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COMPREHENSIVE STUDY OF THE SYSTEMIC FORMATION «OBJECT–ENVIRONMENT» SAFETY STATE

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Abstract

The article deals with topical issues of ecological assessment of natural-technogenic study objects state, taking into account its interaction with the surrounding environmental systems and the necessary internal mechanisms to regulate these influences in order to maintain appropriate equilibrium and stationarity regarding the dynamics of such interactions. Attention is paid to research into environmental safety as a major component of human safety and the pledge of human health, in providing a sound solution to human health and environmental issues. The main tendencies in the formation of system objects view «natural-technogenic system–environment» are considered. Priorities have been given to create a comprehensive framework for the study of such systems. The benefits of the cooperative methodology for assessing the state «system–environment» are substantiated. It is suggested to use entropy function for estimation of state conformity and complex systems functionality with requirements of equilibrium «system–environment», usage of theoretical base of structural matrices for solving problems of complex systems (system objects) modelling for their state assessment and functional correspondences, software of implementation such assessment according to the methodological foundations of these approaches. The advantages of these methods in the study of complex objects from the standpoint of their versatility and the possibilities of using them in creating the necessary knowledge base and obtaining complex models of system objects and working with them to identify the evaluation characteristics of the state and development tendencies of interacting with the environment systems are shown.

The practical application results of the proposed solutions to the safety issues for the system objects «organism–environment» are given in the example of the relation between the brain work and the environment properties. The gradual estimation algorithm of target systems ecological state of and their interactions with environment by entropy function is presented, which allows to correlate states and processes.

Key words: system object, probabilistic entropy estimation, entropic state function, structural matrix, cognitive approach, complex estimation, equilibrium, research model.

Problem statement. System analysis by a comprehensive methodology covers the processes of spontaneous, natural manifestation of systems self-organization within the research object, the assessment of its state in achieving information-goal stability due to the implementation of causal relationships that arise between the sequence and nature of relevant changes management decisions state, information parameters, organization and efficiency of functioning of socio-economic, ecological-economic, socio-ecological systems.

On this basis, various matrices of managerial decisions are developed, which allow to choose the appropriate options for managing the systems in relation to the probable situation changes with the maximization of the cooperative structure informativity, that is, the possibility of realizing the systems interaction in the direction of obtaining the desired consequences – a positive variant, removing the system from the equilibrium – negative ones. The assessment of such changes and the states set realization is carried out by information-entropy system analysis according to the measure of R. Hartley [1].

The complexity quality assessment of complex systems is to establish the conformity of the structural organization to its stated goals and conditions of the required processes; the systematic approach of determining such an estimate makes the organization for the unconditional fulfilment of the research object. The research system in this case is a two-way interaction – the subject (object) and the measurement and calculation system, which is additionally basic / comparative (reference) information about the object. Compliance as a resultant assessment of a complex system state is established through identification, which is the process of comparing information about a subject or object with the provided identifier.

Thus, the task of finding a solution to uniquely comprehensive assessment of the research object of different nature as a result of information interaction between different parties and adequate reproduction of compliance with the requirements of the safety system.

The purpose of work is adequate to the real situation of determining systems state in their coexistence terms with the environment according to the safety requirements view «(environment–system)–process–(system state–environment)» in a situation of varying degrees uncertainty.

In accordance with the stated research goal, the article proposes to consider graphoanalytic solutions for modelling such system formations and proposals for their use:

1) to consider a complex system for the realization of self-organizing factors of its structuring in conditions

of variability of interaction with the environment, to determine the role of information and entropy as universal state characteristics of the research object and processes in it to maintain stationarity in the object on the example of «organism–environment» ;

2) to substantiate the expediency of using a cognitive approach for a comprehensive study of the object safety realization conditions view «system^0–process–system^1» on the example of interaction «organism–environment»;

3) to give an example of practical implementation of the graphoanalytic model «system–environment» in the form of nested graphical constructions on the cognitive analysis base.

Analysis of the recent researches and publications. For research where the object of study is a complex system taking into account human factor, classical imitation modelling methods developed and improved recently, such as statistical modelling (Mont-Carlo method, etc.), classical system dynamics (models of world dynamics and population, J. Forrester, Donnel and Dennis Meadows, VM Matrosov), system dynamics, including qualitative models (graphical diagrams of direct and inverse causal relationships and global effects of one parameter on the other in time), quantitative model (streaming – Resource-Based Viev, RBV, Discrete Event – Discrete event modelling, agent-based – agent simulation) and situational modelling (situational simulation) are not effective for the final state of the object in real conditions. It is acceptable to use cognitive analysis and situation management, cognitive modelling of complex systems [1].

Cognitive methodology for the study of complex systems is defined as the organization of cognitive activity, consisting of the definition of the purpose, object and research subject, the implementation of the model research meta-set, the application of the system of methods, ways, models, information technologies of cognitive modelling. To analyse the state and dynamics of complex systems on the basis of observations, expert, statistical and theoretical information in the process of simulation receive and use topographic and logical maps, cognitive maps for the provision of interacting objects and their environment [3–7].

Statement of the problem and its solution. The methodology for complex assessment of the ecologity dynamic state (i.e., taking into account thermodynamic flows) involves a macrosystem research level with the determination of the probabilistic macrostate of an integrating object and its components by entropy function.

