General System Principles of Architectural Systems Formation

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Abstract. Due to the insufficient knowledge about the regularities of formation and development of architectural objects and their components, the used methods are often based on conception that apartments, buildings, complexes, cities and objects of areal planning can be considered as a certain sum of elements, which can be studied and taken into account separately, without considering the general combination of factors. The present-day practice strongly suggests nowadays that such approach to solving architectural problems can’t be acceptable. At the boundary of architectural science and practice the controversies due to inefficiency of conventional methods of researching and designing architectural and city-planning systems become more and more frequent. This work presents the definition and substantiation of an architectural environment and an object of architectural activity as an ecological system of «population ↔ environment» type – i.e. a demoecosystem. The general system principles and the sphere of their application in the formation, functioning and development of architectural systems are given, which substantially expands the knowledge about an object and subject of architectural theory and practice. The general principles of architectural systems (demoecosystems) behavior are the basis for developing logical and mathematical models. The knowledge about the principles of behavior of integral architectural systems of various hierarchical levels and various complexities allows developing general methodological recommendations at designing specified methods of research and expert evaluation of architectural objects at version designing and forecasting.

1. Introduction

Due to the complication of an object of architectural activity and in the context of cybernetics and general system theory the integral architectural objects are open self-regulating systems, freely exchanging mass and energy with the environment. Architectural systems have a very complex and dynamic inner structure.

The problems of researching systems and developing system methods in mathematics, cybernetics, philosophy; principles and methodological organization of system-structural research and development, and the general theory of systems are considered in a number of fundamental works by the authors [1–10] and other researchers. The problems of human ecology, the concepts of the present-day «large» ecology, its theory, laws, regularities, principles and hypotheses within the natural systems hierarchy are considered in a number of fundamental works by scientists in the sphere of biology, physics, medicine [11–27]. The issues of adapting general system principles and system
methods of research, designing and expert evaluation to architectural objects are studied in works by
the authors [28–32] etc.

2. Topicality
The topicality of the problem of human ecology is conditioned by the currently existing possibility to
perform a scrupulous scientific analysis of a whole complicated set of factors on the basis of
achievements of a number of sciences, first of all, cybernetics, general system theory, biology,
physics, and medicine. Discrepancies in the sphere of determining the boundaries and purposes of
architectural activity indicate the appearing of a new area of knowledge, which requires a different
unconventional approach, having a more efficient research and methodological apparatus, which
would allow reconsidering the existing discrepancies and finding their solution. The purpose of this
research is the definition and substantiation of system principles of formation and behavior of
architectural objects as integral systems.

3. Research objectives
– definition and substantiation of architectural environment, the object of architectural activity as an
ecological system of «population ↔ environment» type;
– specification of methodological peculiarities of applying general system principles of integral
objects functioning to architectural activity.

The object of research is architectural environment as an integral ecological system of «population
↔ environment» type. The subject of research is the regularities of functional structure formation of
integral architectural objects of various hierarchic levels.

The methodology of research is based on methodological provisions of general system theory with
regard to architectural environment of various hierarchic levels of its organization.

4. The theoretical part
In the early 70ies the new terms were first suggested, and in 1980 they were successfully approbated –
i.e. such terms and concepts as «demoecosystem» (from Greek: demos – people, population; oikos –
house, home, birthplace) and «demoecology», which determined the necessity of rendering an object
of architectural activity as an ecological system of «population ↔ environment» type, including three
functional-spatial subsystems: artificial (architectural and city-planning) environment, natural
environment and the people, inhabiting them [29, 30]. Due to their high complexity, dynamism and
integrity, architectural objects require using system approach. At present the concept «system» implies
a number of properties, shared by all system objects, and first of all, the properties of integrity and
orderliness [29 p. 35; 30].

A general principle means an essential and necessary interrelation of objects and phenomena of the
objective reality. General principles act at the level of nature laws. General system principles are the
essence of nature and society laws’ manifestation in architectural systems. In fig. 1 the general system
principles and the areas of their application in formation and development of architectural systems are
presented. The suggested table makes no pretence of completeness or fullness, but shows a number of
essential system regularities, existing in architectural objects of any level of complexity.

Table 1(a). General system principles and the area of their application in formation and development
of architectural systems.

| General system principles | Area of application (function) | A specialist, having contributed much to this area of knowledge |
|--------------------------|--------------------------------|-------------------------------------------------------------|
| Structure hierarchy principle (hierarchical organization axiom, integrative levels principle) | It consists in separation of lower-order elements from higher-order elements. Interrelation and interinfluence of elements occur in the form of subordination – from lower to higher and implies the hierarchical (multi- | Bertalanffy L von [1], Reimers N F [22 p 57], Frank–Kamenetsky L A, Weyl H K H, |
2 Principle of integrity (ecological complementarity and ecological correspondence)

No functional part of an ecosystem (component, element) can exist without other functionally complementary parts. A set of elements of the system can be divided into subsets, singling out subsets as component parts of the system. Each subsystem can be also considered as an independent separate system. Bertalanffy L von [1], Commoner B [11], Dedyu I I [12], Macintosh R P [18], Reimers N F [22 p 118], Smith R L [24] etc.

