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МАЗМҰНЫ

ӘЛЕУМЕТТІК-ЭКОНОМИКАЛЫҚ ЖҮЙЕЛЕРДІ ДАМЫТУДАҒЫ ЦИФРЛЫҚ ТЕХНОЛОГИЯЛАР

АҚПАРАТТЫҚ ТЕХНОЛОГИЯЛАР

СОДЕРЖАНИЕ

ЦИФРОВЫЕ ТЕХНОЛОГИИ В РАЗВИТИИ СОЦИО-ЭКОНОМИЧЕСКИХ СИСТЕМ

ИНФОРМАЦИОННЫЕ ТЕХНОЛОГИИ

CONTENTS

DIGITAL TECHNOLOGIES IN THE DEVELOPMENT OF SOCIO-ECONOMIC SYSTEMS

INFORMATION TECHNOLOGY

INTERNATIONAL JOURNAL OF INFORMATION AND COMMUNICATION TECHNOLOGIES
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THE PROBLEM OF EMERGENCE IN THE MANAGEMENT OF COMPLEX SYSTEMS

***D. Lukianov* [1]**, O. Kolesnikov* [2] *T. Olekh*[3]**
[1]GIGACloud, Kyiv, Ukraine;
[2]PM Solution, Almaty, Kazakhstan;
[3]Odesa Polytechnic National University, Odessa, Ukraine.
E-mail: akoles78@gmail.com

Dmytro Lukianov — Doctor of Sciences, Associate professor, GIGACloud, CIO, Kyiv, Ukraine
E-mail: dlukiano@gmail.com, https://orcid.org/0000-0001-8305-2217;
Oleksii Kolesnikkov — Doctor of Sciences, Associate professor, PM Solution, Project manager, Almaty, Kazakhstan
E-mail: akoles78@gmail.com, https://orcid.org/0000-0003-2366-1920;
Tetiana Olekh — PhD, Associate professor, Odesa Polytechnic National University, Odessa, Ukraine
E-mail: olekhta@gmail.com, https://orcid.org/0000-0002-9187-1885.

Abstract. The research delves into the intricacies of emergence within managing complex systems. It provides a comprehensive examination of how new properties that are not inherent in their components manifest at the system level. This phenomenon, known as emergence, holds significant implications for project management, particularly in assessing risks and interrelations among various factors. The study explores the foundational techniques that L. Bertalanffy and A. Hall proposed for analyzing system integrity, emphasizing their application in social and technical systems. These methodologies underscore the importance of understanding the dynamic interplay between system components and the system as a whole. Particular emphasis is placed on identifying systemic objectives and patterns, such as equifinality — the principle that different initial conditions can lead to the same final state — and progressive factorization, which involves breaking down complex systems into more straightforward, manageable parts. By focusing on these aspects, the research highlights the importance of a holistic approach to system management, where the interaction between parts leads to emergent properties that cannot be predicted by analyzing the parts in isolation. The findings of this research furnish novel theoretical and practical approaches for the effective management of complex systems and projects. By considering facets like interaction, coordination, and management efficacy, the study offers valuable insights for improving project outcomes. These approaches are particularly relevant for project managers and system analysts who must navigate the complexities of modern, multifaceted systems, ensuring that emergent properties are identified, understood, and effectively managed to achieve desired outcomes.

Keywords: emergence, management of complex systems, system integrity, information models, equifinality, progressive factorization, project management

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КҮРДЕЛІ ЖҮЙЕЛЕРДІ БАСҚАРУДАҒЫ ПАЙДА БОЛУ МӘСЕЛЕСІ

Д. Лукьянов*[1], *А. Колесников*[2], *Т. Олех*[3]***

[1]GIGACloud, Киев, Украина;
[2]PM Solution, Алматы, Казахстан;
[3]Одеса Политехникалық Ұлттық Университеті, Одесса, Украина.
E-mail: akoles78@gmail.com

Лукьянов Дмитрий Владимирович — доктор технических наук, доцент, GIGACloud, CIO, Киев, Украина
E-mail: dlukiano@gmail.com, https://orcid.org/0000-0001-8305-2217;
Колесников Алексей Евгеньевич — доктор технических наук, доцент, PM Solution, проектный менеджер, Алматы, Казахстан
E-mail: akoles78@gmail.com, https://orcid.org/0000-0003-2366-1920;
Олех Татьяна Мефодиевна — кандидат технических наук, доцент, Национальный университет «Одесская Политехника», Одесса, Украина
E-mail: olekhta@gmail.com, https://orcid.org/0000-0002-9187-1885.