The equilibrium functioning of all large systems components in accordance with the accepted postulate of the synergistic effect importance from interaction at the level of subsystems and elements of each of them as a whole is implemented in such a corporate formation microstate that corresponds to the maximum entropy. The functioning of a complex system in a certain external environment, its state and properties at each time are characterized by numerical of parameters set values

$$E = E(a_i, b_i, x_i, t), \qquad (1)$$

where a_i, b_i, x_i, t – respectively external and internal data parameter indicators, managed parameters and time.

Information counteracts the tendency of changes in the system to disorganization with increasing entropy, increasing the amount of information in the system helps to increase its organization, and thus contributes to the situation certainty, gaining knowledge about the object (fig. 1).

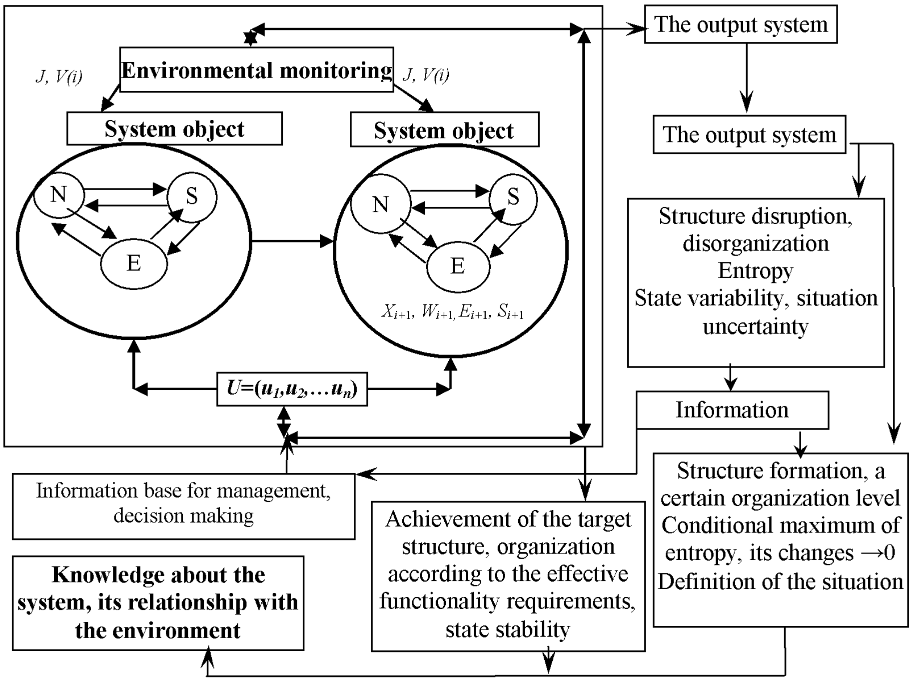

Figure 1 – The diagram of the relationship between entropy and information when evaluating complex objects «system–environment» state

The depicted macro-system is a complex of interconnected natural and social systems and technosphere – «technical shell», artificially transformed space, which is influenced by products of human production activities: X, W, E, S composition, structure, energy, biosystem entropy, organism and environment.

Thus, the close meaningful connection between entropy and information defines the former as not a sufficiency of information, but the second as a counteraction to entropy, that is, the violation of established order, the need to seek new knowledge about new systems and processes. These two measures of complex systems state are connected by negentropy – the movement to ordering, to the system organization. Any system, interacting with the environment to preserve its natural state counteracts the environmental chaos by importing negentropy [8]. Thus, the principle of self-organization of systems in search of stable state is realized through cooperation, compatible action of necessary factors, factors, processes, etc., which is a synergistic effect, the synergetics subject, causes synergistic system to emerge when combining individual components, maintaining the system dynamic state according to the effect of joint actions of each individual component in the form of their simple sum.

The combination of content elements for system analysis – entropy, information and synergy, is used to study the features of socio-economic systems management [9, 10–12]. It is advisable to use such a framework for the research and study of complex and poorly structured system formations functioning containing natural, social and economic / technogenic systems [13, 14]. It is proposed to provide such a researched system in the form of «monitoring object (system–environment)–state and functionality data = external influence processes, internal regulation–self-organization processes–steady object state, stationarity (system–environment)». The entropy approach for such a complex study is determined to be effective because it deals with one function of state and change, statics and dynamics, namely entropy. In studying the processes nature that return a disorganized system from chaos to an orderly structure, elements of synergetics are involved, that is, interaction cooperation factors of imbalance regulation, unregulatedness situations. The fixation of the necessary change direction is followed by the course of arbitrary processes and changes in the entropy level. Such a delineation in a comprehensive system analysis of a complex object of the entropy theory elements and synergetics determines the basis for entropy-information assessment of the system objects state [15].

Entropy-information quality assessment is considered as a universal analytical system for determining an object state of any nature and complexity. Such a comprehensive approach to the analysis of compliance with environmental / safety requirements is proposed to be applied when solving the problems of studying the state of weakly structured «object–environment» systems due to the stochastic dynamics, which corresponds to the uncertainty area regarding the parametric characteristics of such system.

Given the changes in the system in its interaction with the environment (systems in the object – the internal environment, with the environment – the external environment) there is uncertainty with its final state by N probable consequences (outputs) p_n, which is defined as the entropy of the form (R. In L. Hartley, 1928 [1, 16]):

$$S = \log_2 N . \qquad (2)$$

For independent random events X with N probable states described by probabilities $p_n \left(n = \overline{1,N}\right)$, set the average entropy that takes the following values:

– minimum for the case when the probability of one of the stands is equal to one;

– maximum with uniform distribution of the states' realization probability for $n = \overline{1,N},\ p_n = 1/N$;

– zero for other cases.