3 Principle of harmony of elements interconnection (principle of optimal component complementarity; «law» of ecological (structural) correlation of Cuvier J L); law of coordination of structure and rhythms (functions) of parts (subsystems)

In an integral system all its parts correspond to each other, both in structure and in functions. Alteration of the parameters of one element of the system influences in a certain way the parameters of other elements, usually in a nonlinear way. Alteration of any of the elements depends on all other elements of the system. Removal of one element of a system alters the structure and functions of other elements or of the whole system. Dedyu I I [12], Macintosh R P [18], Odum E P [20], Cuvier J L, Reimers N F [22 p 53], Vernadsky V I [25, 26], Watt K E F [27] etc.

4 Multiplicity of elements; law of requisite variety; time diversity law of development (alteration) of subsystems in large systems

An integral architectural system consists of a set of elements, each of which performs various system-determined functions. No system can be formed of absolutely identical elements. For each type of systems the necessary variety is numerically different and often strictly specified. Dedyu I I [12], Huxley J, Fairbairn D J, Reimers N F [22 p 47] etc.

5 Principle of unity organism – environment («law» of system’s development by means of the environment; «law» of ecological congruence); law of biogenic energy maximum (entropy) of Vernadsky V I – Bauer E S

An organism develops in a close interaction, dialectical unity with the living environment on the basis of energy flow in the combined unity of the environment and the organisms inhabiting it. A totally isolated self-development is not possible. The form of an organism’s existence always corresponds to the conditions of its living. Any ecological system, being in a dynamic equilibrium with the environment and evolutionally developing, increases its influence on the environment. The influence increases until it is strictly limited with external factors, or the evolutionary-ecological catastrophe occurs. Commoner B [11], Dedyu I I [12], Macintosh R P [18], Sechenov I M, Bauer E S, Reimers N F [22 p 60], Smith R L [24], Vernadsky V I [25, 26], Watt K E F [27] etc.

6 Principle of isomorphism or the whole and the parts similarity; principle of structure invariance

The correspondence of regularities of subsystems and elements of one system to the properties of subsystems and elements of another system. The subsystem elements of the same hierarchical level are identical (isomorphic) to subsystem elements of other hierarchical levels of that system and alter «within the accuracy of isomorphism». Yongzai Ye, Reimers N F [22 p 45], Frank–Kamenetsky L A, Weyl H K H, Lavrik G I [29 p 44–45] etc.

7 Principle of feedback of human – environment interaction

A part of renewable natural resources (animals, plants) can become exhausted, non-renewable. Any change in the natural environment caused by human economic activity returns and has undesirable consequences affecting the economy, social life and human health. The ecosystem after the termination of influence on its components of Commoner B [11], Dedyu I I [12], Macintosh R P [18], Dansereau P M, Reimers N F [22 p 140–143], Smith R L [24], Lavrik G I [29 p
anthropogenic factors seeks to restore the ecological balance and stability

8 Principle of signatures (determining features) A signature is an ordered set of several features, characteristic for the system. At the management in integral architectural systems it is necessary to operate only the defining messages of the whole information input. The more complicated is the object and the higher is its hierarchical level, the more generalized the source information should be

9 Principle of energy conductivity The flow of energy, matter and information in a system as a whole should be comprehensive, embracing the whole system or implicitly resonating in it. Otherwise the system will not have the property of unity. For any system, including ecological systems of a certain hierarchical level, the duration of energy, matter and information flow would be specific. Life can exist only in the process of matter, energy and information flow through a living body. The cessation of the motion in this flow stops the life

10 First law of thermodynamics (energy conservation law, mass conservation law); kinetic energy conservation principle Any alterations in an isolated system keep its total energy constant; the sum of the system’s matter mass and the mass of equivalent energy, obtained or given by the system, is constant; or: at all macroscopic processes the energy is not created and does not disappear, it is just converted from one form to another. The sum of virtual (possible) actions of a system in an equilibrium state is equal to zero

11 Second law of thermodynamics; the principle of ecological pyramids of Lindenman R 1) the energy processes in systems can proceed spontaneously only on condition of the energy conversion from the concentrated form to the dissipated form; 2) energy losses in the form of heat unavailable for usage makes the hundred-percent conversion of one type of energy (kinetic) into another (potential), and vice versa, impossible; 3) entropy increase law: in a closed (thermally and mechanically isolated) system the entropy either remains the same, or increases and at equilibrium state it reaches its maximum. In general, using the energy flow, the system doesn’t lose its orderliness

12 Principle of energy conservation or optimality law, energy dissipation minimum law of Onsager L; law of system dilution in strange environment; «maximum simplicity» principle (or «adequate structure» principle), compactness principle General physical principle: at the probability of a process development in a certain set of directions, allowed by laws of thermodynamics, that one will be implemented which provides the lowest energy dissipation. The spatial form of an object, which would correspond to this function of an object to a greatest extent, is the most compact (at the given input values and normatives)
Table 1(d).