Аннотация. Зерттеу күрделі жүйелерді басқарудың қыр-сырын тереңдетеді. Зерттеу жүйелік деңгейде олардың компоненттеріне тән емес жаңа қасиеттердің қалай көрінетінін қарастырады. Пайда болу деп аталатын бұл құбылыс жобаны басқару процестеріне әсер етеді, әсіресе жобаның әртүрлі факторлары арасындағы тәуекелдер мен қатынастарды бағалау кезінде. Зерттеу л.Берталанфи мен А. Холл жүйелердің тұтастығын талдау үшін ұсынған негізгі әдістерді қарастырады. Оларды әлеуметтік және техникалық жүйелерде қолдануға ерекше назар аударылады. Бұл құралдар жүйенің компоненттері мен жалпы жүйе арасындағы динамикалық өзара әрекеттесуді түсінудің маңыздылығын көрсетеді. Эквиваленттілік және прогрессивті факторизация сияқты жүйелік мақсаттар мен заңдылықтарды анықтауға ерекше назар аударылады. Осы аспектілерге назар аудара отырып, зерттеу жүйені басқарудың біртұтас тәсілінің маңыздылығын атап көрсетеді, онда бөліктер арасындағы өзара әрекеттесу бөліктерді жеке талдау арқылы болжау мүмкін емес жаңа қасиеттерге әкеледі. Зерттеу нәтижелері күрделі жүйелер мен жобаларды тиімді басқарудың жаңа теориялық және практикалық тәсілдерін ұсынады. Өзара әрекеттесу, үйлестіру және басқару тиімділігі сияқты аспектілерді қарастыра отырып, зерттеу жобаларды іске асыру сапасын жақсарту үшін қолдануға болатын құралдар мен әдістерді ұсынады. Бұл тәсілдер, әсіресе, қажетті нәтижелерге қол жеткізу үшін пайда болатын қасиеттерді анықтауды, түсінуді және тиімді басқаруды қамтамасыз ете отырып, заманауи көп қырлы жүйелердің күрделілігін басшылыққа алуға тура келетін жоба менеджерлері мен жүйелік талдаушыларға қатысты.

Түйін сөздер: пайда болу, күрделі жүйелерді басқару, жүйенің тұтастығы, ақпараттық модельдер, эквиваленттілік, прогрессивті факторизация, жобаларды басқару

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ПРОБЛЕМА ЭМЕРДЖЕНТНОСТИ В УПРАВЛЕНИИ СЛОЖНЫМИ СИСТЕМАМИ

***Д. Лукьянов*[1]**, *А. Колесников*[2], *Т. Олех*[3]**
[1]GIGACloud, Киев, Украина;
[2]PM Solution, Алматы, Казахстан;
[3]Одесский политехнический национальный университет, Одесса, Украина.
E-mail: akoles78@gmail.com

Лукьянов Дмитрий Владимирович — доктор технических наук, доцент, GIGACloud, CIO, Киев, Украина
E-mail: dlukiano@gmail.com, https://orcid.org/0000-0001-8305-2217;
Колесников Алексей Евгеньевич — доктор технических наук, доцент, PM Solution, проектный менеджер, Алматы, Казахстан
E-mail: akoles78@gmail.com, https://orcid.org/0000-0003-2366-1920;
Олех Татьяна Мефодиевна — кандидат технических наук, доцент, Национальный университет «Одесская Политехника», Одесса, Украина
E-mail: olekhta@gmail.com, https://orcid.org/0000-0002-9187-1885.

