# ANALYSIS OF SYSTEMOLOGICAL TOOLS FOR CONCEPTUAL MODELING OF APPLICATION FIELDS

The efficiency of systemology as a new concept for a system approach to solving problems of the noospheric stage of science's development is substantiated. Systemological tools for conceptual classification modeling of application fields are considered. On the basis of consideration of external systems as functional objects, an external way of manifesting systematicness is analyzed.

## 1. INTRODUCTION

Scientific and technical progress and the development of a world market have led mankind and, in particular, science to realization of the world's integrity, based on the process of formation of the noosphere as a natural stage of development of our planet's biosphere. The development of communications and information science has led to the appearance of complex geopolitical, ecological, social, technical, and other problems. New problems of statebuilding and administration, and also of informatization, education, and formation of personality have appeared in connection with the changing space and time scales and goals of human activity determined by the world's developing noospheric integrity.

Widespread introduction of the results of system research (a system approach, in particular) to all spheres of scientific, design, and management activity is considered to be the means of solving such complex and poorly formalizable problems, including organization and improvement of the noosphere. However, the traditional system approach uses an obsolete system concept, which in essence does not fit the noospheric stage of science's development. We will try to demonstrate below that a new systemological concept, the result of development of the system approach, is the most promising and efficient in the current conditions. This concept makes it possible to reveal the essential properties of complex objects of an arbitrary nature, and also the reasons for their occurrence, adaptation, and development, and, consequently, to predict and manage any complex system more efficiently.

Ensuring the efficiency of "intelligent" computer systems and technologies based on knowledge requires construction of conceptual models of application fields. The adequacy of these models depends, to a significant extent, on the methodology of their construction. The quality and efficiency of this methodology are determined by the possibility of its use in application fields of an arbitrary nature, including for construction of a picture of the world as a whole. In our view, the methodology that is needed is a systemological approach, the foundations of which were laid in the works of G. P. Mel'nikov, and Yu. A. Shreider and have been developed in a number of the authors' works [1,2]. The suggested approach, as will be shown below, is distinguished by more consistent application, in comparison with the generally accepted system approach, of the dialectic principles of systematicness, integrity, multiple aspects, hierarchy, and development.

## 2. ANALYSIS OF THE BASIC IDEAS OF THE SYSTEMOLOGICAL APPROACH AND SUBSTANTIATION OF ITS ADVANTAGES

The significant advantages of this approach that beneficially distinguish it from already customary ones can be substantiated by comparative analysis of the fundamental principles on which any concept of a system approach are based. This is connected with the fact that a system approach, as an essential aspect of the noospheric stage of the development of science as a whole and system research in particular, is fundamentally oriented toward application of the dialectic principles of systematicness, integrity, multiple aspects, hierarchy, and development [3,4].

First of all, systemology, which consistently brings to life the principle of systematicness, in contrast to the generally accepted system approach [5], looks at any phenomenon as a system, taking into account a measure of systematicness. For systemology, there is no absolute systematicness, nor systemless objects and phenomena. In reality, there is nothing but systems differing in their measure of systematicness [6].

Secondly, by consistently applying the principle of integrity and multiple aspects, systemology not only takes into account structural integrity, when the nature of the related elements is considered nonessential, or only substantial integrity, when the relations between parts of a whole are not taken into account, but also the functional integrity of a system, which stems from matching of properties of the structure of the whole and properties of its elements, with obligatory interaction with the external environment [7]. A system is considered primarily not as an organized, structured set of elements, which is characteristic of the generally accepted system approach, but as a functional object [8,9].

The functioning of systems is considered within the framework of the generally accepted system approach. However, it is investigated, as a rule, only at the level of a so-called "gray box" [4], which, in contrast to the "black box" method (this method fit the approach that preceded the system approach), provides for consideration of the system's internal structure, but only as far as its subsystems. Application of the principle of hierarchy to the structure of the system under investigation and its subsystems, of course, makes the box "lighter and lighter" [4], but consideration of hierarchy in just one direction (from the top down) does not permit making the "box" completely "white," for which the system approach, in principle, strives. As will be shown below, a system can be investigated as a "white box," but to do this one must take into account hierarchy not only in the direction from the top down, as in the traditional system approach, but also from the bottom up, in the direction of the supersystem. This more consistent application of the principle of hierarchy is characteristic precisely of the given systemological concept.

Moreover, an undoubtedly positive feature of the given systemological concept is its consideration not only of a system's static parameters (structure, substance, function, and so on), but also its dynamic characteristics, thanks to which such processes as formation of the system, its adaptation, cause-and-effect matching of its properties, and the like are taken into account in the course of systems analysis. All of these features make it possible to formulate, within the framework of the given concept, an idea of the system's essential properties and, for the first time, to investigate from a scientific standpoint the ontology of the dialectic category of essence and methods of determining it in the interests of conceptual modeling of application fields.

In our opinion, the systemological concept under consideration is the most methodological tool, the need for which in order to bring the perspectives of a specific investigator of nature and gnoseologist closer together is substantiated in [10] as follows. On the one hand, to overcome the barriers of scientific knowledge proper when "irregular situations" arise and, on the other, for "dialectic processing" of the knowledge created by a specific science, i.e., "organization" of the noosphere as the human habitat.

Comparative analysis of the application of fundamental principles of dialectics by the traditional system approach and the systemological one (the results of this analysis are given in Table 1) shows that the former approach, to a significant extent, continues to use the methodological technique of the previous analytic stage of science's development and, consequently, is not very effective or promising in the current conditions. The systemological approach, which consistently applies the principles of dialectics, methodologically definitively fits the new, noospheric stage of development of society and science and, consequently, is more effective and promising for solving contemporary scientific and practical problems.