Thus, this average characteristic determines the level of knowledge about the state of the system and is defined as information entropy (KE Shannon, 1948 [17]):

$$S_x = -\sum_{n=1}^{N} p_n \cdot \log_2 p_n = -M\left[\log_2 p_n\right], \qquad (3)$$

where M [ ] is the mathematical expectation operator.

The entropy according to formula (3) is calculated on the interval at the calculation $\left[0, \log_2 N\right]$.

K-entropy (Kolmogorov-Sinai entropy or Krylov-Kolmogorov entropy) is used to characterize the degree of randomness at the output of dynamic systems.

$$s = \lim_{\substack{d(0)\to 0\\ t\to\infty}} \frac{\ln\left[d(t)/d(0)\right]}{t}, \qquad (4)$$

where $d(t)$ – distance between trajectories $x_1(t), x_2(t)$, that runs through the dots $x_1(0), x_2(0)$:

$$d(t) = x_1(t) - x_2(t);$$

$d(0)$ – the distance in phase space between points $x_1(0), x_2(0)$ in $t = 0$; t – time [18].

Uncertainty in the occurrence of destructive elements «system–environment» is resolved by the sequence (stage) of its elimination on the basis of systematic analysis of correspondences in decomposition systems for their analytical evaluation -–system, statistical state; factors of functionality and interaction; processes of interaction and adaptation, the equilibrium system state.

The coherence of the object and the environment, that is, the stationarity establishment of their relations, the adaptability to each other is identified by the increase of structural entropy level by thresholds, which causes information entropy as its integral component increases. Increasing the entropy to its maximum at the point of contradiction causes the transition to a probabilistic state, transforming the structural into an information entropy with zeroing of its local component and approaching the maximum of the integral.

Provided the creation of a purposeful system of a certain quality, they implement managed changes by the measures system of specialized management. External action against the backdrop of a natural environmental impact should help to achieve a compliance point, which is only guaranteed with minimal risk of decision making, without intervention, control of unauthorized adaptation and arbitrary processes; regulation and end control. In all three of these decisions, the system or object must reach an attractor – a structure (function) that sets (determines) the stable system state due to arbitrary processes, synergistic effects, nonlinear phenomena. In this way, the probable system state is realized, the probable purposeful action that will lead to the maximum ordering and self-organization of the object ($\Delta S \to 0, S_1 \to \min \to \Delta S > 0, S_2 \to \max$).

The Shannon information (3) is a statistical and probabilistic interpretation of the information amount for an object-environment system. The initial date about such an object state ξ are determined by the probability distribution $P\{\xi \equiv x_i\} \equiv p_i$. With only such a distribution of possible values $x_1, x_2,..., x_k$, that really reflect the real ξ, uncertainty situation arises. It is suggested to eliminate it through additional allocation for a random object η with consideration of the joint probability distribution $P\{\xi = x_i, \eta = y_j\} = p_{ij}$.

If complex objects are investigated, more reliable data (information about the natural object state) is more likely $\eta = y_j$ and establishing conditional distribution ξ : $P\{\xi = x_i \mid \eta = y_j\} = p_{i|j}$. In the study of complex systems of natural-technogenic nature, monitoring information is supplemented by a knowledge base (phenomenological approach), which allows to remove uncertainties at certain stages of systematic analysis and, if necessary, to establish risk factors for disturbing the «object–environment» state stability (fig. 2).

