
Development Regularities of Technical Systems as a Means of Scientific, Methodological and Information Support of Idea and Innovation Management

A.I. Bashmakov¹, V.V. Popov², D.N. Zhedyaevskii³, D.N. Chikichev⁴, E.A. Voyakin⁵

Abstract:

In recent decades scientists are increasingly engaged in the identification and formulation of the laws of development of machinery, technology, and products (i.e. technical systems, or TS). Regularities of the TS development represent ascertained consistent trends of incremental changes of TS operational or structural properties, leading to the improvement of their consumer qualities.

The article describes the development results of scientific and methodological bases of use of the TS development patterns to search for the best ways for their further enhancement. Informational and methodological approaches are suggested to create an automated innovation management information system based on the laws and regularities of the TS development.

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Key Words: *Laws of development, regularities of development, conceptual design, innovative activity, enhancement methodology, productive knowledge, technical systems*

¹ PhD (Technical Sciences), Research & Manufacturing Association "Inform-Systema", info@informsystema.ru

² PhD (Technical Sciences), Research & Manufacturing Association "Inform-Systema", info@informsystema.ru

³ PhD (Technical Sciences), Russian State University of Oil and Gas named after I.M. Gubkin, info@informsystema.ru

⁴ Russian State University of Oil and Gas named after I.M. Gubkin, info@informsystema.ru

⁵ IBS Group, Director of Education Department, evoyakin@ibs.ru

1. General information about the regularities of the TS development

The evolution of technologies, machinery and products (technical systems, or TS) is influenced by many factors, in particular, current felt-needs of society, the objective level of scientific and technological progress, availability and the level of competition, etc. However, since the second half of the 19th century, scientists began to notice that the process of the TS improvement is exposed to the influence of certain laws and regularities.

Initially the mechanisms and trends of technical progress were the subject of philosophical research. Then these studies acquired applied nature, focused primarily at developing of heuristic forecasting tools, allowing to choose effective ways to search new design and technology solutions to advance competitors and optimize expenditures. These studies resulted in identification of a number of universal laws of the TS development, among which the law of stage development of the TS and the law of progressive evolution of the TS are the most well-known. The application of these laws is mostly related to the determination of the most probable avenues for the TS development and the strategic decision-making when designing TS.

In recent decades scientists are increasingly engaged in the identification and formulation of the regularities of development of machinery, technology, and products (i.e. TS). Regularities of the TS development represent ascertained consistent trends of incremental changes in the performance specifications or structure of the TS, leading to the improvement of their consumer qualities.

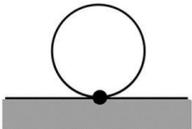
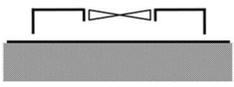
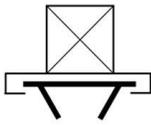
Significant contribution to the study of the TS development laws was made by Soviet researchers in the second half of the XX century. The basis of today's knowledge about these laws was laid by the works of G. S. Altshuller, Yu. S. Meleschenko, E. P. Balashov, A. F. Kamenev, A. I. Polovinkin, and S. S. Tovmasyan. Among foreign studies on the TS development laws the works of D. Mann, G. Linde and P. Hill are mentioned the most frequently. Currently, the TS development laws are recommended to be studied as a section of TRIZ (Theory of Inventive Problem Solving) by specialists of Russian and foreign organizations (Russian TRIZ Association, International TRIZ Association, The Altshuller Institute, The TRIZ-Journal, Association Mexicana de TRIZ, etc.) [1-6].

Regularities of the TS development have a great potential for applications in innovative activity, since they suggest developers not only promising areas to search for new solutions, but often – specific, associatively-hued new solutions, having new competitive properties in comparison with their counterparts.