As is known, there are two ways of manifesting such a basic trait of systematicness as integrity and, thus, two types of systems to be considered by systemology.

The internal way of manifesting integrity (systematicness), as is known, corresponds to a system *(internal system)* that is an integral formation (specific phenomenon), which can be naturally subdivided into components (subsystems), representing this system in the form of the structure of its parts.

Integrity (systematicness) can also be manifested not as the possibility of subdivision into components, but as the possibility of joining together into a class *(external system)* of systems existing beforehand, thanks to the common nature of their properties. These systems may possess neither spatial, nor temporal commonality, nor even genetic relation; only the commonality of these systems' nature (properties, essence) is important [13].

In accordance with the principle of systematicness, the model of an application field can be represented in the form of a collection of interacting systems. Therefore, we will first analyze the idea of a system as a methodological tool for creating conceptual models, having considered the types of systems mentioned. We will define the place and role of each type of system as a tool for conceptual modeling of application fields.

| SYSTEM APPROACH | SYSTEMOLOGICAL APPROACH |
| --- | --- |
| • Principle of systematicness<br><br>The idea of a system has more than 40 definitions. There is no idea of a measure or degree of systematicness. Objects are seen as systems only in certain conditions [5]. | • Principle of systematicness<br><br>The idea of a system has one, maximally abstract definition. The idea of a measure of systematicness is introduced for consideration of any object as a system that has a certain measure [6]. |
| • Principle of integrity and multiple aspects<br><br>Either structural integrity alone is taken into account, when the nature of the related elements is considered nonessential. or substantial integrity alone, when the relations between parts of the whole arc not taken into account [11.12]. | • Principle of integrity and multiple aspects<br><br>The complex nature of a system's integrity is taken into account, which provides for mutual matching of the system's structure and substance as it interacts with the environment. The basic aspect of integrity is functional [7]. |
| • Principle of hierarchy<br><br>Hierarchy of the system's internal structure alone is taken into account, which provides for investigation of objects by the method of a so-called "gray (light) box" [4]. | • Principle of hierarchy<br><br>In this case, hierarchy of the external environment's structure is taken into account, which provides for investigation of objects by the method of a "lighter and lighter box" [4.6] |
| • Principle of development<br><br>Only static parameters of the system are considered. The reasons for the system's origin and stages of its formation are not considered. There is no idea of the system's adaptation [12,5]. | • Principle of development<br><br>In this case, the system's dynamic characteristics are considered, which provides for understanding the reasons for its origin and stage of its formation. The idea of a system's adaptation is introduced [7.8]. |

In connection with the fact that the terminology of the suggested systemological approach is not widely known, we will give a list of terms needed to understand the essentials of the present investigation, and also their definitions, as determined by our reading, of the sources [6,8]. When they first appear, the original terms are in italics.

*System* - an object the properties of which are determined by a function, which amounts to maintaining certain properties of an object at a higher *level.* This object is a *supersystem* in relation to the object (system) under consideration.

*Substance of a system* - elements or components of the system, usually considered as *subsystems.*

*Structure of a system* - the scheme of relations and interactions of a system's substance.

*Node of relations in the structure* - an element of the system's substance (subsystem) considered as a point in the scheme of relations.

*Relation between systems* - manifestation of motion as a process of exchange between these systems, where the units being exchanged are elements of certain deep levels of the related systems; this process is usually defined as an *exchange flow.*

*Property of a system (valence)* - the ability to maintain (in certain conditions) relations of one type and to prevent realization of relations of other types.

*Functional property of a system* - a property that a system must possess in order to perform its functions; the ability to maintain relations (flows) on the basis of which interactions that are important for the supersystem occur between the system and *surrounding systems.*

*Maintaining property of a system* - a property necessary for maintaining and supporting the stability of functional properties, the ability to maintain relations (flows) serving as a means of internal maintenance and stabilization of functional properties (flows).

*Extensional valence* - a property realized in the form of a relation of the corresponding quality and constituting one of the varieties of reality.

*Free valence* - a property only as an ability, not manifested in an existing relation and constituting one of the varieties of possibility (weak: *potential,* strong: *intention).*

*Internal determinant of a system* - the main, determining, functional property of a system, in relation to which the remaining properties only support it from within.

*External determinant of a system* - the main reason for formation of a system: the supersystem's functional need for certain interactions of the system under consideration with other (surrounding) systems of this supersystem, which dictates the choice of the system's determinant.

*Adaptation of a system* - growth of compatibility between the system's properties and a certain function in a node of the supersystem's network of relations.

*Essential property of a system* - a property for the sake of which or to maintain which the given system was formed in the process of adaptation.

*Essence of a system* - a consequence of the supersystem's functional need, and the internal reason that the system has essential properties: the result of adaptation.

## 3. ANALYSIS OF THE INTERNAL WAY OF MANIFESTING SYSTEMATICNESS

The conceptual basis and methodological technique of the suggested systemological approach, as well as the generally accepted system approach were worked out in investigating internal systems only, which are characterized, by definition, by the relation "part - whole." From the point of view of the internal way of manifesting systematicness, we will clarify the basic ideas of this systemological concept for their subsequent application in the course of analyzing external systems, in the investigation of which this conceptual basis has not yet been used.