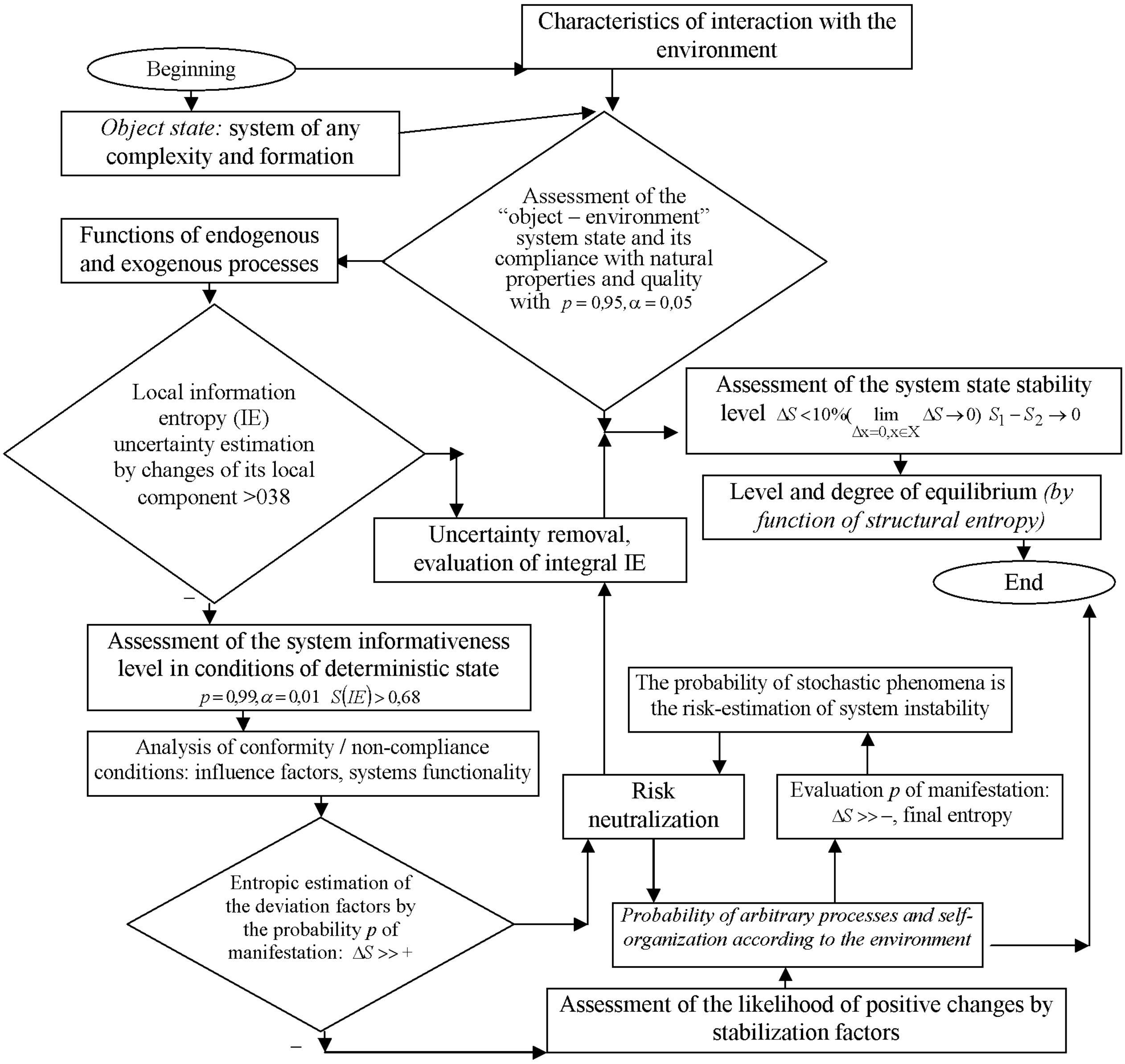

Figure 2 – Probabilistic-entropic estimation of the system state and factors of its stabilization

Knowledge in systems analysis is naturally linked to a cognitive approach that focuses on improving the object (complex system) rather than the subject. According to the model of meta-set of research in accordance with the tasks systematization in terms of fuzzy information, the solution is obtained in the following sequence of cognitive analysis [19, 20]:

– identification of the object and environment in the form of a cognitive model (expert, statistical and other identification methods);

– cognitive model analysis (graph theory methods);

– analysis of observations, controllability, stability, sensitivity, adaptability (control theory methods);

– decomposition - composition (general systems theory methods);

– connectivity analysis (graph theory methods, topological systems analysis - q-connectivity)

– scenario analysis (methods of scenario modelling, situational analysis, impulse modelling);

– decision making in uncertainty based on the study of a complex system (decision making theory methods for problems in probability uncertainty - methods of solving the optimal value of the face value in conflict, cooperation - game theory methods).

Cognitive models in the form of cognitive maps and impulse modelling (scenario analysis) are used to obtain information about the complex-structured system state. The correspondence of its stationarity, equilibrium in the «object–environment» system, the possibility of achieving the goal of control is established on the basis of methods, ways, models, information technologies of cognitive modelling (fig. 3) [2–7].