Аннотация. Исследование углубляется в тонкости управления сложными системами. В исследовании рассматривается, как на системном уровне проявляются новые свойства, не присущие их компонентам. Это явление, известное как эмерджентность, имеет влияние на процессы управления проектами, особенно при оценке рисков и взаимосвязей между различными факторами проекта. В исследовании рассматриваются основополагающие методы, предложенные Л. Берталанфи и А. Холлом, для анализа целостности систем. Особое внимание уделяется их применению в социальных и технических системах. Эти инструменты подчеркивают важность понимания динамического взаимодействия между компонентами системы и системой в целом. Особое внимание уделяется выявлению системных целей и закономерностей, таких как эквифинальность и прогрессивная факторизация. Сосредоточив внимание на этих аспектах, исследование подчеркивает важность целостного подхода к управлению системой, при котором взаимодействие между частями приводит к появлению новых свойств, которые невозможно предсказать путем анализа частей по отдельности. Результаты исследования предлагают новые теоретические и практические подходы к эффективному управлению сложными системами и проектами. Рассматривая такие аспекты, как взаимодействие, координация и эффективность управления, исследование предлагает инструменты и методы, которые можно использовать для улучшения качества реализации проектов. Эти подходы особенно актуальны для менеджеров проектов и системных аналитиков, которым приходится ориентироваться в сложностях современных многогранных систем, обеспечивая выявление, понимание и эффективное управление возникающими свойствами для достижения желаемых результатов.

Ключевые слова: эмерджентность, управление сложными системами, целостность системы, информационные модели, эквифинальность, прогрессивная факторизация, управление проектами

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Introduction

Complex systems are characterized by many interacting components, which may be physical, biological, or social. For example, a microservice architecture is a complex system where each service performs a specific function, but together, they form a single (holistic) functioning environment.

System integrity (connectedness, unity of the whole) is inextricably linked with emergence (unexpected emergence, appearance of a new one).

Two key concepts in the study of complex systems are emergence and self-organization. Emergence refers to the emergence of new properties or behaviors of a system that cannot be explained in terms of its constituent parts alone. This means that the properties of the whole are not a simple sum of the properties of its constituent elements, although they depend on them. On the other hand, elements combined into a system can lose properties inherent to them outside the system or acquire new ones. An example of emergence in programming is the behavior of a distributed system, where the simple interaction of individual nodes gives rise to new operation patterns. This concept follows an essential characteristic of project management: the emergence of a project linked to a system for developing value in the form of a new product, result, or service.

Materials and methods

Many studies have been devoted to the issue of classifying systems by “degree of complexity”, including many approaches to defining “complexity”. The most straightforward approaches are based, as noted in (Volkova et al., 2006: 848), simply on a quantitative assessment of the elements included in the system without considering the specifics of the connections and relationships between them. For example, G.N. Povarov (Povarov, 1970), assessing the complexity of a system depending on the number of elements included in the system, identifies four classes of systems:

1. Small systems (10...103 elements);
2. Complex (104...107 elements);
3. Ultra-complex (107...1030 elements);
4. Supersystems (1030…10200 elements).

Speaking about the taxonomy of complex systems, V.Ya. Tsvetkov, in his article (Tsvetkov), notes: “The next stage in the development of the theory of complex systems should be considered the work of Hiroki Sayama” (Hiroki Sayama, 2015: 498), according to which the theory of complex systems includes several scientific directions, including systems theory. This theory is more general in relation to systems theory and systems analysis. According to this point of view (Hiroki Sayama, 2015: 498), the theory of complex systems includes the critical issue of emergentism (Tsvetkov, 2017: 137–138) and self-organization (Ashby, 1966: 332). Complex systems theory is related to game theory, collective behavior, distributed systems theory, evolution and adaptation, nonlinear dynamics, structural modeling, and general systems theory.

Hiroki Sayama calls complex systems networked systems (Hiroki Sayama, 2015: 498) "having a large number of components interacting with each other, which are characterized by nonlinear functions".