An internal system, forming a union in space and lime, is physically included in some internal supersystem. Within the framework of its supersystem, it interacts with different kinds of internal systems at the same level, which constitute its *surrounding conditions*. The elements (substance) of an internal system are different kinds of internal subsystems interacting in space and time.

The chain of transitions from an internal system to an internal supersystem has no limitations, since it is a movement from a part to the whole and an expansion of the space and time scales (example: a *wolf* as specific individual - a *forest* as a specific phenomenon - a *biocenosis - the biosphere - planet Earth - the Solar System - ...)* in an infinite and boundless hierarchy of functioning systems.

The founders of modern systemology consider a system not simply as a material thing, and not only as an abstract idea, but as an ontological analog of what in dialectics corresponds to the idea of the "pith of the matter," i.e., as an individualization of the category of essence [6]. However, in our view, this proposition requires clarification in connection with consideration not only of internal systems, but also of external ones.

An internal system, by definition, is a specific phenomenon, the properties of which, as a rule, are extensional valences. As is known, any phenomenon is characterized by multiple aspects, particularly due to the fact that any phenomenon is a manifestation of more than one essence [14]. From the point of view of internal systems, this means that during its existence a system is a substance (element) of more than one supersystem and, consequently is formed under the action of more than one functional need (external determinant). Consequently, an internal system can have (and, most likely, will have) one functional property that is essential for one supersystem, another that is essential for another supersystem, and so on. Accordingly, the first essential functional property will be maintained by one set of properties, another by another set, and so on. Thus, an internal system can be characterized by several essential properties, including functional ones, and even by multifunctionality. For the purpose of distinguishing and singling out the one among them that is most important and characteristic of the system under consideration, the given systemological concept provides the idea of *a system's essential property.*

The multiple aspects of an internal system are also connected with the fact that, besides its essential properties, an internal system also possesses a large number of nonessential ones. These properties, most often as extensions (but, in certain circumstances, which will be considered below, also as intentions or potentials), are consequences of random functional needs, and also of temporary needs that existed previously. As a result, an internal system as a phenomenon possesses a diversity of properties providing for its fundamental irreducibility to a certain essential property or to a certain single-aspect essence.

Consequently, an internal system can be considered as an essence ("pith of the matter") only at the limit, as a result of the system's infinitely thorough adaptation to the supersystem's corresponding need. That is why systemology emphasizes that in nature there are no absolutely adapted, absolutely systematic objects. We will consider the process of an internal system's adaptation in greater detail later, from the point of view of manifestation of its essential properties.

The idea of a system's *process of formation* is an important one for any system or systemological concept [6]. We will consider this process in detail, since in analyzing it the conceptual basis will be fairly fully manifested. According to the given concept, a prerequisite for the beginning of the process of formation of an internal system is the occurrence of conflict between the supersystem's functioning and the functions of its systems maintaining the supersystem, i.e., a conflict between functional and maintaining flows in the supersystem. This conflict, which serves as the basis for the system's origin, is a disruption of the balance of flows of relations (extensional valences) in the supersystem's corresponding node, when free intentional valences of surrounding systems arise, and the node is *vacant.*

From the point of view of the system that will begin to form due to the occurrence of this conflict, it is a functional need of the supersystem. This need, which is called the system's external determinant, determines what the supersystem requires, i.e., the need that has originated in it for a system with a given function. This need (the system's external determinant), which is represented in the form of a vacant node of the supersystem, assigns the *region of required functional states* for the system being formed, in terms of intentional valences of the surrounding systems.

Thanks to the presence of a system's external determinant assigning the region of required functional states, from some reserve (set of systems) *original material* (a system) is selected that has a *region of possible states* characterizing its predisposition (intention) to perform certain functions.

In order to remove the conflict in the supersystem that laid the foundation for the system's formation, it is necessary that the region of possible states of the system that is taken as the original material fully correspond to the region of required functional states of the supersystem's vacant node. Due to the specific nature of the internal system's essence as having multiple aspects, which is fundamentally irreducible to a certain property, the region of possible states of the internal system will always be broader than the corresponding region of required functional states of the supersystem's node. This circumstance will be additionally substantiated when we discuss the process of internal systems' adaptation.

If the region of possible states of the system that is taken as the original material intersects with the region of required functional states of the supersystem's vacant node, but does not rally include it, then the conflict in the supersystem that laid the foundation for the system's formation will be partially preserved. In this case, the region of possible states will be corrected so as to fully include in it the region of required states by means, for example, of more precise selection of the original material. Thus, a system, as the original material, should arise as a natural consequence of the occurrence of conflict in a supersystem, as the foundation for the system's formation, i.e., the appearance of a functional need of the supersystem for a system with a certain function (the system's external determinant). The region of its possible states should, in the final analysis, include the region of required functional states of the vacant node, since only in this case can the conflict in the supersystem be removed.

As a result of the original material's actual entry into the supersystem's vacant node, the need is transformed into a possibility; the flows are closed; intentions are transformed into extensions; the forming system begins to function in accordance with the need; and the original material is transformed into a substance of the supersystem. The region of required functional states of the supersystem's vacant node, as a manifested extensional function of the forming system, becomes the internal determinant of the properties of that system, now a substance of the supersystem.

The internal determinant of the system being formed to maintain the supersystem's functioning is the system's main, determining, functional property, which becomes the reason for development of a conflict between the system's functional and maintaining flows. This conflict, in turn, becomes the reason for formation of subsystems with certain functions that maintain the system, i.e., the system adapts to the supersystem's functional node.