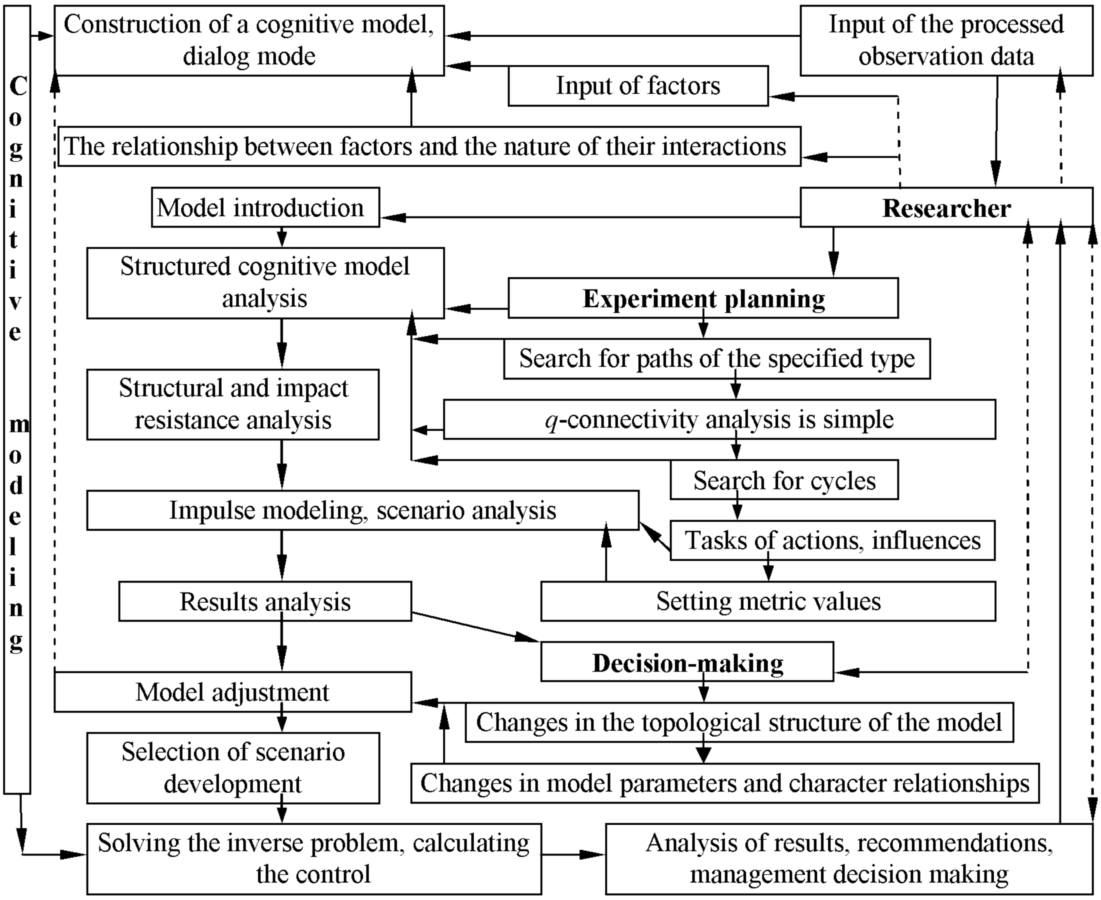

Figure 3 – Scheme of building a model of a complex system for the assessment of the object based on the cognitive model

The methodology of cognitive modelling used in the concept of complex entropy-information study of complex system objects involves the construction of a cognitive model of various shapes according to purpose, subject area of study, information base and represents in a generalized form a parametric vector functional graph:

$$\Phi_n = \langle G, X, F, \theta \rangle, \tag{5}$$

where Φ_n – parametric vector functional graph, $G = \langle V, E \rangle$ – cognitive map, a sign-oriented graph in which $V = |v_i|, i = 1,2,...k$ – multiple vertices (concepts, objects, subject areas of study)), $E = |e_{ij}|$ – the set of arcs that connect the vertices v_i *i* v_j; $X = |x_i|$ – the set of vertex parameters; $F = f(v_i, v_j, e_{ij})$ – function (functional $f(v_i, v_j, e_{ij})$, coefficient f_{ij}) connection between the vertices; θ – the space of the vertex parameters.

In order to take into account the forms of interaction of heterogeneous objects in one state space – cooperation, coalition or competition, a complex perception of the situation becomes necessary. In this case, the general model of the object as a complex system of research with view «system–internal and external environment» is a hierarchical cognitive model in which the R-rules of change in the structure of cognitive models, A-rules of interaction;

$$IGG_N = \{IG_{jk}, R, A\}, \; IG_k = \langle G_{jk}, G_{j(k+1)}, E_{jk} \rangle, \tag{6}$$

where $G_{jk}, G_{j(k+1)}$ – cognitive maps at levels $k, k \ge 2, E_k = \{e_{k,k+1}\}$ – multiple arcs between levels k, $e_{k,k+1}$ – the relationship between the vertices of different levels; $\{v_i^{(k)}\}$ – the set of vertices k-th level, $\{e_{ij}^{(k)}\}$ – arcs that determine the relationship between vertices of one level.

Spatial-temporal changes for complex systems are presented in the composition form of cognitive models and system dynamics models, which as a result is determined by a parametric vector functional graph of this form:

$$\varPhi_{\Pi} << V, E >, X, F, \theta >, \qquad (7)$$

where $G < V, E >$ – a sign-oriented graph in which V is a set of vertices, «concepts» $v_i \in V, i = 1,2,...,k$ – elements of the studied system; E – the set of arcs $e_{ij} \in E, i, j = 1,2,\ldots,n$ – interaction between vertices v_i, v_j; $X : Y \to \theta$, X – the set of vertex parameters,

$$X = \left\{ X^{(v_i)} \mid X^{(v_i)} \in X, i = 1,2,..., k \right\}$$

$X^{(v_i)} = \left\{ x_g \right\}, g = 1,2,\ldots,l$, where $x_g^{(i)}$ – g-th vertex parameter v_i; θ – the vertex parameters space; $F = F(X, E) = f\left(x_i, x_j, e_{ij}\right)$ – functional adjustment (transformation) of arcs, where f_{ij} – it is a functional dependence of the vertex parameters that is matched to each arc.

System dynamics model is a diagram of cause and effect in the form of a certain structure G_S and is displayed by a graph that reflects the relationship of model parameters. In the general cognitive map of the research object, this is a subgraph Φ_n.

