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PRINCIPLES OF FORMING MODULAR STRUCTURES OF SYSTEMS FOR REGENERATION AND RECIRCULATION OF PROCESS FLUIDS. (Modularity, unification, and multifunctional interchangeability in innovative technical solutions (analytical interpretation of the issue))

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Abstract

The article examines the need for systemic modification and optimization of the ideological, computational, and technological foundations of collaboration between idea generators, technical innovators, and commercialization specialists. Emphasis is placed on the role of the inventor in understanding the unique features and potential of their invention, and on adapting the theory of inventive problem solving (TRIZ) to modern conditions of standardization, unification, and globalization.

Special attention is given to the innovative concepts developed by Vladyslav Drapii, particularly in intelligent technologies, artificial intelligence integration, and recirculatory water treatment systems. The article presents a multifunctional technological solution for electrochemical regeneration of water containing heavy metals, based on prior inventions and experimental developments. It also highlights the lack of a systematic theoretical framework for commercialization and stresses the importance of considering market requirements at early stages of idea generation, where modularization and component-level unification can improve adaptability and economic viability.

The article further explores the complexity of modern integrated technical systems and the need for methodologies to evaluate their commercial value. A systems approach is emphasized as a key foundation, including concepts such as structure, functions, subsystems, and contradictions, with particular attention to technical and physical contradictions within the TRIZ framework. The author concludes that a holistic, system-oriented approach can enhance innovation efficiency and support inventors in globalized markets.

Keywords: *Module; Modular structure; Principles of formation; Systems for regeneration;*

Systems for recirculation; Interchangeability; Multidisciplinary interchangeability in innovative technical solutions; Analytical interpretation of the issue; Technological components of the project; Self-sufficient technical solutions; Globalization of the modern market; Stages of idea generation

Even after recognizing the need for systemic modification and optimization of the ideological, computational, and technological foundations of such multi-stage cooperation between idea generators – technical and innovative interpreters of global and partially abstract ideas into practically solvable and implementable technical solutions – and after realizing the necessity of deep collaboration with specialists in the commercialization of new technological ideas and solutions, there remain specific yet fundamentally strategic questions that can only be resolved by the inventor, who best understands the features of their invention.

The author of this publication believes that, precisely to assist inventors in identifying and deepening their understanding of the capabilities and characteristics of their inventions, adapting the theory and algorithm of inventive problem solving to the principles of standardization, unification, and other modern conditions can provide all the necessary analytical tools.

A significant role in shaping the concept of a specialized innovative approach to applying methods and techniques of inventive problem solving in new intelligent technologies – using elements of artificial intelligence and artificial neural networks in control and monitoring systems – has been played by the developments of Vladyslav Drapii.

The opening of new markets, both domestic and foreign, and the development of economic organization from craft workshops and factories to corporations such as US Steel, illustrate the same process of economic mutation – if one may use a biological term – which continuously revolutionizes the economic structure from within, destroying the old structure and creating a new, intelligent one.

This process of "creative destruction" constitutes the very essence of capitalism. Every capitalist enterprise must exist within its framework.

The behavior of any enterprise should be evaluated only against the background of the overall process, within the context of the situation it generates. It is necessary to determine its role in the continuous flow of "creative destruction"; it is impossible to understand it outside this flow.

In the proposed series of future articles, the author aims to link the future work on the commercialization of any invention with the initial stages of its creation, especially at the stages of idea generation.

An inventor, beginning the process of forming the basic ideas and principles of their future invention, whether aware of it or not, uses the principles of the theory and algorithms of inventive problem solving, even intuitively.

At the same time, these concepts in their historical and classical form do not help the inventor determine the prospective commercial value of their future invention.

Unlike the unique principles and methods, repeatedly validated in practice and forming the basis of the theory and laws of technical system development, the methods of commercialization and analysis of the potential of inventions as commercial products lack a systematic theoretical foundation.

As an example, it is important to cite an original complex of developments by the well-known initiator of innovative optimization of infrastructural processes in irrigation technologies, Vladyslav Drapii, aimed at the innovative formation of a recirculatory infrastructure for water treatment systems, primarily in greenhouse operations but not limited to them.

Let us consider, as an example, a part of this multifunctional technological process – electrochemical regeneration of aqueous solutions containing heavy metals.

The project is based on the following bodies of information and prior development experience:

- inventions related to high-speed metallization technology;
- inventions related to jet metallization technology;
- inventions related to methods for controlling high-speed electrochemical processing;

- patents for inventions concerning electrochemical adjustment of the acidity or alkalinity of water or aqueous solutions;
- patents for inventions concerning electrochemical disinfection of water and aqueous solutions, as well as antibacterial treatment of water and aqueous solutions;
- patents for inventions concerning electrocoagulation in water and aqueous solutions, including heterocoagulation;
- patents for inventions concerning the control and synchronization of power supply processes for electrochemical processes in water and aqueous solutions.