| Table 1(d). | Rosenberg A V [31] |
|-------------|-------------------|
| 12 Principle of constraining factor (Liebig's law of the minimum); principle of constraining (limiting) factors of Blackman F; factors action law of Tineman; natural factors collective action law (law of Mitscherlich – Tineman – Baule) | The most important for an organism is the factor, which deviates from its optimal value most of all. The limiting factor of an organism’s or species’ prosperity can be either the minimum or maximum of environmental impact, the range between which determines the value of resistance (tolerance) of an organism to this factor. The composition and structure of an ecosystem are determined by that environment factor which approaches its minimum Dedyu I I [12], Liebig J V, Shelford V E, Mitscherlich E, Tineman A, Baule B, Brodsky A K, Reimers N F [22 pp 55–56, 74–75; 158] etc. |
| 13 Principle of energy and information maximization; principle of power maximization | The best chances for self-preservation are possessed by a system, which to the fullest extent conduces to the input, production and efficient usage of energy and information; the highest input of matter as it is doesn’t guarantee success in a competing group of the similar systems. As a rule, systems with the highest energy displace the systems with the lower energy «power», though in some cases low-energy systems may have advantage due to lower impact on the environment and better correspondence to the similarly low energy potential of the environment Dedyu I I [12], Odum G and Odum Eu [20, 21], Watt K E F [27], Reimers N F [22 pp 55–56] etc. |
| 14 Principle of base exchange; specific productivity law | Any large dynamic system in its steady-state condition uses the input of energy, matter and information mostly for its self-maintenance and self-development. Such is the ratio between the basal metabolism and the work performed by an organism; such is the state in ecosystems and economy Dedyu I I [12], Odum Eu [20], Lindeman R, Reimers N F [22 pp 104], Watt K E F [27] etc. |
| 15 Principle of operative factor refraction within a system. Systemic-functional nonuniformity law | The factor, which influences the whole system, is refracted through the whole hierarchy of its supersystems and through the functional peculiarities of the system itself. The external effects on the system are usually not manifested directly, but are mediated by the mechanisms of the systems’ functioning. The rate of reactions and development phases of the system are naturally nonuniform – they can be accelerated (strengthened), or decelerated (weakened). The rhythm of such oscillations is usually multiple of three Dedyu I I [12], Rosenberg G S, Ruderman S U, Reimers N F [22 pp 60–61] etc. |
| 16 Principle of development vector; evolutionary irreversibility law of DolloL; law of system organization complication of Rouille C F; progress unlimitedness law; biogenetic law; geogenetic law | Universal development vector law: the development is unidirectional. The tendency of everything to the complication of organization and differentiation of functions and subsystems is global. The historical development of any ecological systems results in the complication of their organization by means of increasing differentiation of functions and subsystems, performing these functions. The development from simple to complicated is evolutionary unlimited Dedyu I I [12], Dollo L, Rouille C F, Muller F M, Haeckel E H, Rundquist D V Reimers N F [22 pp 50–51] etc. |
If the world of systems is functionally similar, which was stated by Ludvig von Bertalanffy [1], apart from the similar regulations of systems combination there must be the similar regularities of their development – both evolutionary and individual. Regularities, characteristic for ecological systems broadly defined, are grouped by Reimers N F [2] into 5 sets: systems combination, their internal development, thermodynamics, hierarchy and the system – environment relations.

Nowadays it is safe to say that, for example, the systems of populated areas have several hierarchical levels: primary (local), interdistrict, interregional etc. Singling out hierarchy levels and the boundaries of each of the levels is connected with the essential system properties of these objects. The correct solution of this task is a key for the quality of the system’s and its elements’ functioning.

5. The practical relevance
The purpose of the work consists in applying system methods to the objects of architectural activity, as well as the principles of interaction and interrelation of their separate elements. These results are of practical value, for both theoretical and design works, as well as for the educational process in architectural higher educational institutions. The action of system principles possesses the properties of reproducibility and repeatability, if desired by a researcher, is potentially formalizable, and the principles themselves are the basis for developing mathematical models of architectural systems.

6. Conclusions
1. The key aspect of research and designing of architectural objects is the understanding of them as not «technical» systems (material sphere of population’s life activity), but as ecological systems of «population ↔ environment» type – demoeosystems. Any integral architectural object (demeosystem) and its elements have a hierarchical structure, which allows singling out the levels of hierarchy (integrity) from the top to elementary ones. All the components (elements) of a demeoosystem have a property of integrity – unity of purpose.

2. Interrelations between the types of activity of whole objects (demeosystems) are invariant for all such objects, no matter how they differ in qualitative or quantitative definition of their elements or relations. In demoeosystems management it is necessary to operate only the defining messages of the whole information input (determining factors). The spatial form of an object, which would correspond to the function of the object to a greatest extent, is the most compact (at the given input values and normatives).

3. A number of general system principles of functioning and development of architectural systems (demeosystems) are of qualitative character of manifestation (for example, integrity principle, structure hierarchy principle, structure invariance principle), and the others are of metric (quantitative) nature (for example, signatures principle, compactness principle).

4. Solving research and design problems in architectural and city-planning activity requires using systemic approach and system methods. System regularities are the basis for developing mathematical, functional and informational cybernetic models of architectural systems.

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