A model of a complex system must be understandable, valid, and reliable (Nikolis, 1989: 488). Let us consider these properties (Tsvetkov, 2017: 137–138):

Perception is a cognitive factor, sometimes replaced by the term simplicity. However, simplicity is a conditional concept that depends on the choice of criterion for assessing it.

Hiroki Sayama (Hiroki Sayama, 2015: 498) defines the validity of a complex system model as the quality of information correspondence, which shows how accurately the forecast of the behavior of a complex system, as a model, agrees with its real behavior.

According to Hiroki Sayama (Hiroki Sayama, 2015: 498), the "reliability" of a model of any system is determined by its sensitivity to external influences. If minor influences (conditional characteristics) do not change progress towards the goal, then such a model of a complex system can be considered reliable.

As highlighted in (Mesarovic), there are two approaches to defining the categories "Complexity" and "large-scale systems" — abstract and hierarchical. The mathematical theory of abstract systems can be applied in engineering in various contexts and for different purposes. The challenge of complexity primarily surfaces with large-scale systems. From this perspective, the competency models used in project management can be considered "quite complex" in comparison with systems for creating new products and systems for operating engineering infrastructure on a scale, for instance, a state. However, considering the nonlinearity inherent, primarily in the "human factor", which is an integral component of the competency model of specialists in almost all fields of activity, and the structural connections in complex socio-technical systems, the problem of "complexity" demands special attention. To address this issue, it is crucial to construct models and structural representations of the system under consideration. One of the key steps in engineering design is the selection of the structure of the designed system or, in other words, the analysis of structural representations of the behavior and activity of the system. A detailed mathematical model is not suitable for this purpose, even if it exists. Traditionally, engineers have relied heavily on block diagrams to comprehend the complete composition of a system and further its structural representations. The main appealing aspect of flowcharts is, of course, their simplicity, but their main drawback is their lack of precision. General systems theory can be a valuable tool for constructing basic structural representations of a system that maintain the simplicity of block diagrams and simultaneously meet all the requirements of mathematical accuracy. General systems theory models bridge the gap between block diagram representations of systems and mathematical models. The construction of system-wide models is essential, particularly when analyzing complex technical systems. The existence of some system-wide methods that enable solving a specific problem at the level of general systems theory underscores the usefulness of introducing this stage into the process of analysis and design of complex systems, which are any project management systems.

The pattern of integrity (emergence) manifests itself in a system in the emergence (in english: Emerge) of new properties that are absent in the elements. L. Bertalanffy considered emergence the main systemic problem (Bertalanffy, 1972: 20–37).

The manifestation of this pattern is easy to explain using examples of the behavior of populations, social systems, and even technical objects; for example, the properties of a machine tool differ from the properties of the parts from which it is assembled. The enterprise can produce complex technical complexes from components and parts manufactured by individual production units or employees, united by the rules of interaction, determined by production technology and industrial relations, etc.

In project management, the pattern of integrity is best illustrated by the logic of risk management. To fully grasp the situation and trends in its development, it's not sufficient to analyze only the "final" factors that influence the possibility of deviations from the original plan. The "classical" approach to risk management, relying on SWOT analysis (Lukianov et al., 2020: 7–92), is inadequate. However, by analyzing the influence of factors on each other, transforming many factors {SWOT} into a SWOTxSWOT adjacency matrix, we can create a much more informative system model. This comprehensive approach is equally beneficial in analyzing schedules, stakeholders, communications, and competency models.

To better understand the pattern of integrity, it is necessary first of all to take into account its two sides:

1) The understanding of a system's (whole) properties Q_S is not a mere summation of the properties of its constituent elements (parts) q_i. This comprehension is crucial as it lays the foundation for understanding the system's behavior.

2) The behavior of a system (whole) is contingent upon the properties of its constituent elements (parts): $Q = f(q)$. This understanding of system behavior is essential for comprehending the system's response to changes in its constituent elements.

