# DETERMINING THE OBJECT STRUCTURE OF ECOLOGICAL AND ECONOMIC RESEARCH AND KNOWLEDGE BASE FOR DECISION SUPPORT

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The mathematical model of natural-technogenic objects is substantiated in the article. Natural-technogenic object of research is defined in form of a system model, which includes the economic, ecological and social components and processes system occurring in the selected systems and in their interaction. Basis for introduction systematic analysis methods for consistent problematic environmental safety tasks solution under conditions of uncertainty has been formed. The complex methods system includes entropy theory provisions on the objects state evaluation, the comparator identification method, substantively substantiated for solving complex environment quality assessment problems. An example of ecological state technogenically loaded landscape-geochemical complexes on the proposed methodological support studied in the work.

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## 1. INTRODUCTION

Currently, research is increasingly faced with a complex object structures, which are responsible for specific solvable problem tasks, take effective management decisions with a view to harmonize the interaction of "nature-society" [1].

Relevant developments in this respect is to determine the object structure of study that reflects the economic, social and environmental (natural aspect) problems in modern conditions of innovative development of scientific and technical progress.

In the field of system analysis mostly pay attention to the dimension of the system, hence the complexity of the structure is considered as the formation of links between elements of definite complexity (complex, large, extra large, global), taking the research object in the field of interaction between "man $\leftrightarrow$ object $\leftrightarrow$ environment" [2]. However, the management of complex systems is faced with objects, in which faced interests of socio-economic, ecological, economic and socio-ecological systems operating in the field of objectives harmonization to maximize the effectiveness of their development. One of rational approaches in the study of complex objects study is a reference to the objective laws of self-organization, self-support of natural systems qualities [3].

The management as the definition of problem solving to achieve specific ecological and socio-economic objectives with attaining specific maximum effect, without prejudice to other subordinate the interests of scientific and technological development is considered this approach. From these positions in work is proposed system research object structure and offered methodological provisions for knowledge expansion in study sustainable development [4].

## 2. THE STUDY GOAL AND TASKS

Methodological foundations development for a comprehensive approach to the management of complex organizational objects provides establishment of priority and weighty factors regulating state and process for models form "System + System = object − environment", "system − process − system", "system-process − environment". Thus, the aim of this work was to determine the structure of a complex object of research questions of ecological and economic regulation of environmental quality of natural and man-made contents and the definition of the mathematical model of management decision [2, 3, 4]. Consistent achievement of performance goals related to the solution of such problems:

1) substation of mathematical model of natural and technogenic nature objects by study sustainable development questions of the regions (areas) with regard to their status and processes in them, defining them stabilizing effect for the homeostatic systems;

2) laying the foundations for introduction of identification comparator method for the purpose of regulation factors of sustainable development of diverse nature and functionality of the system object of the study;

3) realization of the proposed method of state estimation system object on the example of solving the problem of environmental management for natural and man-made territorial complex.

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## 3. SCIENTIFIC RESULTS

Natural and man-made object of study is defined as a system model, providing the mandatory allocation of economic, environmental and social aspects in the tasks system analysis and accounting processes of interaction in the object and the environment. For this is supposed to establish the characteristics of the transition from the system for determining the course of the processes based on the use of the theory of entropy and synergy negentropy.

Homeostasis of system object internal environment balance "system – environment", tense degree of situation at destabilization in the fixed communications between systems in object and elements of systems, processes changes proposed to characterize by entropy function $S$.

Problematic aim of heterogeneous aspect study is divided into stage components, involving following identification: – definition of analysis object in form "structure – functionality – violations – processes probability – processes development (not controlled release of spontaneous changes that lead to self-organizing structures) – stabilization and corresponds to natural functionality of the system"; – identify tangible stabilizing process according to results of conformity assessment according to $\Delta S \to 0$.