For example, several decades ago, the regularity of the TS development (improvement of consumer qualities), when changing the geometrical adjectives of the mechanical contact of the objects (contact of TS with a person, environment or other TS), was described in a logical sequence "point – line – surface – space". An

example of the demonstration of ground vehicles development regularity (when increasing the speed and/or off-road performance) is shown in Fig.1.

Figure 1. An example of demonstration of regularities of engineering systems development associated with changes in the geometrical adjectives of the object's mechanical contact.

Contact type	Contact at a point	Contact along a line	Contact over a surface	Contact by volume
Scheme				
Example of the TS	 Vehicle	 Tractor	 Air-cushion craft	 Maglev train

Professor V.V. Popov formulated a generalized description of this regularity allowing to predict the possibility of implementing previously undescribed intermediate development stages: "the TS development regularity, in case of changing the geometrical adjectives of the mechanical contact of a person or the TS with the environment or another TS, which consists in the fact that the development of the TS occurs through the increase in the number of contact points, and the number of contact points converge from one point to infinity (continuous contact), and contact configuration complicates from evenly or unevenly spaced points, geometrically correct and then becoming incorrect solid or broken lines, turned further into two-dimensional or three-dimensional surfaces" [7].

Based on knowledge about the existence of this regularity, the authors have developed and patented thermal insulation, characterized by a combination of high load capacity and low thermal conductivity coefficient (due to the implementation of the "point" contact between solid spherical insulating elements) [8].

Among the TS development regularities, the most common were the regularities associated with the following changes, occurring with technical systems (leading to the improvement of consumer qualities of these TS):

- changes in properties of the TS working surfaces (e.g., smooth, rough, and hydrophobic);
- changes in type of physical fields (e.g., gravitational and electromagnetic) and energy (e.g., mechanical, electrical, and nuclear) transformed in the TS;
- changes in type of mechanical motion, directly or indirectly associated with the TS operation (e.g., reciprocative, rotational, and complex (consisting of reciprocative and rotational), horizontal, vertical, inclined from horizon by an angle, uniform, uniformly accelerated, uniformly decelerated, and non-uniform));
- changes in the number of degrees of freedom in the TS movement in the environment, as well as relative to another;
- changes in geometrical adjectives of the mechanical contact of a person or the TS with the environment or another TS (e.g., contact at a point, at several points, over a surface, and by space);
- changes in functional structure of the TS (e.g., linear, branched, and network);
- changes in the TS symmetry properties (e.g., bilateral, axial, spherical, and translational);
- changes in the TS properties distribution in space and their anisotropy in the TS (e.g., uniformly distributed monoproperties, polyproperties with sharp boundaries and uniform or nonuniform alternating of the areas with different properties);
- changes in the state and properties of empty space and the internal structure of material objects in the TS (e.g., continuity, separation into parts, the presence of through "voids", the presence of fragmented "voids", a capillary structure, and a powder structure);
- changes in a mobility limiting nature of the connections in TS (e.g., fixed rigid contact, rigid movable contact (swing joint), elastic or plastic contact, contact through liquid and/or gas medium, and contact through field) [9].