In addition to the listed properties, you should keep in mind one more property:

3) Elements combined into a system generally lose some of their properties characteristic of them outside the system. That is, the system seems to lose a number of properties of the elements; on the other hand, elements, once in the system, can acquire new properties.

For example, a project team is capable of managing a large project, and each team member bears the imprint of such collective (systemic) abilities that are not characteristic of each team member. For artificial (for example, technical or production) systems, the integrity property is associated with the purpose for which the system is created. Moreover, suppose the goal is not explicitly specified, and the modeled object has integral properties. In that case, you can determine the goal (target function, system – forming criterion) by studying the reasons for the emergence of the pattern of integrity. In complex systems, such as organizational or other systems with an active element – a person, it is not easy to immediately understand the reason for the emergence of integrity, and it is necessary to carry out an analysis to identify what led to the emergence of integral, systemic properties (Lukianov et al., 2017; Lukianov et al., 2018: 3–22).

Any evolving system typically exists between the states of absolute integrity (completeness) and absolute additivity. This dynamic nature of a system is key to understanding its adaptability and evolution.

In this case, absolute integrity corresponds to a state of complete order (in information theory – 100 % certainty) of the system, and additivity characterizes 100 % entropy or chaos, that is, the degeneration of the system into a conglomerate of elements devoid of any connections among themselves and, consequently, integrity.

The temporary state of the system can be characterized by the degree of manifestation of one of these properties or trends toward its increase or decrease. To assess these trends, A. Hall introduced two combined patterns, which he called progressive factorization – the desire of the system to a state with more and more independent elements and progressive systematization – the willingness of the system to reduce the independence of elements, etc. To assess integrity, A. Hall introduced some indirect assessments that make it possible to determine which patterns are manifested in the system to a greater extent. However, these estimates were introduced for specific communication systems (Table 1).

Table 1 – Patterns of interaction between part and whole

Patterns of interaction between part and whole	Degree integrity a	Element utilization rate b
Integrity (emergence)	1	0
Progressive systematization	$a > b$	
Progressive factorization	$a < b$	
Additivity (summative)	0	1

These estimates are obtained based on the relationship that determines the relationship between the systems C_C, its own C_0, and the mutual C_B complexity of the system:

$$C_c = C_0 + C_B \tag{1}$$

Let's start with the concept of "intrinsic complexity", which is essentially the total complexity of the elements of a system, excluding their connections with each other. In the context of pragmatic information, it's the complexity of the aspects that directly influence the achievement of the system's goal.

The system complexity of a C_C is the system's content as a whole (for example, before it is used).

Finally, we have 'mutual complexity '. This term characterizes the degree of interconnection of elements in the system. Think of it as the system's complexity as a device, circuit, or structure. It's a measure of how the elements of the system interact with each other, contributing to the overall complexity of the system.

If we divide (1) on C_0, we obtain the fundamental law of systems:

$$a + b = 1 \tag{2}$$

Where is the relative connectivity of system elements,

$$a = -(C_B / C_0) \tag{3}$$

their relative freedom

$$b = C_C / C_0 \tag{4}$$

The first expression (1) characterizes the degree of integrity, coherence, and interdependence of system elements in organizational systems and can be interpreted as the degree of centralization of management.

The second expression (2) is independence, the autonomy of the parts as a whole, and the degree of decentralization of the system. For organizational systems, it is convenient to call this the utilization rate of elements in the system.

The minus sign in (3) is introduced so that *a* is positive since C_B in stable systems, characterized by $C_0 > C_C$, formally has a negative sign. C_B associated (what remains inside the system) content characterizes the system's work for itself, not for fulfilling the goal set before it.

From (4), it follows that the sum of the freedom and restrictions of the system's parts is a constant value.

Regarding social systems, this means that an increase in justice *a* is achieved only by limiting freedom *b*, and vice versa. Therefore, a real complex, developing system is always between two extreme states – absolute integrity and absolute decay, chaos. Society faces a choice of the degree of regulation of integrity.