Thus, the process of a system's adaptation to the supersystem's need, as the concluding phase of the system's formation, begins from the moment when the given system is placed as original material in the appropriate vacant functional node of the supersystem. Prior to the beginning of adaptation, when the given system is still original material, its internal maintaining properties (flows) have potentials (or rather, even intentions) for maintaining the required functional properties (flows), which promotes the choice of precisely that system as the original material. But, at the same time, the internal properties (flows) of the given system, as a phenomenon, potentially and even extensionally can and do maintain a great many other functional properties not required in the given case. This provides breadth of the region of possible states of the system (original material) sufficient for inclusion of the region of the vacant node's required functional states, i.e., a certain surplus of properties prior to the beginning of adaptation. In the course of the given system's adaptation to a specific functional need under the action of its internal determinant, the system's internal properties (flows) maintaining the required function will be transformed from intentions into extensions; and the maintaining functional properties not needed in this case, on the contrary, are transformed from extensions into intentions and even potentials. Thus, as a result of adaptation, the surplus of the system's properties is reduced; its properties that are essential for the given supersystem are manifested ever more strongly; and the system is transformed from original material potentially suitable for performing the assigned function into a more ideal substance of the given supersystem that fits the functional need ever more closely.

The more thoroughly a system is adapted to the supersystem's functional need, the clearer its essential properties will be manifested, the higher the degree of formation of its essence will be, and the smaller the surplus of its properties will be. Systems in which, as a result of adaptation to the function that the supersystem requires, the region of possible states does not simply cover, but is maximally close to the region of required functional states, are called *optimally adapted* or *ideal* [6]. Such systems are distinctly formed, clearly manifested, fully stable phenomena with a definite essence.

Defining a system as an object, the function of which amounts to maintaining certain properties of a supersystem, reveals a hierarchy of systems' functional properties based on the fact that systems and their properties at various levels of the hierarchy are in a relation of maintaining the functional ability of the whole [8]. From the point of *Automatic* view of maintaining the functional ability of the supersystem as a whole, the sequence of phases of formation of an internal system discussed above discloses a chain of cause-and-effect relations of the internal system's properties. It becomes obvious that the reason for the presence of essential functional properties in the system is the supersystem's functional need for them, i.e., the system's external determinant. This determinant itself is a consequence of the supersystem's functioning in a supersupersystem. The reason for the presence of the system's internal properties that maintain its essential functional properties (and, consequently, the reason for the presence of also essential, but only maintaining properties) is the system's function that maintains the supersystem: its internal determinant that forms the system's needs for certain functions of subsystems to maintain it, and so on.

Clarification of the cause-and-effect relations of internal systems' properties makes it possible to consider the category of essence from the point of view of stages of the system's functioning. In the systemological concept that is being used, the essence of a system is considered, first of all, as a consequence of the supersystem's functional need, i.e., as the system's function that is required by the supersystem. The reason for and source of this function is the functional need arising as a result of disruption of the supersystem's balance of flows (relations), i.e., the system's external determinant. Consequently, the essence of an internal system is most fully manifested in terms of functional flows and relations, since the system is formed precisely in order to satisfy the supersystem's functional need. Secondly, the essence of a system is considered as the internal reason for the presence of the system's essential functional relations (flows). This essence is formed as a result of the system's adaptation to the assigned function (to the supersystem's functional node), i.e., as the totality of the system's internal, maintaining, essential relations (flows), the reason for and source of which is the system's function: its internal determinant.

Proceeding from what has been said above, we can see that in the stage of selecting the original material for a system that is being formed, when the given system is not yet a substance of the supersystem and has not yet been included in it, the following situation is created: the system's external determinant (the supersystem's need) already exists, but there is not yet a functioning system with the appropriate internal determinant (collection of functional and, moreover, maintaining relations). There is not yet the required system, as a manifestation of the given essence, but it is predetermined by the already existing external determinant. In this case, it is said that "there is a system before it exists" [15]. This is connected with the fact that, first of all, in the given stage, the extensionally existing external determinant of the required system, in the form of disruption of the balance of the supersystem's functional and maintaining flows, corresponds to the given system's essence as the reason for it. Secondly, the essence of an internal system, as a consequence of the supersystem's functional need, is manifested intentionally in this stage, as the predisposition of the forming system (original material) to perform the function corresponding to the extensional need. In the given case, this predisposition is assigned from above, by the supersystem. Thirdly, the system's essence, as the internal reason for the presence of its essential functional relations, is only manifested potentially or is not manifested at all.

After the given system has been transformed from original material into substance as a result of its inclusion in the supersystem's vacant node, the process of the system's adaptation to the supersystem's need gradually encompasses deeper and deeper levels of the system, since the performance of functions at any level always requires certain support from the system's elements. The given system's internal determinant formed as a result of this process is manifested as essence at the level not only of functional relations, but also of internal maintaining ones. This leads to a situation in which the system's essence, as a collection of maintaining relations, can be preserved in the case of the given system's elimination from the supersystem in which its functioning was required. There is now no reason (i.e., external determinant) for the system's functioning, as a manifestation of the given essence, but it still exists, since its internal relations maintaining its internal determinant are preserved. In such a case, it is said that "there is no system before it ceases to exist" [15J. This is connected with the fact that, first of all, in this stage there is no external determinant of the given system (no need on the part of the supersystem). Secondly, the essence of an internal system, as a consequence of the internal supersystem's functional need, is manifested intentionally in this stage, as a predisposition of the given system (former substance of a certain supersystem), developed as a result of adaptation, to perform a function corresponding to the former extensional need. This predisposition, in the given case, is assigned from below, by the subsystems. Thirdly, the collection of maintaining relations formed as a result of adaptation that is extensionally manifested in the system corresponds to the essence of the given system at the level of its subsystems, as the internal reason for possible functional relations.