Stabilization and harmonization are achieved in establishing balance in adopted for the consideration system formation that achieved due to strict compliance with self-determination requirements to its natural functionality or to harmonization "object of influence – process – object changes – process – new level organization object". Preservation of stability and adaption to environment under the provisions of synergy characterized as a measure of order and conformity, which defines entropy evaluation function. Thus, it becomes possible through the function to set change conditions in the system and passage processes which are essential stabilizing, supporting absence of disturbances state in systems and object generally $\Delta S \to 0$ (Fig.1)

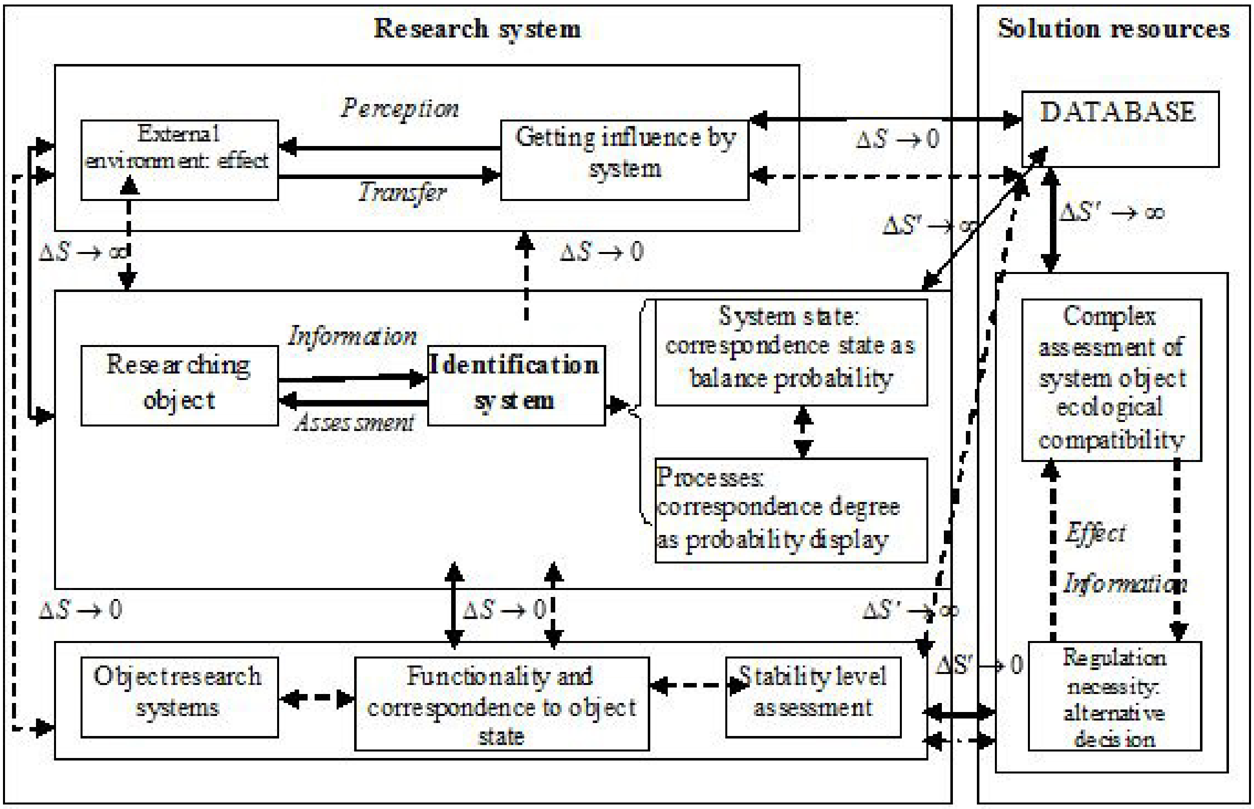


***Fig.1.*** *Imitation model material information support assessment of system object ecological compatibility: $\Delta S$, $\Delta S' \to 0$ – balance state with correspondence of target cooperation "system-environment" in term of difference between influence result and stabilization object state ($\Delta S$) and difference between result and correspondence requirement ($\Delta S'$); $\Delta S$, $\Delta S' \to \infty$ – stationary state of infinite system progress in term of target balance correspondence*