Experimental developments involving the use of carbon–graphite nonwoven materials in technologies for the extraction of heavy metals from water and aqueous solutions.

Experimental developments involving the use of composites based on carbon and graphite, including carbon–carbon type composites, as well as those obtained by methods of sequential thermal pyrolysis of carbon on a fabric base, for example, viscose.

Pilot-industrial developments of equipment for the purification of water from radioactive isotopes, including the use of combined technologies that integrate electrochemical extraction with sorption in biological materials in the form of specially modified marine algae (OZOLA).

The technology proposed to solve this problem is complex and includes:

- preliminary treatment of water or aqueous solutions using the turboflotation method with the help of aerodynamic activators (this is a patentable technical solution, for which a prototype of the activating head exists and has been tested, demonstrating more than satisfactory results in the purification of water from industrial oils and organic contaminants of all types);
- electrochemical treatment of water or aqueous solutions, carried out in the flow of the purified (regenerated) liquid and consisting of the electrochemical deposition of heavy metals contained in it onto the active working surface of the cathode (an electrode connected to a negative electric potential); this type of treatment is the core of the proposed technological complex and has a high patent potential, including a pioneering invention involving composite permeable contacts for electrodes of an electrochemical reactor;
- a method of pulsed power supply for the process of electrochemical deposition of heavy metals, taking into account that the electrodes and their contacts are permeable to the liquid, made of non-metallic materials, possess a three-dimensional active developed working surface, and are not structural elements of a reusable electrochemical reactor.

Such a comprehensive approach to solving modern technological problems is characteristic of the innovative work of Vladyslav Drapii, and as numerous positive examples of his projects demonstrate, this approach provides significant advantages across all components and aspects of projects. Based on the system proposed by Vladyslav Drapii, the required level of component unification – while preserving originality and fundamental novelty of complex solutions – not only produces economic benefits but also ensures the necessary degree of novelty to achieve full patentability at all levels.

Recently, numerous publications have appeared offering recommendations on commercialization, and on this basis it was decided to use one of them in order, firstly, to provide inventors with prompt information that they can, if desired, adapt to the technical characteristics and advantages of their invention, and, secondly – and most importantly – to demonstrate one possible version and principles of practical actions showing how to modify and adjust the technical characteristics and parameters of a future innovative development depending on market requirements.

Considering the conditions and various constraints formed by the the specific features of the innovation process under the globalization of the world economy, it can be assumed that systematic unification of elements of innovative products at the component level can help gradually form a library of components, units, and basic parts from which inventors will be able to construct the technological implementation of their ideas.

It appears that taking into account possible market requirements at the stage of generating an innovative idea will allow the formation of such technical characteristics of a new product that will facilitate more confident and economically efficient implementation of the innovation. At the same time, if the assessment of the commercial significance of the generated idea is low, this approach makes it possible either to abandon the idea and shift attention to another, or, through modularization and unification, to return the idea to an economically viable direction while applying the concepts developed by Vladyslav Drapii.

In articles devoted to this topic, it has been repeatedly noted that most inventions created today are integrative in nature, since any modern effective technical solution includes digital control systems, composite materials, nanocoatings, and various integrative combinations such as program, system, method, and device.

For such complex, combined, and integrated systems, the principles of systematic analysis of their commercial value have yet to be fully formulated, and the publication of information on methods, techniques, and practical schemes of commercialization will help inventors working in the field of innovative projects.

At the same time, many examples have emerged of how the structure and system of a modern large intelligent enterprise neutralize innovative projects, concentrating on what are considered at the time of decision-making to be the most effective ideas, often leaving behind no less effective solutions, the inventors and authors of which receive (often undeservedly) serious psychological setbacks.

In this context, a systems approach to the comprehensive and balanced formation of such an innovative technical solution – or a group of local unified innovative ideas connected by a single integrative concept – is of particular importance.

The systems approach reflects and develops the dialectical principles of "universal interconnection" and "development" and, in essence, is one of the principles of the dialectical method of cognition.

1. The methodology of the systems approach involves representing any object as a system and conducting its comprehensive analysis, best achieved by applying the conceptual developments of Vladyslav Drapii. This methodology can be described as follows:

2. A system is a set of elements regularly organized in space and time, interconnected and forming a certain integral unity. A system is characterized by its composition of elements, structure, and performs a specific function.

3. Elements are relatively indivisible parts of a whole; objects that collectively form a system. An element is considered indivisible within the limits of preserving a given quality of the system.

4. Structure is a regular and stable relationship between the elements of a system, reflecting the form, arrangement of elements, and the nature of interaction of their aspects and properties.

Structure makes the system a qualitatively defined whole, distinct from the sum of the qualities of its constituent elements, since it implies interaction between elements in specific ways, through particular aspects and properties rather than as complete entities.