We can give as an example of a system (a functionally adapted object) a person as a specific "official" who executes his functional duties according to the position that he occupies in a specific department (supersystem) of a scientific research organization (supersupersystem). In this case, we can trace all of the stages of the system's functioning and its interactions with the supersystem that were noted above.

In particular, assignment of a new, previously unforeseen task to the department by the organization leads to a discrepancy between the volume and type of work performed by the department, on the one hand, and also the department's staffing (structure) and the staff members' functional duties, which were designed for the former range and volume of work, on the other. A consequence of this discrepancy may be the appearance of a vacant node ("vacancies") in the department's structure, first substantively, and then formally, through the introduction of a new job with certain functional duties to the staffing. The presence of a new, vacant position in the department (supersystem) is a clear example of the appearance of a system ("official") with an assigned function before it actually begins to exist, particularly if the department is forced to perform all types of work.

Reduction of the department's volume of tasks by the organization also leads to a discrepancy between the volume and type of work to be performed by the department, on the one hand, and the department's staffing and the staff members' functional duties, on the other. A consequence of the discrepancy in this case may be the elimination of some job in the department's staffing, which is a clear example of the disappearance of a system with a given function before it actually ceases to exist, particularly if the staff member has not yet been fired.

For analyzing and comparing the essential properties of systems (functional adaptive objects), it seems advisable to us to consider a generalized characteristic: a measure of systematicness *(Ms)*. Substantively, it will be an index of systematicness, integrity, stability, the degree of formation of an essence, and the depth and optimality of adaptation, like the characteristics introduced in [8]. Formally, in a set-theory sense, we suggest that *Ms* be determined as the ratio of the region (set) of possible states of the original material for a forming system (we will represent it as *RPS)* to the region (set) of functional states of the vacant node required in accordance with the supersystem's need (we will represent it *as RRFS)*.

It is obvious that for an optimally adapted system that has a fully formed essence and a distinct measure *Ms* should approach 1. From the point of view of the relationship of the regions *RPS* and *RRFS,* the optimum adaptation and final formation of essence are achieved when *RPS* = *RRFS.* Thus, *Ms* = 1 when *RPS* = *RRFS.* For a slightly adapted system that has poorly formed essential properties and an indistinct measure, *Ms* should tend to 0. From the point of view of the relationship of the regions *RPS* and *RRFS,* this is the state of a system in the stage of original material, when the region *RPS* is enremely large. Thus, when $RPS \to \infty$, $Ms \to 0$.

Hence a formal expression can be derived for evaluating the measure of systematicness of an internal system that is adapting to some functional code of a supersystem, i.e., on the condition that *RRFS C RPS:*

$$Ms = RRFS/RPS,$$

where *RRFS* and *RPS* are the powers of the corresponding sets.

From this expression, in particular, we can see that in reality there are no systemless objects, since the region *RPS* of an actually existing internal system cannot be practically infinite. Simultaneously, we can see that there also cannot be absolute systematicness, since for an internal system *RPS* practically cannot be exactly equal to *RRFS,* taking into account that at present or, at least, in the past the system belongs or belonged to not just one supersystem (i.e., the surrounding conditions of its functioning).

In the general case, with consideration not only of the phase of a system's adaptation to a supersystem's need, but also the phase of choosing the original material, i.e., on the condition that $RRFS \cap RPS$, the measure of systematicness can be expressed as follows:

$$Ms = RPS \cap RRFS/RPS,$$

where *RRFS* and *RPS* are the powers of the corresponding sets.

As was noted above, the region *RRFS* entering into the region *RPS* of an internal system that has begun to function in a node of a supersystem in accordance with a need is the system's internal determinant, and for the supersystem the region *RRFS* is the supersystem's functional requirement, i.e., the system's external determinant. Consequently, for an internal system that is adapting to some node of a supersystem $RRFS = D^{in}$, where $D^{in}$ is the system's internal determinant. For the supersystem's functional need, which the selected original material must fit, $RRFS = D^{ex}$, where $D^{ex}$ is the system's external determinant.

Moreover, taking into account the multiple aspects of an internal system as a phenomenon, which was noted in analyzing the specific essence of internal systems, the region *RPS* of an internal system can be considered as the totality of all *RRFS* corresponding to all of the supersystems of which the given system is (or was) an element. Hence, the measure of systematicness of an internal system that is adapting to a functional node of a supersystem can also be expressed as follows:

$$Ms = D^{in} / \sum_{i=1}^{n} D_i^{in},$$

or

$$Ms = D^{ex} / \sum_{i=1}^{n} D_i^{ex},$$

where the denominator corresponds to the totality of all internal or all external determinants under the action of which the system under consideration was or is being formed.

Taking into account the clarifications that were made and in the same methodological sequence, we will apply this conceptual basis to analysis of so-called external systems, for the purpose of subsequent comparison of types of systems as tools for conceptual modeling of application fields.

## 4. ANALYSIS OF THE EXTERNAL WAY OF MANIFESTING SYSTEMATICNESS

Besides internal systems, as was already noted, systemology also studies external systems, which are characterized by genus-species relations. The systematicness (integrity) of these systems is determined not by the possibility of subdividing them into components, but by the possibility of joining them together into a class, thanks to the common nature of properties of the objects forming an external system [13]. We will consider the phenomenon of an external system in greater detail and the prospects of constructing conceptual models of application fields with consideration of this type of system.