2. Employment of knowledge about the TS development regularities for searching the best ways to improve the TS

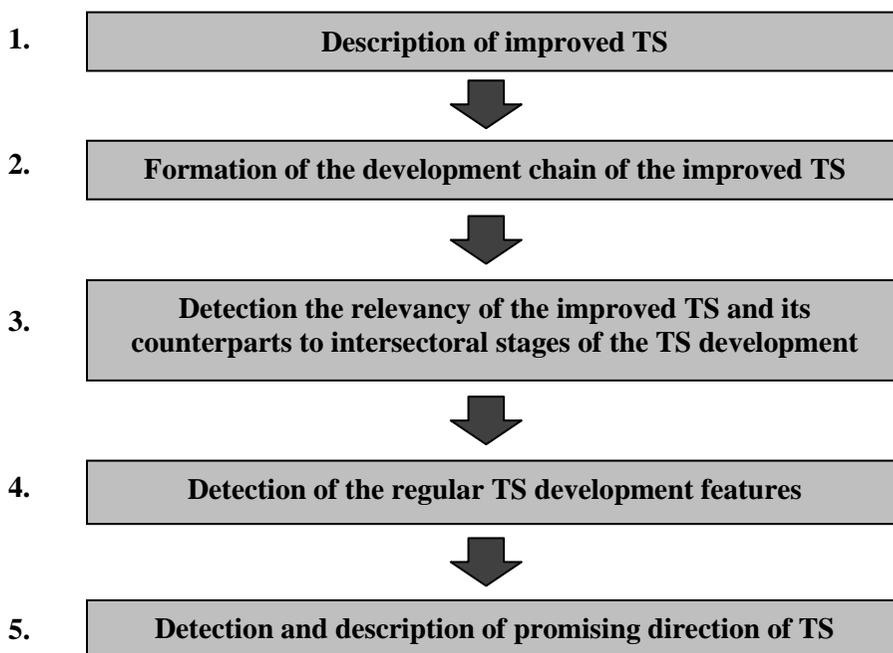
In the course of the project of the Ministry of Education and Science of the Russian Federation "Development of a tool providing information support of idea and innovation management, ensuring modernization of economy, and increasing the competitiveness of the subjects of the Russian Federation on the basis of higher education institutions", the authors of the present article have developed the concept of formation and use of productive knowledge to enhance the efficiency of innovation activities at all stages of the idea and innovation management at higher education institutions.

The developed concept presents the methodology to intensifying of innovative activity, including knowledge of the TS development regularities and

methodological foundations of their employment for searching the best ways to improve the TS, as one of the effective means of scientific, methodological and information support of idea and innovation management.

The methodology of use of TS development regularities to search for the best ways of the TS improvement lies in the fact that one should successively perform the following steps, when there is a need to improve the TS (Fig. 2).

Figure 2. Execution sequence when searching for promising direction of TS development, based on the knowledge of the TS development regularities



First, one must produce description of the TS, which is to be improved (hereinafter – the improved TS), including the description of the main function of the improved TS, to describe its main elements and highlight key consumer qualities that determine the effectiveness of the implementation of its main function (step 1, Fig. 2).

Next, based on the analysis of available information sources, it is necessary to draw up the chain of development of the improved TS (hereinafter – chain of development), i.e. a linear sequence of descriptions of counterparts of the improved TS (TS performing the same main function), essentially differing in terms of effectiveness of the implementation of a certain key consumer quality (step 2).

For example, the development of the TS, such as car, can be explored towards enhancing the off-road performance, increasing its steerability, reducing fuel consumption, etc.; in each case, the chain of development will be different. At that, descriptions of the counterparts of improved TS in the chain of development are arranged towards increase of the efficiency of implementation of the selected consumer quality, expressed through the quantitative values of the parameter characterizing this consumer quality. In the general case, when searching for the TS improvement areas, we recommend to choose the consumer quality as a basis to draw up the chain of development, whose change in terms of quality of its implementation affects most obviously on utility of the improved TS and has the highest value to the end user. An example of the drawn up chain of development is presented in Tab. 1.

Table 1. An example of the drawn up TS chain of development (vibrating screen)

TS: Vibrating screen

No of the TS	TS1	TS4	TS5
Full name of the TS	Revolving screen	Flexible-drive screen	Vibrating screen
Main function	The separation or sorting of milled material by particle size		
Description of the qualitative changes made with respect to the previous stage	The material is sifted through the holes in the wall of the revolver	Screens are shaken by eccentric mechanism, increasing thereby the performance	Inclined screen makes frequent oscillatory motions by means of a vibrator that reduces clogging of the screen and increases its performance
The range of specific performance (which is principle characteristic when drawing up the chain of development)	2.5 - 4 t/m ³ per hour	30 - 35 t/m ³ per hour	35 – 40 t/m ³ per hour