Dependence f_{ij} is determined not only by functional changes but also by the stochastic influence, which is given in the simple version in the form of a weight factor w_{ij}. Blocks (subgraphs) are distinguished in the matrix of a functional graph – cognitive maps, such as «weighted graph» with relations w_{ij}, function block with function type arcs $f\left(x_i, x_j, e_{ij}\right)$:

	V_1	V_2	...	V_{j-1}	V_j	V_{j+1}	...	V_{k-1}	V_k
V_1	0	$+1$	...	-1	$w_{1,j}$	0	...	-1	0
V_2	0	0	...	$+1$	0	$w_{2,j=1}$	...	0	$w_{2,k}$
...	...	...	...	...	...	...	...	...	...
V_{i-1}	$+1$	$+1$	...	0	-1	0	...	$+1$	$w_{i-1,k}$
V_i	$f_{i,1}$	$f_{i,2}$	...	0	f_{ij}	$w_{i,j+1}$	...	0	$w_{i,k}$
V_{i+1}	$f_{i,1}$	$f_{i+1,2}$	...	$f_{i+1,j-1}$	0	0	...	0	0
...	...	...	...	...	...	...	...	...	...
V_{k-1}	$f_{k-1,1}$	$f_{k-1,2}$	...	0	$f_{k-1,j}$	$+1$	...	0	$+1$
V_k	$f_{k,1}$	0	...	$f_{k,i-1}$	$f_{k,j}$	0	...	0	0

The overall model is determined in two ways: top and bottom. The structure of the «top of the cognitive model» implies at the initial stage of determining the «starting» cognitive map G_0, which is further refined and added to a parametric functional graph (7) with reflection in it of qualitative factors (eg, natural environment) and quantitative (eg, population income, industrial production, pollutant emissions, etc.). In this case, the system dynamics model is determined by the structure of the link according to the technology changes in the form of a subgraph G_S. The form of the structure from «below» is the synthesis of individual blocks of the cognitive model into a common cognitive map.

In complex research of complex structured system objects of type «system–environment», «state–process» it is advisable to consistently alternate the ways of construction «from above»–«from below» with realization of graphs composition operation G_0 and G_S:

$$\varPhi_{\Pi} = G_0 \circ G_s \,. \qquad (8)$$

Thus, for the life support of organism systems interacting with the socio-ecological and economic environment [20–24] define a complex structure for the study «(environment–brain (system))–action (process)–system state–regulatory influence on other systems–processes internal order–the final system state». Analysis and assessment of self-organizing changes for the system object «system state–interactions (functionality restoration)–end state of the system» are conducted in accordance with the knowledge of processes realization of functional disorders stabilization in the brain system as a result of nerve cells destruction due to replacement by neighboring neurons that «have been re-educated», meaning their obligatory presence within the entire cluster of nerve cells.

The flow of the stabilization processes is arbitrary and their direction is related to the determination of the entropic function of the state and the processes «system–environment» according to the effect of stabilization (*) or structure disturbance (**) (see fig. 2):

$$S_{\max}^{\text{input, log-in}}\left(S_{\max}^{\text{load input}}\right) \to S_{\max}^{\text{system}} \xrightarrow{\text{process aboard}} S_{\min}^{\text{system}} \to S_{\min}^{\text{output}}\left(S_{\min}^{\text{systemfinalstate}}\right)^{*},$$

$$S_{\max}^{\text{input, log-in}}\left(S_{\max}^{\text{load input}}\right) \to S_{\max}^{\text{system}} \xrightarrow{\text{process aboard}} S_{\text{maximalvariety}}^{\text{system}} \to S_{\max}^{\text{output}}\left(S_{\text{maximumstress}}^{\text{systemfinalstate}}\right)^{**},$$

where $S_{\max}^{\text{input, log-in}}\left(S_{\max}^{\text{load input}}\right)$ – entropy estimation of logon under external influence (load on system elements – destabilization conditions – entropy maximum); $S_{\max}^{\text{system}} \xrightarrow{\text{process aboard}} S_{\min}^{\text{system}} / S_{\text{maximalvariety}}^{\text{system}}$ – influence transformation due to processes in the system with obtaining of state stabilization (minimum entropy achievement) $S_{\min}^{\text{output}}\left(S_{\min}^{\text{systemfinalstate}}\right)$ or the maximum variability of its realization under the condition of maximum entropy at the state of maximum voltage $S_{\max}^{\text{output}}\left(S_{\text{maximumstress}}^{\text{systemfinalstate}}\right)$.

Considering the description of the system interaction with the external environment (metamodel (8)), the processes in its stabilization synergy of initial state consider a number of interconnected impulse processes in the following form:

$$\Delta\bar{S}^{\text{input}}(k+1) = A\,\Delta\bar{S}^{\text{input}}(k) + D\,\Delta\bar{S}^{\text{output}}(k);$$

$$\Delta\bar{S}^{\text{output}}(k+1) = C\,\Delta\bar{S}^{\text{output}}(k) + R\,\Delta\bar{S}^{\text{input}}(k), \quad (9)$$

where $\Delta\bar{S}^{\text{input}}(k) = \bar{S}^{\text{input}}(k) - \bar{S}^{\text{input}}(k-1)$ and $\Delta\bar{S}^{\text{output}}(k) = \bar{S}^{\text{output}}(k) - \bar{S}^{\text{output}}(k-1)$ – first differences; A, B, D, C, R – adjacency weight matrices.

In the first equation (9), in the impulse process model, the increments in the system are not measured $\Delta\bar{S}^{\text{output}}(k)$ defined as limited perturbations to achieve compliance with the «environment–system». To control the model, a control vector is introduced as follows:

$$\Delta\bar{S}^{\text{input}}(k+1) = A\,\Delta\bar{S}^{\text{input}}(k) + B\Delta\bar{U}(k) + D\,\Delta\bar{S}^{\text{output}}(k), \quad (10)$$

where $\Delta\bar{U}(k) = -K\Delta\bar{S}^{\text{input}}(k)$ – control vector of state regulator reducing perturbation $\Delta\bar{S}^{\text{output}}(k)$.