Until now, external systems have been considered only as a classification tool, i.e., mostly in their gnoseological aspect. Study of external systems by means of systemology itself has not yet been done. For the first time, having subjected the external way of manifesting integrity to systemological analysis with the help of the concepts of a "system class" and a "property class" [16], we discovered the prospect of considering external systems by analogy with internal ones, i.e., as functional objects. In our opinion, the construction of conceptual models of application fields acquires new possibilities as a result of giving external systems the status of internal ones (the status of functional objects). Moreover, this makes it possible, as will be shown later, to generalize the concept of a system itself, and to see the cause-and-effect relations providing for the presence of the observed properties of surrounding reality in a new way.

An external system, the objects of which possess neither spatial nor temporal commonality [ 13], is an element of an external supersystem, which is a broader class of objects possessing a more general property. An external system interacts in its supersystem with external systems of the same *level,* which make up its surrounding conditions and are of the same kind as the given system. The external system's elements (substance) are subsystems, which constitute narrower classes of objects possessing particular species properties.

Movement from an external system to an external supersystem is movement from species to genus, i.e., to broader and broader classes of objects possessing more and more common properties. This movement, as will be shown below, cannot continue infinitely. Example: *house cat* (species) - *cats* (genus) - *Felidae* (family) *-predators* (order) - *mammals* (class) - *vertebrates* (subtype) - *Chordata* (type) - *animals* (kingdom) - *nuclear organisms* (superkingdom) - *organisms* - *objects.*

An external system, by definition, is a class of objects unified by some common essence. Considering an external system, we are only dealing with a quite specific common essence (with a certain aspect) - with the given essence as such. To whatever degree the external system's essence has been formed, it is always represented in a "pure form." Consequently, in our opinion, it is precisely external systems that are the ontological analog of the category of essence ("the pith of the matter"). This allows us to see internal (specific) systems as system phenomena; and external systems (system classes), as system essences.

Extending the status of internal systems (functional objects) to external systems requires application of an analogous conceptual basis .to analysis of them. In this case, we must keep in mind that, in contrast to internal systems, external systems do not have extensionally expressed properties (extensional valences) in the form of flows of relations. The properties of external systems only exist as abilities (free valences), i.e., as intentions or potentials. In connection with this, we will analyze the idea of formation of a system and the idea of a measure in regard to the specific nature of the external way of manifesting systematicness.

Occurrence of a conflict between a supersystem's functional and maintaining properties (abilities), obviously, also serve as a prerequisite for formation of an external system, but not between flows (relations), which also serves as a basis for formation of a system. This conflict arises in the form of a vacant node in the structure of the supersystem's maintaining properties that support its corresponding functional properties.

From the point of view of the system that will begin to form thanks to the development of this basis, the conflict is a functional need of the supersystem, which is called *the system's external determinant* and determines what the supersystem requires, i.e., the need that has originated in the supersystem for a system with a given functional property. This need of the supersystem (the system's external determinant), existing in the form of its vacant node, assigns the *region of required functional properties* for the system that is being formed.

Thanks to the presence of an external determinant of the system assigning the region of required functional properties, some class (external system) is selected as the original material, which has a certain *region of possible properties* characterizing the degree of its correspondence to the functional need.

In order to remove the conflict in the supersystem that laid the foundation for the system's formation, it is *Automatic* necessary that the region of possible properties of the external system taken as the original material fully correspond to the region of required functional properties of the supersystem's vacant node. In connection with the specific nature, discussed above, of the essence of an external system that is forming thanks to correspondence of all of the system's elements to one certain property, the region of the external system's possible properties will coincide with the corresponding region of required functional properties of the supersystem's node.

If the region of possible properties of the system taken as the original material intersects with the region of required functional properties of the supersystem's vacant node, but does not completely coincide with it, then the conflict in the supersystem that laid the foundation for the system's formation will be partially preserved. In this case, the region of possible properties will be adjusted to completely coincide with the region of required properties, by means of more precise selection of the original material. Thus, an external system, as the original material, should arise as a natural consequence of the appearance of a conflict in a supersystem, as the foundation for the system's formation, i.e., the supersystem's functional need for a system with a certain functional property. In the final analysis, the region of possible properties of this external system should coincide with the region of required functional properties of the vacant node, since only in this case can the conflict in the supersystem be removed.

As a result of the actual reception of original material into the supersystem's vacant node, the functional property of the forming external system corresponding to the need becomes a maintaining property for the external supersystem. The region of required functional properties corresponding to the region of the original material's possible properties, as a functional property of the forming system, becomes its internal determinant.

The internal determinant of an external system forming in order to maintain the functional properties of an external supersystem, as the main, determining, functional property of that system, becomes the reason for development of a conflict between the system's functional and maintaining properties. This conflict, in turn, becomes the reason for formation of external subsystems with certain properties that maintain the system, which is an analog of the process of a system's adaptation to a supersystem's functional node. The analogy of this process with the adaptation of internal systems consists in the fact that they are both processes of deeper and deeper (more and more complete) matching of the chain of maintaining and functional properties.

However, in this case there will be no adaptation, as a process of decreasing the surplus of properties by reducing the region of possible properties to the size of the region of required functional properties. This is because of the lack of a surplus of properties and the coincidence of these regions, due to the fact noted above that the essential property of an external system has only one aspect. Consequently, the idea of optimum adaptation is not applicable to external systems.