Modern methods of theoretical analysis of heterogeneous (decentralized) economic systems pay increasing attention to the problems of coordination (regulation and coordination) of the actions of economic agents rather than to the "free development" of the economy. The market is considered a source of information exchange and the provision of its participants with the necessary knowledge.

When an object is conceptualized as a system, the laws of integrity dictate that the combination of elements into a system and the transition from a system to its constituent elements will lead to qualitative changes. These changes occur at every level of system dissection. Initially, the object or process is represented as a structure for study, which may not immediately lend itself to a mathematical model. The process then involves the identification of precise deterministic relationships between the elements of the system, a task that often requires further investigation.

The intricate logic of the IPMA Delta model is best understood through the interplay of the ICB, OCB, and PEB models (Bushuyev et al., 2022: 1–12). However, the detailed description of the interaction between the final elements of these subsystems, each of which is a subsystem in relation to the system described by IPMA Delta, is yet to be fully explored. This model, in its complexity, can be scaled from the enterprise level to the industry, state, etc. level, offering a rich field for exploration and application (Lukianov et al., 2021: 70–84).

Practically, the property of structure integrity in the IPMA Delta model allows for the description of problem situations that are riddled with significant uncertainties. This model breaks down large uncertainties into smaller, more manageable ones, aiding in the identification of the causes of qualitative changes in forming a whole from parts. This practical application of the model underscores its relevance and usefulness in real-world problem-solving scenarios.

By dissecting the system, it is possible to analyze the reasons for the emergence of integrity based on the establishment of cause-and-effect relationships of various natures between parts, apart, and the whole, identifying the cause-and-effect conditionality of the whole environment, first carried out by the authors in their works aimed at understanding the deep mechanisms of the competency models of IPMA ICB version 3.0 (Lukianov et al., 2019: 506–512).

Hypothesis 1

The entropy of the entire control subsystem upon transition to a new target state is determined by the sum (integral estimate) of the entropy of all its elements.

This can be demonstrated by an increase in the total number of (missing) connections between elements when calculating an adjacency matrix of order n, in which the corresponding matrix does not contain empty (zero) elements.

The pattern of equifinality is one of the patterns of systems' functioning and development, characterizing the system's maximum capabilities. This term was proposed by L. Bertalanffy, who, for an open system, defined equifinality as "the ability, in contrast to the state of equilibrium in closed systems, entirely determined by the initial conditions, ... to achieve a state that does not depend on its initial conditions and is determined exclusively by the parameters of the system" (Bertalanffy, 1972: 20–37).

Hypothesis 2

The total information flow directed to the control object during the period of its transition to a new target state is equal to the difference between the entropy of the entire control subsystem during the transition to a new target state and the energy of the control object spent by the control object on the transition to the new state.

Consider all system elements as a "control object" except elements that are part of the "control subsystem". This approach allows us, for instance, to determine a complete information flow aimed at the entire complex of competencies of a project manager in the logic of the IPMA ICB model from such an element as "leadership", like "power", correspond to the elements of competence of the vertices of the graph in relation to incoming and outgoing connections (Sherstiuk et al., 2019: 496–500).

Hypothesis 3

The information work of the control subsystem to transform resources is crucial and consists of two parts – the work of the control subsystem spent on compensating for its initial entropy and the work aimed at the controlled object, that is, at maintaining the system in a stable state. This, in essence, reflects the logic of collecting information about the current state of the project's work and reconciliation with the project's baseline plans, presented in the logic of the monitoring and control processes, and relates to change management in the project.

This hypothesis requires an important, in the author's opinion, not-control elements must, by definition, "generate" more "influence" than they "accept" on themselves, incl. on the part or parts of a "similar nature." In this regard, it is indicative of considering not only the logic of interaction between the elements of the control subsystem but also its possible representation as a "complex", "cluster" or "core", which has "strong connections" between each other (or "essential", in terms familiar to mathematicians).

Hypothesis 4

The valuable work of the control subsystem during a specific period must correspond to the full information flow affecting the controlled system (by axiom 2) for the analyzed period.