In order to obtain comparable results, for each structure element of the analyzed system, relative entropy characteristics are determined, calculated as follows:

$$\delta\bar{S}^{\text{input}}(i) = \frac{\bar{S}^{\text{input}}(i+n) - \bar{S}^{\text{input}}(i)}{\bar{S}^{\text{input}}(i)} = \quad (11)$$

$$= a_{i,\,i+n},\ (i \pm n) = \overline{1,11},$$

which determines the corresponding information-entropic structure of the system state according to the data of figure 2 and the relation in formula (11) (fig. 4) [15, 25].

x_i	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
1	×	a_{12}							a_{19}	$a_{1\ 10}$	$a_{1\ 11}$
2	a_{21}	×	a_{23}						a_{29}	$a_{2\ 10}$	$a_{2\ 11}$
3	$-a_{31}$	a_{32}	×	a_{34}					a_{39}	$a_{3\ 10}$	$a_{3\ 11}$
4	a_{41}	a_{42}	a_{43}	×	a_{45}	a_{46}	a_{47}	a_{48}			
5	a_{51}	a_{52}	a_{35}	a_{54}	×	a_{5X_1}	a_{5X_1}	a_{5X_1}	a_{5X_2}	a_{5X_2}	$a_{5\mathrm{X}_2}$
6						×	a_{67}	a_{68}	a_{6X_2}	a_{6X_2}	a_{6X_2}
7						a_{76}	×	a_{78}	a_{7X_2}	a_{7X_2}	a_{7X_2}
8						a_{86}	a_{87}	×	a_{8X_2}	a_{8X_2}	a_{8X_2}
9						a_{9X_1}	a_{9X_1}	a_{9X_1}	×	$a_{10\ 9}$	$a_{9\ 11}$
10						a_{10X_1}	a_{10X_1}	a_{10X_1}	$a_{10\ 9}$	×	$a_{10\ 11}$
11						a_{11X_1}	a_{11X_1}	a_{11X_1}	$a_{11\ 9}$	$a_{11\ 10}$	×

Figure 4 – Information-entropy analysis «environment–environment systems–brain–regulation processes–systems state»

For example, to investigate the brain state of the type «environment–system», its model is presented as a system object in the form of a structural matrix (see fig. 3) in accordance with the methodological provision of a complex solution to the DM problems. The brain as a complex system is divided into distinct areas by functional responsibilities [25–24]. The complexity of the object involves the estimation of damage sites, a complex of neurons interactions within different zones between themselves by the structuring results of the external and internal environment of the brain (fig. 5). At Figure 5 the following descriptions are used: topological-cognitive graph view $X\{x_1, x_2, x_3, x_4, x_5\}$ – external inputs: gaseous, liquid, solid impurities, ionizing radiation, extreme factors; X_j – morpho-functional systems: $X_{j=1} = X^i\{x^6, x^7, x^8\}$ – regulatory – nervous, endocrine, immune systems; $X_{j=2} = X^i\{x^9, x^{10}, x^{11}\}$ – provision – respiratory, digestive, cardiovascular; $X_i^i\{x_6^6, x_7^7, x_8^8, x_9^9, x_{10}^{10}, x_{11}^{11}\}$ – core systems – neurons, hormones, immune cells and antibodies, O_2 and CO_2 in the blood, nutrients in the blood, nutrients and O_2 and CO_2 in tissues; $Y_n\{y_1, y_2, y_3, y_4\}$ – functions – regulation, exchange, digestion, circulation.

Thus, the self-preservation of the brain system in the surroundings of environmental systems and the environment is a reaction to changes external and internal due to the activity of components and their activation, that is, increasing disorder for energy release to stabilize the system.

A specific feature of biological systems is orderliness, since naturally the elements are incorporated into such systems according to self-organization into complexes due to systemic factors. Chronic illness, as a long-term destructive system state, has a certain effect on the interaction with the environment – organism adaptation to the formation of a stable pathological condition associated with the transition of the organism (in particular the brain) to a new functioning mode, partial stable normalization. Such a regime is achieved through the destabilization phases, which are determined by the course of slow-motion physiological processes (SMPP), which are considered as a complex of constant, stable potential, and slow physiological fluctuations of different durations. Continuous potential with an appropriate optimal range for different brain regions supports the functioning of normal systems (in particular the brain).

Pathological conditions are determined by the output of constant potential beyond the optimum range, develop in two directions – the brain goes into the excited state with the possible realization of a nervous breakdown; the inclusion of protective mechanisms and the onset of mental drowsiness. Persistent pathological systems states have the ability to spread and cause the whole object to global instability. Such states of imbalance with their memory matrix and the reactions that support them are determined by some adaptation to long-term disorders, degradation states.

Naturally, the dynamics of a system object with the inclusion of a processes-interactions system is determined by the results of multimethod local and general studies of local events, microzones and functionality in general systems and the object as a whole. Changes in the degree of complexity and randomness in the occurrence of pathology and altered brain states causes a clear decrease in the complexity and chaotic organism rhythms. Thus created chaos in the body according to the dynamics of the processes contributes to increasing the systems randomness, which allows them to work in a wide conditions range with adaptation to changes in the environment and support functionality.

