ is the set relations occurring between sets $X_i$ and $X_j$, where $X_j$ is the set of elements that do not belong to the system, that is,

$X_j = \langle a_{j1}, a_{j2}, ..., a_{jn} \rangle$, $X_j = \bar{X}_i$.

The formal notion of the system is a convenient point of departure for constructing various substantial notions of system, such as the socio-economic system, the ecosystem and such like, for it is to this model that further substantial conditions concerning the specific properties of objects in view of their significance for the given research field or discipline are reduced.

Thus for the construction of substantial concepts of system it is necessary that a substantial interpretation of the formal notion of system is at hand.

In practice, however, in various sciences such a substantial interpretation is on the whole intuitive and rather imprecise. To be fully adequate, the substantial interpretation must comprise a definition of the formal notion of system: elements, internal relations, and external relations, all expressed as appropriate modelling assumptions.

The substantial description of the components is very diversified. Attempts made in different disciplines to utilize the formal notion of system show that incommensurate conditions are superimposed upon one another so that in effect different concepts of system are obtained and consequently also different research directives based on those concepts. The most precise and specific conceptual apparatus has so far been developed in cybernetics; it can also be utilized in geographic studies.

The postulates of systems methodology in socio-economic studies find their justification also in the fundamental tenets of ontological and methodological wholism, an idea that can be traced back to the postulates Marx made in the *Capital*.

Ontological wholism points to the integral character of social reality which is a system of operating elements (people and products of their activity) which are connected by various relations. The basic tenet of methodological wholism is that both in description and interpretation the researcher adopts as his point of departure a certain body of knowledge which is composed of knowledge of certain wholes. This brings to the fore the cognitive role of statements concerning objective wholes which constitute systems.[7] While leaving aside any closer considerations of this topic let us emphasize that the systems approach is an inseparable element of Marxist methodology.

[6] A. Rapaport, Zastosowanie izomorfizmów matematycznych w ogólnej teorii systemów (Uses of mathematical isomorphisms in general system theory), *Prakseologia*, 2 (46), 1973, p. 72.

[7] J. Topolski, *op.cit.*

These formal properties of systems and their substantial interpretation together constitute the foundation for constructing system models of towns. The strategy of such a procedure consists in using the modelling assumptions for a substantial interpretation of the notion of systems such as would conform to the theoretical requirements of economic geography and for presenting the methodological consequences of such an interpretation. The same assumptions imply also the fundamental directives of the systems-oriented methodology such as integrity, functionality, and dynamism.

## THE BASIC MODEL OF THE SPATIAL SYSTEM OF TOWNS

Analyses of earlier studies employing the systems methodology yielded no elaborate definition of the spatial system of towns. But K. Dziewoński gave a tentative description of the settlement system, which is closely related to the system of towns.[8]

In its essence the concept of the fundamental model of the spatial system of towns is a substantial interpretation of the formal system expressed in a collection of assumptions which characterize the systemic properties of the spatial system of towns.

But this system of towns must not be treated autonomously. It is actually a subsystem of the overal geographic-economic (and social) system which is a spatially and historically defined system of operating elements, that is, territory, people, and the products of human activity.

Without discussing the model of the overall geographic-economic system let us emphasize here that it is multi-systemic and diversified in character.

It is multi-systemic in the sense that it is composed of several subsystems or system of lower order that are subordinate to it. Such subsystems are collections of interconnected elements simultaneously being sufficiently separable, and hence based on certain valid criteria of separation which differ from case to case in that they are selected so as to conform to the requirements of the concrete research problem to be tackled.

This system can be relativized in two different ways: regionally and generically, in either case producing complexes that are specific, hierarchic and highly complex subsystems such as industrial or settlement systems, which include urban, agricultural, transportation and other systems.

The diversity of the overall geographic-economic system derives both from the generic differences in the subsystems and in the specific system properties as well as from the role they fulfill in the general system.

Thus, for a tentative formulation of the basic fundamental model of the spatial system of towns it is necessary both to characterize the system properties of the system of towns and to relate it to the more comprehensive overall geographic-economic system. This model consists of the following assumptions: (1) the spatial integrity of the system, (2) the identification or spatial delimitation of its elements, (3) the interdependence of its components, and (4) the relative isolation of the system.

The postulate of the spatial integrity constitutes the foundation for distinguishing the spatial system of towns in the form of a highly closed geographic-economic region. The notion of system as a whole is connected with that of

[8] K. Dziewoński, Theories of settlement network: a survey, in: K. Secomski (Ed.), *Spatial planning and policy. Theoretical foundations*, Warszawa 1974, pp. 155–173.



element as its component. In this sense, the term "whole" is used here to denote something that is spatially extendable whereas a component is anything contained in it. Thus conceived, the term "whole" does not imply the condition of spatial continuity for the components; the set of towns is one example.