After drawing up the chain of development, one must pass step 3 (Fig. 2) by comparing physical, chemical, and other properties of the TS, represented in the chain of development, to detect the compliance of the basic elements of the improved TS and its counterparts to intersectoral stages of the TS development

(whose ordered lists are included in the TS development regularities descriptions, developed by the authors (an example of such a list is shown in Fig. 3). As a result, considering the chain of development in the context of each individual TS development regularity, we can represent it as a series of identified intersectoral TS development stages. For example, in the case, presented in Fig. 1, where consistent pattern is demonstrated through the changes in the geometrical adjectives of the object's mechanical contact, the chain of development "vehicle – tractor – air-cushion craft – magnetically levitated train" can be represented as a sequence of the following stages "contact at a point – contact along a line – contact over a surface – contact by space".

Figure 3. Example of the list of intersectoral stages in the TS development (9 – the number of development regularity)

9. The consistent pattern of qualitative improvement of design and technology properties of the TS during the transition to new kinds of connections of structural elements of the TS.

The sequence of development stages:

	[9.1] Rigid fixed connection;
	[9.2] Rigid mobile connection (swing joint);
	[9.3] Elastic connection;
	[9.4] Plastic connection;
	[9.5] Connection through the liquid and/or gaseous medium;
	[9.6] Connection through the field;
	[9.7] No connection.

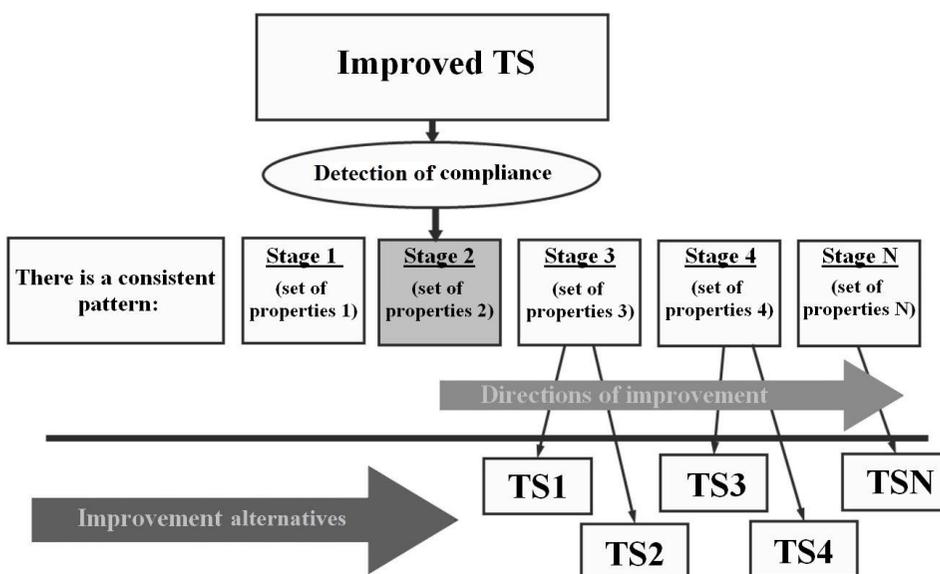
Considering the drawn up chain of development separately in the context of each regularity of TS development, one should build further a linear sequence of the

intersectoral development stages, following the order of the TS descriptions in the chain of development (step 4, Fig. 2).

Full or partial compliance of the sequence of detected development stages to the sequence of intersectoral development stages in the description of any regularity of TS development brings us to the conclusion that there are signatures of the regular TS development process in the chain of TS development.

When detecting therefore the features of a regular development of the TS, it is necessary to describe the promising directions of TS development of the improved TS (step 5, Fig. 2) on the basis of knowledge about existence of intersectoral development stages, theoretically more advanced than the stages detected. At that, in each case one should think over and describe possible design and technology implementation of the TS improvement alternatives, corresponding to the identified promising development directions (Fig. 4).