From the point of view of the relation of maintaining the functional ability of the supersystem as a whole, which is inherent in functional objects, the sequence of phases of an external system's formation considered above also discloses a chain of cause-and-effect relations of properties - in this case, of external systems. Here, it also becomes obvious that the reason for the presence of essential functional properties in an external system is an external supersystem's functional need for them (an external determinant). The reason for the presence of an external system's internal properties that maintain the essential functional property is the functional property of the external system that maintains an external supersystem. This property, the external system's internal determinant, forms its needs for certain functional properties of external subsystems to maintain it, and so on.

Clarification of the cause-and-effect relations of the properties of external systems allows us to see the category of essence (but now in the material of these (external) systems) from the point of view of stages of the system's functioning. By analogy with internal systems, we will also consider the essence of an external system, first of all, as a consequence of a supersystem's functional need, i.e., in the given case, as the functional property (ability) of a system required by a supersystem. The reason for and source of this property is the supersystem's functional need (requirement), i.e., the system's external determinant. Consequently, the essence of an external system is also most fully revealed in terms of functional properties (but not flows), since an external system is formed precisely in order to satisfy the functional need of an external supersystem. Secondly, we will consider the essence of an external system as the internal reason for the presence of the system's essential functional properties, which arises as a result of some analog of the process of a system's adaptation to an assigned intentional function (a supersystem's functional node), i.e., as the totality of the system's essential maintaining properties (not relations). The reason for and source of these properties is the system's function (ability, free intentional valence): its internal determinant.

Proceeding from what has been said above, we can also see here that in the stage of selecting the original material for a forming system, i.e., when the given system is not yet a substance of the supersystem and has not yet been included in it, the following situation is created: there is already an external determinant of the system (the supersystem's requirement), but there is not yet a system with the corresponding internal determinant (collection of functional and, moreover, maintaining properties). There is not yet the required system, but it is predetermined by the already existing external determinant. In this case, it is also appropriate to say that "there is a system before it exists" [15].This is connected, first of all, with the fact that, in the given stage, the external determinant, intentionally existing as a free valence, in the form of disruption of the supersystem's balance of functional and maintaining properties, is identical to the essence of the given system at the level of the supersystem (not just as a reason). Secondly, the essence of an external system, as a consequence of an external supersystem's functional need, is potential in this stage, as a predisposition of the forming system (original material) to an intentional functional property corresponding to the intentional need. In this case, the predisposition is assigned from above, by the supersystem. Thirdly, there is no essence of the system, as an internal reason for the presence of essential functional properties.

After the given system is transformed from original material into substance as a result of its inclusion in the vacant node of a supersystem, a process analogous to the process of a system's adaptation to the supersystem's need gradually encompasses deeper and deeper levels of the system, since the presence of functional properties of a system at any level requires certain maintenance on the part of its elements. As a result, the system's internal determinant is formed, as essence assigned at the level not only of functional properties, but also of internal maintaining properties. This leads to a situation in which the system's essence, as the totality of maintaining properties, can be preserved when the given system is eliminated from the supersystem that required its functional properties. There is now no reason (external determinant) for preservation of the given system (essence), but it still exists, since its internal properties maintaining its internal determinant are preserved. In such a case, it is also appropriate to say that "there is no system before it ceases to exist" [15]. This is connected with the fact that, first of all, in the given stage, the system's external determinant does not exist. Secondly, the essence of an external system, as the consequence of an external supersystem's functional need, is potential in this stage, as a predisposition of the given system (which was formerly a substance of a certain supersystem) to an intentional functional property corresponding to an intentional need. In this case, the predisposition is assigned from below, by subsystems. Thirdly, the intentional collection of maintaining properties that have been formed (free intentional valences) is identical (not only as the internal reason for functional properties) to the given system's essence at the level of its subsystems.

Furniture as a class of objects can serve as an example of an external system, on which we can trace all of the stages of its existence and interaction with a supersystem noted above, from the point of view of development of new types of furniture and disappearance of obsolete types as a result of changes in society's needs.

The idea of a measure can be used to analyze and compare the essential properties of external systems as functional objects, just as it is for internal systems. But, since there is no adaptation of the system to a functional node, as a process of reducing a surplus of properties, the measure cannot be used in the sense in which it was introduced in the preceding section, as a measure of systematicness.

In our view, in this case we can use the idea of a measure of naturalness (Mn), which is an index of the correspondence of the selected system's functional properties to the supersystem's need, i.e., correspondence of the region of possible states *(RPS)* of an external system, as original material, to the region of required functional states *(RRFS)* of an external supersystem's corresponding node.

It is obvious that *Mn* will be larger, the greater the correspondence (i.e., intersection) is between *RPS* and *RRFS. Mn,* as an index of this correspondence and, consequently, of the validity of the selection of original material, and hence of naturalness, should be equal to 0 if $RPS \cap RRFS = 0$. If $RPS = RRFS$, which means that the original material fully fits the functional need, *Mn,* naturally, should be equal to 1. Consequently, the formal expression, in terms of set theory, for evaluating the measure of an external system's naturalness (when selecting it as original material) will look like this:

$$Mn = RPS \cap RRFS/RPS,$$

where *RRFS* and *RPS* are the powers of the corresponding sets.

As we can see from this expression, the value *of Mn* shows that the greater the degree of correspondence between *RPS* and *RRFS* is, the greater the functional correspondence will be between the external system selected as original material and the external supersystem that formed the functional need, and the greater the degree to which the selected system will be a functional object occupying its natural place.