The fundamental feature of the virtual solid environment is up to maximum entropy principle [5]: $S^*_\rho = max(S_\rho)$, i.e. entropy of the system retains its value, which is true for stationary regimes of chaotic dynamics. Entropic expression convert with glance maximum principle defines fundamental property:

$$\int_\Omega \rho d\Omega = 1, \qquad (1)$$

i.e. in a virtual solid environment that satisfies maximum entropy principle, take into account all the possible states of the system and no uncertainties, except those present in the system, no.

The phase space type $\Omega = \Omega_q \times \Omega_p$ characterized by entropy measure:

$$S_\rho = S_q \times S_p, \quad (2)$$

where $S_q$ – structure entropy, $S_p$ – entropy impulse (random vector has its own entropy).

Entropic content duality defines two important entropy properties:

1) physical properties invariance of virtual continuum, not a physical characteristic;

2) geometric interpretation of functionally important object systems in space and their geometry relations reflection.

For a comprehensive assessment of the territorial object systems comparator identification is more objective and reliable than expert evaluation in points: it gives a quantitative value in two settings – 0 and 1. This allows you to connect by parameter $\Delta S$ changes in system state, and object and probability $P$ communications blackout with environment [4], [6], [7].

Under the terms of comparator identification method [6]: Comparator – compliance measure with the structure, system functionality of internal homeostasis integral object, which provided by a tuple $X^s$ and $X^t$ input influence $X$ type:

$$\begin{aligned} F(A, X^{(s)}) &= F(A, X^{(t)}), \\ F(A, X^{(s)}) &< (\leq) F(A, F^{(t)}), \\ s, t &= \overline{1,k}, s \neq t. \end{aligned} \quad (3)$$

Provided tuples are thermodynamic flow components, which defined as a certain relationship – the relation $R$ between system components and the object respectively to model parameter $A$ and operator $F$ (structure) (1) that implement internal system homeostasis. If uniqueness system characteristics through ecological compatibility assessment parameters provided by operator view $F$ and model parameters $A$, for which the non-compliance of safety requirement (non-equivalence situation) leads to the inequality (3).

According to analysis results of individual system characteristics for specific state conditions an integral object established probability estimate of sales structure and its compliance with the requirements of environmental safety provided in the form of $P : X \to V$, where $P$ – evaluate model operator, and $V = P(X)$ – multiple-factor assessment model for alternative solution $v_i = P(x_i), i = \overline{1,n}$.

The idea of such approach to system state assessment and safety level involves using measurement risk procedures, which in case of relevant implementation realize a predicate type.

$$D_1(v_q, v_n) = \begin{cases} 1, \text{ for } v_q = v_n, \\ 0, \text{ for } v_q \neq v_n. \end{cases}$$
$$E_1(x_q, x_n) = D_1[P(x_q), P(x_n)], \forall x_q, x_n \in X, \quad (4)$$

where $v_q$, $v_n$ – usefulness assessment of used and natural state, as $v_q = P(x_q)$, $v_n = P(x_n)$ taking into account the costs on environmental system maintaining.

Ecological compatibility or usefulness of this system state is determined by immutability entropy function evaluation and $\Delta S \to 0$, negative evaluation is an increasing the probability processes passing of system destabilization $S_q > S_r, \Delta S > 0$ and occurrence of triggering effect on them in internal object environment $P(x_q) > P(x_r)$.