Essentially, the "principle of adequacy" refers to the suitability of management decisions made based on the information received about the project's status and the changes in its implementation environment.

An important note – the calculation of such parameters as "information work" and "useful work" allows us to introduce the concept of "efficiency coefficient" of the control subsystem, introducing the following seventh axiom:

Hypothesis 5 (proposed by the authors)

The efficiency of the control subsystem for a certain period cannot be more than 100 % for the analyzed period ("The project manager is not a magician").

Based on information modeling data carried out by the authors for different models, the efficiency of the control subsystem is not a constant value in the general case (it can change significantly during transient processes and be a periodically changing value for systems that are periodic Markov chains (Kolesnikova et al., 2021: 1–6).

Moreover, based on the logic of such a parameter as efficiency, it is possible to compare different management models, for example, to conclude about a change in the efficiency of the control subsystem in the form of one or another block of competencies during the transition from the IPMA ICB 3.0 model to version 4.0, and also to propose how the control subsystem is a different set of elements, justifying this by a distinct, higher efficiency value of the control subsystem.

Discussion and results

However, the authors present a novel concept, a ‘system landscape’ model, albeit in a simplified form, which they propose to visualize the influence of its elements on the overall ‘entropy’ of the system. This unique approach, considering Markov models as information systems and applying measures taken to analyze information processes, significantly expands the possibilities of analyzing such systems. In this case, it is important to define the concept of ‘model’:

1) Model – an object or description of an object, a system for replacing one system (original) with another system for studying the original or reproducing its properties.

2) Model – the result of mapping one structure through another. By reflecting a physical system (object) onto a mathematical system, researchers obtain a physical and mathematical model of the system or a mathematical model of the physical system.

As is known, the classical modeling problem consists of three tasks:

1. development of a model;
2. research of the model;
3. implementation of the model.

The proposed approach to developing models solves all these three problems:

1. The construction of the model is not just theoretical, but also practical and constructive. An algorithm is proposed for constructing the model, making it a feasible and effective approach.
2. To study the model, methods for its research and analysis are proposed.
3. Specific targeted use of models is provided (as constructive and specific tasks).

Among the methods and tools used in the authors’ work, the application of decision-making theory has proven to be the most effective in practice. This is primarily because, based on the basic definition of a “solution”, a choice can be made from several alternative options. The models being developed are designed to be used, during the decision-making process, as tools for identifying problems, searching for alternative opportunities, and their formalization in a form suitable for analyzing further decisions, as well as those associated with the processes of eliminating problems and realizing opportunities.

Conclusion

Based on the fact that making a management decision is the main decision in the technological management cycle, and the decision-making process is a sequence of selection procedures, the result of which is a system of management decisions ready for implementation, the proposal of a particular “information system” that can act as such a “system” management decision support” in an area where this kind of toolkit has not previously been proposed, then, according to the authors, there is, at a minimum, potential for practical application.

At the same time, decision-making under conditions of certainty, in which the values of the most significant parameters are clearly defined, will differ from decision-making under conditions of uncertainty or when conditions are subject to constant change.

Using a rational model when choosing management decisions is based on selecting a solution that will maximize the organization’s utility (profit). Using a sensible model requires, on the one hand, a balanced approach to determining the evaluation criterion, a thorough search for alternatives, and their complete analysis. On the other hand, there may not be enough time or the necessary qualifications to ensure a balanced approach to determining the evaluation criterion, a thorough search for alternatives, and their analysis. In this case, transitioning from the “ideal rational model” to a limited one is possible. In this case, the main goal of the “boundedly rational” approach will no longer be to maximize utility but to achieve “acceptable satisfaction”. In this case, the problem is defined in a simplified manner, the analysis of alternatives is carried out superficially, and the first decision meets a particular set of criteria (attention is not focused on the optimality of the solution).

Having an information system capable of systematizing information for decision-making will certainly be useful. Considering the capabilities of modern information technologies and the growing potential for the use of AI, one should expect the emergence of such functionality, which is quite suitable for assisting in decision-making in situations where it is necessary to make a choice from several alternatives.