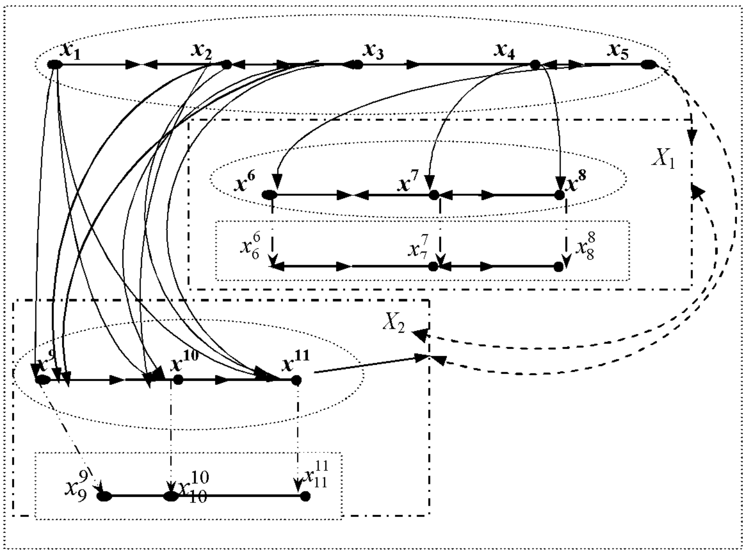

Figure 5 – System structural and graphical analysis of an object view
«external environment–environment systems–brain–processes of internal order regulation–systems state»:
→ permanent connection; – –→ random connection

For technically complex systems, such problems are more deterministic and are solved by multicriteria optimization based on computational experiments to obtain Pareto-optimal solutions with a compromise final conclusion [26].

The practical implementation of the proposed approaches in solving the problems of complex systems environmental assessment related to human health, is provided in a joint research collaboration with the National Medical University. The application of the proposed cognitive models contributed to the development of sanitary and hygienic direction in the assessment of technogenically loaded territories ecological state in the form of a corporate system of research on complex ecological assessment of the systems state (CES) based on the information and software applications development (implementation acts of the work results 2011, 2017) [27, 28].

Conclusions

Assessment of the state of systemic formation is carried out by grouping methods of modelling objects view «system–environment», their complex application in the study of such system objects. To solve the problem of quality assessment, a probabilistic entropy basis was proposed, with a complex state reflection of the investigated systems through the evaluation «input information–internal data processing–the regulation result of interaction with the environment», which allowed:

1) to give the sequence of self-organizing factors action and structuring in the variability conditions of interaction with the environment of the investigated systems, to determine the role of information and entropy as universal characteristics of the object state of research and processes in it to maintain stationarity in the object on the modelling example «organism–environment» (see figs. 1, 2);

2) determine the advantage of using a cognitive approach to comprehensively study the realization conditions of the object safety type «system^0–process–system^1» with the use of structural matrices and cognitive maps on the example of providing information on the interaction of «organism–environment» (see fig. 3, 4);

3) to provide a graphoanalytic model «system - environment» in the form of embedded graphical constructions based on cognitive state analysis «brain–effects on environmental systems» (see fig. 5).

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ВСЕБІЧНЕ ДОСЛІДЖЕННЯ СИСТЕМНОГО ФОРМУВАННЯ СТАНУ БЕЗПЕКИ «ОБ’ЄКТ-СЕРЕДОВИЩЕ»

Стаття присвячена актуальним питанням екологічної оцінки стану природно-техногенних об’єктів дослідження з урахуванням його взаємодії з оточуючими системами навколишнього середовища і необхідних внутрішніх механізмів урегулювання цих впливів для підтримки відповідної рівноваги і стаціонарності щодо динаміки таких взаємодій. Увага приділена дослідженням в галузі екологічної безпеки як головної складової безпеки людини і запоруки його здоров’ю, забезпеченню зваженого рішення щодо завдань охорони здоров’я людини та його навколишнього середовища. Розглянуті основні тенденції у становленні системних об’єктів виду «природно-техногенна система–навколишнє середовище». Надані пріоритети у створенні комплексних основ дослідження таких систем. Обгрунтовані переваги кооперативної методології з оцінки стану «система–навколишнє середовище». Запропоновано використання ентропійної функції для оцінки відповідності стану й функціональності складних систем вимогам рівноваги «система–навколишнє середовище», використання теоретичної бази структурних матриць щодо розв’язання задач моделювання складних систем (системних об’єктів) для оцінки їх стану і функціональних відповідностей, програмного забезпечення реалізації такої оцінки відповідно методичних засад названих підходів. Показані переваги зазначених методів при дослідженні складних об’єктів с позицій їх універсальності та можливостей використання при створенні необхідної бази знань і отримання комплексних моделей системних об’єктів та роботи з ними щодо виявлення оціночних характеристик стану і тенденцій розвитку взаємодіючих з навколишнім середовищем систем.

Надано результати практичного застосування запропонованих пропозицій вирішення питань безпеки саме для системних об’єктів «організм–навколишнє середовище» на прикладі співвідношення роботи мозку і властивостей навколишнього середовища. Наведено алгоритм поступового оцінювання екологічності стану цільових систем і їх взаємодій з довкіллям за ентропійною функцією, що дозволяє співвідносити стани і процеси.

Ключові слова: системний об’єкт, імовірнісно-ентропійна оцінка, ентропійна функція стану, структурна матриця, когнітивний підхід, комплексна оцінка, рівновага, модель дослідження.

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