Task of choosing system development solution by comparator assessment is considered in two aspects respectively to completeness of coming out information and getting results implementing the predicate form:

- confident choices and a unique solution based on analysis (4):

$$D_3(v_q, v_r) = \begin{cases} 1, \text{ for } v_q > v_r, \\ 0, \text{ for } v_q < v_r \,; \end{cases} \quad (5)$$

- fully confident decisions for lack of information about object state, decided internal and external communications – fuzzy output data about system properties, nature and probability of processes passing, etc:

$$D_4(v_q, v_r) = \begin{cases} 1, \text{ for } v_q \geq v_r, \\ 0, \text{ for } v_q < v_r. \end{cases}$$
$$E_4(x_q, x_r) = D_4[P(x_q), P(x_r)], \quad \forall x_q, x_r \in X, q \neq r\,. \quad (6)$$

System state is determined by reaching maximum entropy function value $S_{max}$ and the absence of destabilizing events $\Delta S \to 0$ provide the operator with a detailed drawing attention to priority conservation stability of natural ecosystems $x_1$.

$$\begin{aligned} P(x_s) > (\geq) P(x_1), x_s, x_i \in X, s = \overline{2,n}, s \neq 1, \\ P(x_2) < (\leq) P(x_1), P(x_3) < (\leq) P(x_1)\,. \end{aligned} \quad (7)$$

For the harmonization of probabilistic-entropic environmental indicators and comparator identification (1)-(7) general model $M$ evaluation is provided:

$$V_M(x_i) = P_M(A_M, K(x_i)), i = \overline{1,n}, \quad (8)$$

where $V_M(x_i)$ – generalized utility evaluation of alternatives by ecological quality system assessment, choosing their structure, decision making; $P_M$ – model assessment operator – structure identification as realization certain economic, social and ecological constituent and its link; $K(x_i)$ – $m$-dimensional quantitavely-dimensioned income effect (characteristic of state, structure, alternative); $A_m$ – $r$-dimensional vector of quantitative model object characteristics – parametric identification (state systems, flows that implement the connection between systems (e.g., power and intensity of material flow with socioeconomic system on ecosystem, and so on).

Realization of comprehensive quality assessment methods natural environment surrounding (NAS) considered on example studying ecological state of technogenic loaded landscape-geochemical systems using the proposed programs implementing analytical complex environmental system objects investigation based on monitoring information (Fig.2).

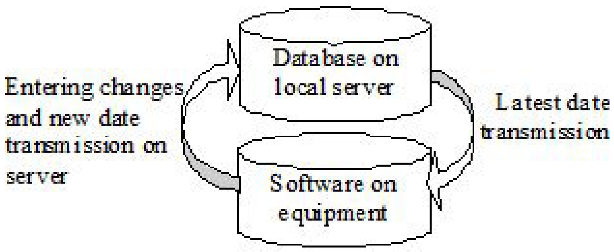


***Fig.2.*** *Software principle work*

The practical method realization of such complex quality NES assessment reviewed on example of researching correspond to ecological landscape-geochemical complex state of Zmiev district territory, which are under the influence of industry and energy complex, respectively, and NES heavy metals (HM) pollution [8, 9].

By comparator identification (ratio (3)-(8)) geochemical subspace is defined $A_1, A_2...A_m$ ($m$ - scale), for which $(x_1, x_2...x_m)$ composed from influence factors with view $x_1 \in A_1, x_2 \in A_2$, which have object space with cationic and anionic forms of HM $A_1 = A_2 = ... = A_m = U$:

$$U = \{Zn, Co, Ni, Pb, Sr, Cu, Mo, Cr, V\}. \qquad (9)$$

To describe transformation in migration flow of heavy metals (HM) state viewed in bipartite graph. For analysis final impact factor state by HM on consistent environment (including human) take into account the reduction in mobility due to spontaneous formation processes them insoluble compounds accumulation in soil and lack of biomaterial, which specifies a set of options classes. To assess the safety of receipt HM is NES objects occurred the necessity of relation characteristics: $\{x_1, x_2\}$ $m = 2$, $A_1 = \{Zn, Co, Ni, Pb, Sr, Cu\}$, $A_2 = \{Mo, Cr, V\}$, then $S = A_1 \times A_2$ is a set pair view $(x_1, x_2)$, for which ratio generated by entropic state value, i.e. analysis change process and self-organized abilities system ground in general. Relationships that are part of a space, the same type sold operations: union – disjunction $\vee\cup$ – or; section – a conjunction $\wedge\cap$- and. For analyzing heavy elements state made for probability deviation values from normative fixed limit in small risk bounds – 20%, this ratio:

$$P(x_1 - x_n) = \begin{cases} 1, \text{ if } x \le 0.2\,, \\ 0, \text{ if } x \ge 0.2\,. \end{cases} \qquad (10)$$

Thus, the phenomenological knowledge about HM behavior in NES objects justified entropy evaluation of their status and comparator identification subjected to "state – process". This allows set the risk factor, possibility of leveling its negative impact due to the transformation processes in migratory flows in presence of other negative factors components.

## 4. CONCLUSIONS

As a result of theoretical and practical research in system analysis field complex objects for solving quality management problems in accordance with modern sustainable development requirements is received following data:

1) the basis for mathematical model of natural and technogenic nature objects in study of sustainable regions (areas) development with regard to their status and processes in them is the provision of self-organizing systems and entropy changes, reflecting the stability of system functioning processes and stationary (see Fig.1, formulae (1), (2));

2) identify regulating sustainable development factors of diverse nature and system object study functionality is carried out on the proposed comparator identification algorithm for system violations (equations (3)-(8));

3) assessment of the system object in solving problem of environmental management for natural and man-made territorial complex carried out based on the model entropy-comparator identification ecological compatibility (see Fig.2, the relationship (9), (10)).

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## ОПРЕДЕЛЕНИЕ СТРУКТУРЫ ОБЪЕКТА ЭКОЛОГО-ЭКОНОМИЧЕСКИХ ИССЛЕДОВАНИЙ И БАЗЫ ЗНАНИЙ ДЛЯ ПОДДЕРЖКИ РЕШЕНИЙ

***Т. В. Козуля, М. М. Козуля***

Обоснована математическая модель объектов природно-техногенной природы. Природно-техногенный объект исследования определяется в виде системной модели, включающей экономическую, экологическую и социальную составляющие и систему процессов, происходящих в выделенных системах и при их взаимодействии. Сформированы основы для внедрения системных методов анализа для последовательного решения проблемных задач экологической безопасности в условиях неопределенности. Комплексная система методов включает: положения теории энтропии по оценке состояния объектов, метод компараторной идентификации, содержательно обоснованный для решения задач комплексного оценивания качества окружающей природной среды. Приведен пример исследования экологического состояния техногенно-нагруженных ландшафтно-геохимических комплексов на основе предложенного методического обеспечения.

## ВИЗНАЧЕННЯ СТРУКТУРИ ОБ'ЄКТА ЕКОЛОГО-ЕКОНОМІЧНИХ ДОСЛІДЖЕНЬ ТА БАЗИ ЗНАНЬ ДЛЯ ПІДТРИМКИ РІШЕНЬ

***Т. В. Козуля, М. М. Козуля***

Обґрунтована математична модель об'єктів природно-техногенної природи. Природно-техногенний об'єкт дослідження визначається у вигляді системної моделі, яка включає економічну, екологічну та соціальну складові та систему процесів, що відбуваються у виділених системах та при їх взаємодії. Сформовані основи для впровадження системних методів аналізу для послідовного розв'язання проблемних задач екологічної безпеки в умовах невизначеності. Комплексна система методів включає: положення теорії ентропії з оцінки стану об'єктів, метод компараторної ідентифікації, змістовно обґрунтований для розв'язання задач комплексного оцінювання якості навколишнього природного середовища. Надано приклад дослідження екологічного стану техногенно-навантажених ландшафтно-геохімічних комплексів на основі запропонованого методичного забезпечення.