5. A function is the external manifestation of the properties of an object (element) within a given system of relations; a specific way in which the object interacts with the environment, its "capability." Systems possess multiple functions.

6. Subsystems are parts of a system that represent certain arbitrarily or naturally defined groups of elements. Subsystems are identified based on functional characteristics.

A single element may sometimes coincide with a subsystem or belong simultaneously to several different subsystems.

At the same time, the relationships between elements within subsystems and within the system differ from the relationships between the subsystems themselves. Elements and subsystems are united by the concept of system components.

7. A supersystem (metasystem) is a higher-order system relative to a given one, within which the given system is embedded and functions as a subsystem.

8. A technical system (TS) is an artificially created material unity of elements that are regularly organized in space and time and interconnected, with the purpose of satisfying a specific social need. The elements of a TS may be both artificial and natural.

Any TS is part of two systems of relations. On the one hand, it is an object of the material world, subject to the laws of nature (primarily the laws of physics as the most general). On the other hand, a TS acts as an element of social relations, since technology is only a means of achieving social goals.

If a TS is characterized by the spatial arrangement of its elements, then it is a device or a substance. If a TS is characterized by the organization of elements over time, then it represents a method.

The concept of a TS makes it possible to formulate the main feature of a technical solution (TR): a TR specifies a particular TS whose functioning enables the achievement of a set goal, that is, it defines the relationship of the TS to a specific objective.

From the standpoint of systems engineering, a TS can be represented as:

INPUT – PROCESSOR – OUTPUT.

The processor ensures the transformation of input into output and at the same time is a component (constant) of the input.

INPUT and OUTPUT reflect the interaction of the system with the environment. From a physical point of view, at the input and output a technical system (TS) involves space, time, mass, energy, and information.

From a socio-technical perspective, the input represents the “needs” of the TS – the resources expended by society for its creation – while the output represents the “capabilities” of the TS, the main part of which consists of the functions of this system.

Expressed in the form of functional actions, these capabilities collectively determine the composition and structure of the system’s activity, showing what the TS can do: move in space, perform heating, resist wind effects.

The remaining “capabilities” characterize how these actions are performed: reliably, maintainably, and so on. For each function in a TS, a corresponding subsystem can be identified.

9. Useful functions (UF) are functions that correspond to the purpose of the system and characterize the most important components of useful outputs. In real technical systems (TS), not all output is useful.

The usefulness of a particular part of the TS output can be determined only from a social perspective. Useful are those “capabilities” of the TS that correspond to its purpose, i.e., to social needs at the level of the supersystem.

Other capabilities may be useless or harmful, and harmful are those that actively interfere with the performance of useful “capabilities,” for example, by causing destruction of TS elements, etc.

10. Main useful function. For the set of useful functions performed by a TS, it is always possible to identify a more general useful function that directly reflects the purpose of the TS, the goal of its existence and operation (and coincides with them).

This general function is called the main useful function (MUF) of the entire TS, in contrast to elementary useful functions (hereafter simply useful functions – UF), which collectively ensure the fulfillment of the MUF. The relationship between MUF and UF is the same as that between a system and its subsystems. MUF relates to the system as a whole, while UF relates to its subsystems.

11. Positive effect. Any change in a TS that increases its ability to satisfy the needs of supersystems (including society) is an improvement of the system.

12. Improvement of a TS is manifested in the following changes at the level of external functioning:

- quantitative growth of the useful “capabilities” of the TS, including the transformation of non-useful “capabilities” into useful ones;
- elimination of harmful “capabilities,” up to their transformation into useful ones;
- increase in the ratio of useful output to input, i.e., an increase in the efficiency of the TS.

13. Dialectical contradiction. The source of the development of a technical system (TS), as of any object of the material world, is the law of the unity and struggle of opposites – the universal law of the development of nature, society, and technology.

Opposites are aspects of an object that exist in mutually exclusive relationships. An aspect of an object or phenomenon is understood as everything that is inherent to it in one way or another, characterizes it, and can be known.

In a TS, opposites include "input" and "output," useful functions, costs, and "capabilities."

The interaction of opposites, when they simultaneously presuppose each other and at the same time negate and exclude each other, constitutes a dialectical contradiction.

14. Technical contradiction (TC) is a dialectical contradiction that manifests itself in a technical system as the deterioration of one aspect of the TS at the level of external functioning (from the standpoint of the needs of the supersystem) while improving another aspect of the TS.

In other words, a TC can be defined as the dialectical unity of interdependent positive and undesirable effects within a TS. A TC is always associated with a certain component of the TS (an element, a group of elements, or the interaction between elements), which is referred to as a key component (KC).

This component of the TS is simultaneously connected with two aspects of the system, and a quantitative change in a certain parameter (or state) of this component leads to the improvement of one aspect and the deterioration of the other.