The following relations can occur between the components of a spatial whole: (a) inclusion, that is the occurrence of components, within the whole; (b) succession, that is the ordering of components by their spatial size; (c) position, that is the situation of components on the scale of spatial coordinates; (d) direction, that is the location of components with respect to a certain point of reference along at least one spatial coordinate; (e) size, that is the length or area occupied by any given component; (f) configuration, that is forms of spatial organization of the components.

The postulate of spatial integrity does not suffice to construct the model of spatial system of towns; if it is restricted to this postulate alone, it does take account of each component's spatial relations but fails to characterize the relations between them. This leads at best to a morphological concept of system. The postulate of spatial integrity for the system of towns is external in character because it bases that system upon the more complex and diversified general geographic-economic system.

The postulate of spatial identification of the elements make us view the town as a fundamental element of the system which, however, must be submitted to spatial delimitation, that is it must be distinguished from among the other components of the geographic-economic system. The delimitation methods necessitate further assumptions concerning certain features of the town which in turn are also specific systems taking different forms (e.g., urban agglomeration, concentration, urban centre, urbanized area and others) and maintaining relations with systems of other types, such as the industrial system. One example of the many difficulties involved is furnished by the attempts to define and delimit urban agglomerations.[9]

The next postulate, that of interdependence of the components, constitutes the foundation for characterizing the operation of the system rather than its spatial morphology. Generally, interdependence occurs when a change in the state of any of the system's elements enjoins a change in the state of the other elements, and conversely.[10] But the notion of interdependence does not predetermine the intensity of that dependence, which is variable. In order to give a more precise meaning to the term "dependence", assume $S$ to be a system and $K$ the class of properties $P_1, ..., P_n$ of the system, that is of its elements; assume, moreover, that the propositions about these properties have the form: "Property $P_i$ of the system $S$ has the value $x$ at time $t$" or, briefly, $P_i(S,t) = x$. Using these symbols we should call interdependent properties such that each and any of them is dependent on the remaining properties of class $K$, or else when for every $P_i$ and $P_j$ in class $K$ the following condition is fulfilled:

If $P_i(S, t_1) = P_i(S, t_2)$ then $P_j(S, t_1) = P_j(S, t_2)$.

It is to be pointed out that the analysis of the interdependence of the components can be either partial or complete. In partial analyses the researcher focuses his attention on one selected element and on the one- and two-way rela-

[9] Cf. *Aglomeracje miejskie w Polsce. Pojęcie i terminologia* (Urban agglomerations in Poland. Concept and terminology), Biuletyn KPZK PAN, 79, Warszawa 1973.

[10] Cf. E. Nagel, Wholes, sums, and organic unities, in: D. Lerner (Ed.), *Parts and wholes*, New York 1963, p. 154. According to Nagel, a property $P_1$ in class $K$ can be called "dependent" on the remaining proporties, in class $K$ when the value of $P_1$ has the same value at different times, if the remaining properties have equal values at those times.

tionships of dependence between that element and the remaining ones. Complete analyses involve an investigation of the dependences of the whole system, and the overall target is to define the state of the whole system, say its equilibrium.

The postulate of interdependence is the criterion of internal complexity of the spatial system of towns. A simple system emerges, when it occurs between all the elements of the spatial whole, but when interdependence occurs only in some parts of the spatial whole, there emerge spatial subsystems of towns and the system is consequently of a complex character.

In spite of its unambiguity, the concept of interdependence creates a number of interpretative difficulties and further particular assumptions may have to be made. The postulate of interdependence of the elements of the spatial system of towns may be interpreted either functionally or dynamically.

The functional interpretation assesses interdependence through definite types of activity of the elements, that is through the functions they fulfill in the system. In the spatial system of towns, those functions are involved in social and economic processes that concern the towns and are indispensable for the system.[11] In this sense, the functions of towns are interpreted as "the total of all social and economic activities that towns fulfill within the system of the national economy".[12]

Not all functions, however, are of a systemic character. Those that are not include exogenous functions, i.e. functions fulfilled by towns with respect to the population of the outside world, as contrasted to endogenous functions, which are fulfilled for the town's own population.

In further analysis of urban functions, two models of towns can be distinguished: (1) the model of isolated urban community due to the existence of central functions, and (2) the model of integrated urban community due to the existence of specialized and complementary functions. This latter model represents a functional interpretation of the spatial system of towns as a set of specialized urban centres with highly open urban economies, low self-sufficiency, and functional-spatial links to the other towns of the given system.