Introduction of the idea of a measure *(Mn)* makes it possible to clarify the idea of a necessary property and the idea of an essential property, and also the idea of multiple-aspect classification and natural classification. Proceeding from the substantive and formal definition of *Mn,* we can state that when $Mn < 1$ an external system will possess properties necessary for some supersystem, and when $Mn = 1$ an external system possesses precisely those essential properties that determine its natural, objective purpose. From the point of view of classification, the hierarchy of external systems in which the equality $Mn = 1$ is observed is a natural classification, regardless of its subjective goals. A hierarchy of external systems in which this equality is not observed is a multiple-aspect classification, which depends on the goals of the subject conducting the classification.

Hence, the larger the measure of naturalness is, the more objective and independent of the subject's understanding the external system under consideration will be; and the smaller the measure of naturalness is, the greater the degree to which the given external system will be a reflection of our idea of the world, and not of the world itself. Thus, if external systems are considered in connection with classification, men when Mn increases we can talk about a process of adaptation, in the sense of *RPS* coming closer to *RRFS,* thanks to improvement of knowledge about the external system and the corresponding external supersystem, and to its increased objectivity. Consequently, Mл can also be called a measure of ontologicity. As we will show, it is valid to state that when Mn = 1 the given external system is ontological, and when *Mn* = 0 the external system is gnoseological.

We are introducing the idea of ontologicity of external systems for which Mn = 1 not only out of considerations of convenience in seeing them as functional objects. This is done because of the need to expand customary ontology to accommodate them, in connection with the fact that external systems participate in the chain of cause-and-effect relations providing for the existence of present properties and phenomena, which will be substantiated later.

As was noted above, identity of the regions *RRFS* and *RPS* of an external system taken into a supersystem's functional node in accordance with a need is the system's internal determinant, and for an external supersystem *RRFS* is a functional requirement of the supersystem, i.e., the system's external determinant. Consequently, for an external system corresponding to some node of a supersystem $RPS = D^{in}$, where $D^{in}$ is the external system's internal determinant; From the point of view of the supersystem's functional need, which the selected original material must fit, *RRFS* = $D^{ex}$, where $D^{ex}$ is the external system's external determinant.

Using the notations for determinants, the measure of naturalness can be expressed as follows:

$$Mn = D^{in} \cap D^{ex} / D^{in}$$

The results and conclusions obtained in the course of extending the systemological conceptual basis to external systems will be used later to investigate the interrelation of different types of systems, and also to analyze and model complex application fields.

## 5. CONCLUSIONS

Investigation of types of systems in regard to the way in which they manifest systematicness shows that systemology provides effective tools with diverse possibilities for conceptual classification modeling of application fields.

Analysis of an application field's internal systems (system phenomena) characterizes the given field from the point of view of its systematicness. This makes it possible to evaluate the integrity, stability, and the depth and optimality of adaptation of systems in the given application field, and also the boundaries of their stable functioning.

## REFERENCES


1. E.A.Solov'eva and S.I.Matorin, "Modeling of conceptual knowledge: a bionic system approach", Nauchno-Tekhnicheskaya Informatsiya, Ser.2, no.3, pp2-8, 1989.
2. E.A.Solov'eva and S.I.Matorin, "Modeling methods and models of conceptual knowledge", Nauchno-Tekhnicheskaya Informatsiya, Ser.2, no.4, pp2-8, 1989.
3. D.M. Gvishiani, "Materialist dialectics – the philosophical foundation of system research", in: System Research: Yearbook [in Russian], p7-28, Nauka, Moscow, 1980.
4. D.M.Polishchuk and V.B.Khon, Theory of Automated Information Banks [in Russian], Vyssh. Shk, Moscow, 1989.
5. F.I.Peregudov and F.P.Tarasenko, Introduction to Systems Analysis [in Russian], Vyssh. Shk, Moscow, 1989.
6. G.P. Mel'nikov, "Introductory article" in: Systemology and Linguistic Aspects of Cybernetics [in Russian, Sov. Radio, Moscow, 1978.
7. Yu.G.Kosarev, "Introductory article", in G.P Mel'nikov, Systemology and Linguistic Aspects of Cybernetics [in Russian], Sov. Radio, Moscow, 1978.
8. G.P.Mel'nikov "Development of a subsystem for linguistic support of an automated information system of the documentary factographic type in the field of materials technology", Otchet o NIR, No. reg. 01.86.0103243, SKTB IS IPM A USSR.
9. S.M.Brekhovshkikh, Principles of Functional Systemology of Material Objects [in Russian], Nauka, Moscow, 1989.
10. Yu. A. Shreider, "Theory of cognition and the phenomenon of science", in : Gnoseology in the System of a Philosophical Worldview [in Russian], pp 173-193, Nauka, Moscow, 1983.
11. M.Mesarovich, D.Mikhailo, and Ya. Takahara, General System Theory: Mathematical Principles [Russian translation], Mir, Moscow, 1978.

12. D.Klir, Systemology: Automation of the Solution of System Problems [Russian translation], Radio I Svyaz, Moscow, 1990.
13. Yu.A.Shreider and A.A.Sharov, Systems and Models [in Russian], Radio I Svyaz, Moscow, 1982.
14. Philosophical Dictionary [in Russian], ed. By. I.T.Frolov, fifth edition, Politizdat, Moscow, 1986.
15. G.Hegel, Science of Logic [ Russian translation], Mysl, Moscow, 1971.
16. E.A.Solov'eva, "Principles of design, structure, and properties of a substantive model of a system of concepts", Nauchno-Tekhnicheskaya Informatsiya, Ser2. no.4, pp.2-8, 1990.