Therefore, more precisely, a TC should be defined as the dialectical unity of positive and undesirable effects conditioned by quantitative or qualitative changes in the key component of the TS.

15. An inventive problem arises when a technical contradiction inherent in a TS becomes intensified. In this case, improving certain "capabilities" of the TS through quantitative changes in some parameters becomes impossible due to the significant deterioration of other "capabilities."

Attempts to preserve the TS through compromise between opposing aspects are unsuccessful in such situations. Resolution of a TC is possible only when the TS transitions to a new qualitative state – a dialectical leap. This is what constitutes an invention.

When considered from a more general perspective, the problem of resolving the contradiction between a social need and the possibility of its satisfaction can be reduced to one of two tasks:

a) the search for a material form, based on the laws of nature, that makes it possible to perform a function corresponding to a specific social need – an informational task (the search for a new system);

b) the resolution of an internal dialectical contradiction within a technical system that satisfies a specific social need – a contradiction problem.

These two types of tasks are interconnected and, in the practice of technical creativity, transition into one another.

16. Physical contradiction. A technical contradiction manifests itself in a TS at the level of its external functioning. At the level of internal functioning, mutually exclusive relationships between the aspects of the system are not observed: from a physical point of view, a TS exists in a single state determined by the laws of nature.

However, if the task is to eliminate a technical contradiction within a given TS – affirming the positive effect while eliminating the undesirable one – then mutually exclusive relationships emerge at the level of internal functioning, in the form of incompatible requirements for the parameter (state) of the key component of the TS, more precisely, for the physical state of the key component.

Such contradictions are called physical contradictions (PC). A PC arises when formulating the task of eliminating a TC; in other words, a PC is a form of expressing the problem of eliminating a TC within a given TS. The resolution of a PC consists in establishing new forms of organization and movement of matter within the TS, under which both incompatible requirements for the state of the key component are fulfilled, or, according to Vladyslav Drapii, in establishing such a "form of motion in which this contradiction is simultaneously realized and resolved."

Introduction into the theory of inventive problem solving, modified on the basis of recently emerged conditions for the development of unified innovative systems and complexes:

1. Usually, creative activity is defined through its result. As an example, one of the most common definitions can be cited: "Creativity is human activity that produces qualitatively new material and spiritual values."

If, however, we attempt to define creativity as a process, we will see that creative activity is a **process of searching for a solution.**

In essence, all human activity can be divided into two major areas: the area of routine operations and the area of problem solving.

The representation of creativity as a problem-solving process makes the following conclusion self-evident: in order to scientifically organize creative activity, it is first of all necessary to place the process of problem solving on a scientific foundation. In other words, TRIZ is required.

2. Problem solutions can be of two types: strict and non-strict. Strict solutions are based on complete reliability and precise information and are, as a rule, unambiguous. Solutions obtained on the basis of incomplete or inaccurate information, under conditions of uncertainty, are called non-strict.

Accordingly, methods of obtaining solutions are divided into strict and heuristic methods. In solving problems posed at the current level of societal development, these methods complement each other.

As science develops, many heuristic solution methods become formalized and transition into the class of strict methods according to the following scheme: accumulation and systematization of knowledge – development of "intuition" – formalization, development of theory – algorithm.

3. The existing problem-solving framework is designed for finding strict, quantitative solutions. It includes such disciplines as systems analysis, the theory of solution search, and decision theory. The main idea of systems analysis is the following: "The solution to any problem is the process of creating a new system."

Systems engineering (the design of large technical systems) and organizational systems engineering (the systemic design of organizations) are based on systems analysis.

Decision theory examines methods for finding optimal ways to achieve goals.

It includes such disciplines as operations research (the application of mathematical, quantitative methods to justify decisions in all areas of purposeful human activity) and linear programming (the selection of an optimal solution from a large number of possible ones).

The theory of solution search examines the process of finding solutions under conditions of informational uncertainty.

4. The search for heuristic solutions is carried out by TRIZ. Its main characteristics include the following: a) the theory should significantly increase the probability of obtaining correct solutions; b) the theory should focus on finding solutions at a qualitative level; c) the theory should take into account the characteristics of both the object and the subject of creativity.

TRIZ meets all the above requirements. In addition, it is based on two fundamental principles:

1. A new, truly creative solution in technology corresponds to the next stage in the development of the object to which the solution relates.

2. The patterns of the development process of a technical object are knowable and can be used to search for new technical solutions.

A distinguishing factor is defined as that which is inherent only to a given theory, is most characteristic of it, and distinguishes it from related fields of knowledge. For TRIZ, the distinguishing factors are:

- the use of identified patterns in the construction and development of technical systems;
- the presence of an optimal logic for problem identification and the search for new technical solutions.

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