It must be pointed out, however, that spatial systems of towns contain properties of both models. This, on the one hand, caused the emergence of regional subsystems of towns due to the existence of central functions, and, on the other, of complex spatial systems of towns induced by specialized functions. Thus the interdependence of the elements of the spatial system of towns rises in proportion to the degree of specialization of the constituent urban centres. At the same time, parallel to the growing interdependence of the urban centres, their own dependence on the whole system grows too.

From the above, it follows that by bringing the tentative functional interpretation of the spatial system of towns a step further, we can perhaps integrate different theories of urban spatial patterns such as the theory of central places, that of the economic base, and the interaction theory.

The dynamic interpretation of the interdependence of towns is more complex and less advanced in both theory and method.

The most convenient point of departure for the dynamic interpretation is to define interdependence tentatively as different types of feedback relations with

[11] Cf. K. Dziewoński, *Baza ekonomiczna i struktura funkcjonalna miast* (Sum.: Economic base and functional structure of towns), Prace Geogr. IG PAN, 63, Warszawa 1967.

[12] M. Jerczyński, *Zagadnienie specjalizacji bazy ekonomicznej większych miast w Polsce* (Sum.: Problems of specialization of the urban economic base of major cities in Poland), Prace Geogr. IG PAN, 97, Warszawa 1973, p. 19.



time lags.[13] More involved models may be of a simulation-stochastic nature or in the form of Markov chains. This group of models includes also dynamic models of the analysis of principal components.

That models of this type are system models in their character is but a supposition, and it must be submitted to closer analysis in order to define its resulting consequences for the systems approach.

The final postulate, that of the system's relative isolation, concerns the relations of the system and its surroundings.[14] These relations find their expression in the interaction between the surrounding and the spatial system of towns which indicates the degree of the system's relative isolation. The systems' surroundings are generally defined as "the set of all objects not belonging to the system whose properties affect the system and are themselves affected by that system".[15] In the case of systems that are but conceptually (and not organically) isolated fragments of the real world, it is entirely up to the researcher himself to decide whether what constitutes the object of his study as viewed from the standpoint of the aim of research is treated as system or as its surroundings.

The surroundings of the spatial system of towns are composed of systems of different degrees of complexity and hierarchy. These include: the overall geographic-economic system and the geographic environment as an ecological system.

With respect to the spatial system of towns, the general geographic-economic system constitutes a subordinate system of regional (national) scope composed of a number of subsystems (of industries, settlements, transports, agricultural subsystems etc.) to which the system of towns belongs and with which it remains in one- and two-way dependences. When the spatial system of towns is not an element of the spatial whole of the overall socio-economic system, the surroundings are spatially external in character (other countries) and those relationships find their expression in the interaction taking place at definite places on the system's boundary.

The study of relations between the spatial system of towns and other subsystems reduces to one-way dependences, with the surroundings viewed as a set of input (independent) variables affecting the spatial system of towns but which themselves are not affected by that system. The way in which the system exercises its owns impact may be more precisely described by further specification.

The geographic environment as the natural surroundings of the overall geographic-economic system establishes both the direct and indirect relationships through other geographic-economic subsystems. But, as a system, the geographic environment is governed by regularities of a different character and has a different spatial organization due to the integration of the spatial structure and the process. R. Chorley's and B. A. Kennedy's typology of physical-geographic systems (morphological, cascade, coupled, and controlled) each of which represents a higher level of organization and integration of structure and process contains also an element of human intervention and control as a one-way dependence on the social system.[16] But normally we have to do with essen-

[13] J. Langton, Potentialities and problems of adopting a systems approach to the study of change in human geography, *Progress in Geography*, 4, 1972, pp. 125–179.

[14] The concept of relatively isolated system has been introduced by H. Greniewski, *Cybernetyka niematematyczna* (Cybernetics without mathematics), Warszawa 1969, p. 21.

[15] A. D. Hall, R. E. Fagen, Definition of system, *General Systems*, 1, 1956, p. 18.

[16] Cf. R. J. Chorley, B. A. Kennedy, *Physical geography, a system approach*, London 1971.

tially two-way dependences, and hence the attempts to construct models of the metasystem: geographic environment — human society.[17]

The basic model of the spatial system of towns fulfills the set of general conditions defining the specific nature of systems methodology in geographic-economic studies. Its postulates, however, are general in their character and demand further specification in the form of particular assumptions. Accordingly, further models of higher degrees of specification would be formed as variants of the basic model of the spatial system of towns.

Adam Mickiewicz University, Poznań

---

[17] Cf. Z. Chojnicki, A model of interaction between the socio-economic system and geographical environment, *Geogr. Pol.*, 22, Warszawa 1972, pp. 173–181.