Issues of complexity and emergence remain unresolved entirely. The hypotheses of information management proposed by the authors can be applied to analyzing a wide range of design systems.

REFERENCE

Ashby W.R. (1966). Principles of self-organization. — M.: Mir, 1966. — 332 p.

Bushuyev S., Bushuyeva N., Bushuieva V., Bushuiev D. (2022). The 5D Competencies Intelligence Model for Managing Innovation Projects. — CEUR Workshop Proceedings, — 3295. — Pp. 1–12

Bertalanffy L. (1973). History and status of the general theory of systems // — System Research: Yearbook, 1972. — M.: Nauka, 1973. — Pp. 20–37.

Hiroki Sayama (2015). Introduction to the Modeling and Analysis of Complex Systems. — Open SUNY Textbooks, Milne Library. — State University of New York at Geneseo, 2015. — 498p.

K. Kolesnikova, T. Olekh, D. Lukianov and D.J. Obenewaa (2021). “Markov Principles of Project Effectiveness, IEEE International Conference on Smart Information Systems and Technologies (SIST). — Nur-Sultan, Kazakhstan, 2021. — Pp. 1–6. — doi: 10.1109/SIST50301.2021.9465881.

Lukianov D., Mazeika M., Gogunskii V., Kolesnikova K. (2020). SWOT analysis as an effective way to obtain primary data for mathematical modeling in project risk management. — CEUR Workshop Proceedings, — 2711. — Pp. 79–92

Lukianov D.V., Gogunskii V.D. (2017). The system of role-based communications in a project team and Markov models. XIV international scientific and practical conference — PM Kiev

Lukianov D.V., Chernova Ld.S. (2018). Modification of the Shewhart-Deming cycle in the Foresight methodology of development management. Materials of scientific methods. seminar “Ways to implement the credit-modular system of organization of training”. — ISS. 14. — Pp. 3–22.

Lukianov D., Prymak Y., Gogunskii V., Kolesnikov O. (2021). Passion and confidence in success as unaccounted factors for ICB 4.0 IPMA model, — CEUR Workshop Proceedings, 2851. — Pp. 70–84

D. Lukianov, K. Mazhei and V. Gogunskii (2019). “Transformation of the International Project Management Association Project Managers Individual Competencies Model”, IEEE International Conference on Advanced Trends in Information Theory (ATIT). — Kyiv, Ukraine, 2019. — Pp. 506–512. — doi: 10.1109/ATIT49449.2019.9030486.

Mesarovic M.D. General Systems Theory and its Mathematical Foundations.

Nikolis, J. Dynamics of hierarchical systems: Evolutionary representation: Transl. from English / J. Nicolis. — M.: Mir, 1989. — 488 p.

Systems theory and system analysis in the management of organizations: Handbook. Ed. V.N. Volkova and A.A. Emelyanova. — M.: Finance and Statistics, 2006. — 848 p.

Povarov G.N. (1970). On the levels of complexity of systems. / Sat. Methodological problems of cybernetics. — Vol. 2. — M., 1970

Tsvetkov V.Ya. Systematics of complex systems // Modern management technologies. — ISSN 2226-9339. — No. 7 (79).

Tsvetkov V.Ya. (2017). Emergentism // International Journal of Applied and Fundamental Research. — 2017. — No. 2-1. — Pp. 137–138.

Sherstiuk O., Kolesnikov O., Lukianov D. (2019). Team Behaviour Model as a Tool for Determining the Project Development Trajectory, IEEE International Conference on Advanced Trends in Information Theory, ATIT 2019 — Proceedings, art. — No. 9030497. — Pp. 496–500

ХАЛЫҚАРАЛЫҚ АҚПАРАТТЫҚ ЖӘНЕ КОММУНИКАЦИЯЛЫҚ ТЕХНОЛОГИЯЛАР ЖУРНАЛЫ

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Раушан Жалиқызы

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