Figure 4. Search pattern for the TS improvement alternatives based on knowledge about the existence of regularities of development



Often the employment of even one of the TS development regularity, which defines the intersectoral stage of development, following the stage, to which the characteristics of the improved TS correspond, suggests a global idea, which can be implemented in several fundamentally different but competitive and patentable design and technology solutions.

3. Formation of approaches to the development of computer tools for information support of idea and innovation management

To implement the knowledge about the TS development regularity and methodological foundations of their use for searching the best ways to improve the TS as an application tool of scientific, methodological and information support of idea and innovation management, the authors suggest information and methodological approaches, as well as developed technical requirements for the creation of an automated innovation management information system based on the laws and regularities of technologies, machinery, and products development.

The proposed automated information system should provide:

- choice of law or regularities that are relevant to the concerned problem of innovative activity;
- formation (in the dialogue with user) of corollaries from the law of progressive development of TS in the context of the problem being solved;
- formation (in the dialogue with user) of corollaries from the law on accordance of functions with functional structure of the TS in the context of the problem being solved;
- formation (in the dialogue with user) of corollaries from the law on the stage development of the TS in the context of the problem being solved;
- formation (in the dialogue with user) of corollaries from the regularities of the TS development in the context of the problem being solved;
- presentation and navigation over databases: descriptions of the laws and regularities of the TS development, application techniques and examples of implementation of the TS development laws and regularities, and the results of the use of the TS development laws and regularities.

To ensure the implementation of these functions, the proposed system should include the following basic information components:

- database of descriptions of the TS development laws and regularities;
- database of stages and steps of the TS regular development;
- database of corollaries from the laws and regularities on the TS development;
- initial content of the database of the examples illustrating implementations of corollaries from the laws and regularities on the TS development;
- database of the employment of techniques and examples of implementation of the TS development laws and regularities;
- database on the employing results of the laws and regularities of the TS development.

The proposed system can be effectively used in innovative activity as a virtual environment, in which the problem on investigation of the TS development and searching for promising directions for its improvement are carried out on the basis of

user-friendly interface, and rapid assess of the necessary information and methodological materials is provided.

The system is to be implemented on the basis of client-server architecture, while the client part should function based on a standard web browser that implements the interface to access the information resources and services through the web-site.

Thus, access to the proposed system can be carried out via the browser of any device connected to the Internet that will allow efficient use of the system as a tool for methodical and information support in idea and innovation management, which is available to all categories of innovative activity agents.

4. Conclusion

Regularities of the TS development, which are the identified consistent trends of successive changes in the TS performance specification or structure, leading to the improvement of the consumer qualities of the TS, have a great potential for innovative activity enhancement, because they are much more effective than conventional methods (the trial-and-error method, analogy-based reasoning caused by fortuitous associations, intuition, and infrequent "insight"). They suggest developers not only promising directions for the TS development, but often prompt specific new competitive solutions through reasoning resulted from associations.

To solve the applied problems of innovative activity through the knowledge of the TS development regularities, the authors identified and described the existing TS development regularities, and elaborated generalized descriptions of the TS development regularities, which have improved heuristic capabilities.

Besides, the authors developed ordered lists of descriptions of intersectoral stages of the regular TS development, as well as methodological foundations for employing the knowledge about the regularities in the TS development to search for the promising directions aimed at improving specific technical solutions [10].

As part of the project implementation under the Ministry of Education and Science of the Russian Federation "Development of a tool providing information support of idea and innovation management, ensuring modernization of economy, and increasing the competitiveness of the subjects of the Russian Federation on the basis of higher education institutions" the authors revealed the significance of the knowledge about the TS development regularities as part of the methodology focused on enhancement of innovative activities using productive knowledge. Informational and methodological approaches are suggested for the creation of an automated innovation management information system based on the TS development laws and regularities.

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