TRIZ IN EVOLUTION

Kirov
2023

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TRIZ IN EVOLUTION

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The collection of scientific articles "TRIZ in Evolution" is intended for TRIZ specialists, engineers, inventors, innovation specialists and teachers in these disciplines. The collection includes current developments of TRIZ specialists in the field of innovation, TRIZ education, training of researchers, as well as on the topic of TRIZ and science.

All articles are published in the original authors' versions.

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Content

INTRODUCTION

«TRIZ Developers Summit» is an international non-profit organization, which was created to the initiative of TRIZ researchers in 2005. The main task of TRIZ Summit is to organize the cooperation of developers and researchers from different countries of the world in the field of developing TRIZ as a science. TRIZ Developers Summit continues the traditions of researchers' TRIZ seminars, organized by G.S. Altshuller.

This collection of scientific articles contains key materials in Russian, which were reported during the conference of TRIZ summit in 2021 and 2022.

The conference of 2021 was devoted to 95th anniversary of TRIZ founder G.S. Altshuller, who not only formulated the basics of theory of inventive problem solving as applied to the development of technical systems, but also became the founder of non-technical direction in TRIZ: TRIZ in science, course of development of creative thinking, TRIZ and chess, TRIZ in forecasting and many other non-technical lines of TRIZ.

Conference of TRIZ Developers' Summit, which took place in 2021 collected about 500 participants from 33 countries of the world. Research work was presented, which was devoted to development of TRIZ as a science based on ontological approach. A new complex of trends of system evolution was presented, as well as tools for statement and solving of inventive problems in technology, business and information systems. The most important of them can be found in the present collection of papers.

The Conference of TRIZ Developers' Summit of 2022 was the eighteenth conference. Three sections were working as part of the conference: «TRIZ in IT and in technology», «TRIZ in business», «Creative personality and TRIZ in education». Totally more than 500 participants from 57 countries of Australia, Asia, North and South America, Africa and Europe were registered as participants of the conference. TRIZ Masters and certified TRIZ specialists took part in the work of the conference.

For more details on TRIZ Summit conference see the following web-sites: https://triz-summit.ru/ and https://triz.team/con/2023/ca2023/

TRIZ IN TECHNOLOGY AND IT SECTION, TRIZ IN BUSINESS SECTION OCTOBER 15–16, 2021

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S. Boika, G. Martsinovskii

Digital transformation in terms of TRIZ laws of system evolution

INTRODUCTION

As a result of the pandemic, many companies consider digital transformation as the most important strategic direction of their development, which will help them maintain and develop their business in new conditions. At the same time, according to McKinsey, only 30% of companies successfully accomplish digital transformation of their businesses [1].

The complexity of digital transformation results from the fact that it affects almost all aspects of the company: the business model, product lines and services, customer segmentation, customer experience, operational processes, and technological solutions. In addition, there are many intangible factors, such as speed of adaptation, agility, innovation culture and leadership, which must not be neglected to succeed in digital transformation.

During digital transformation, companies face multiple complex interrelated problems that need to be identified and addressed. Using TRIZ as one of problem-solving frameworks for digital transformation projects have been already discussed [2-4]. The papers usually consider the use of individual TRIZ tools for solving particular problems that arise during digital transformation.

In this article we would like to investigate digital transformation from the point of view of the system evolution laws of TRIZ. Such analysis will allow us to develop a consistent view of digital transformation process as a stage of the system evolution, prioritize and reframe the arising problems in terms of evolution laws, provide recommendations on application of TRIZ tools. The ultimate goal of this study is to maximize the effect of using TRIZ framework in digital transformation process. We will also validate our conclusions with real cases from our practice.

DIGITAL TRANSFORMATION IN TERMS OF S-CURVE ANALYSIS

S-curve evolution is a central TRIZ concept of system development. Usually the S-curve describes evolution of a technical system utilizing a certain operation principle. As the system approaches the development limit of the operation principle it transits to a new operation principle with a higher development limit.

The same consideration applies to companies as business systems. From this point of view a company can be represented as a combination of a business model that delivers a certain value and a set of technologies supporting the above business model (see Fig.1). Such technologies include design and development of products and services, marketing, distribution, logistics, customers management, finance management etc.

Successful digital transformation affects all aspects of the business. The use of digital technologies themselves does not automatically shift the whole business system to a new S-curve unless the business model is redesigned to deliver a more competitive value and enable higher scalability of this value. We will consider cases from our practice that illustrate this point later in the article.

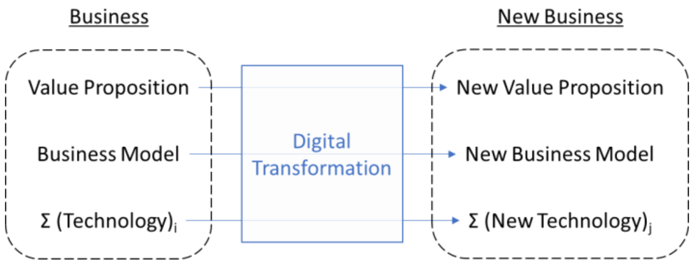

Figure 1. Different levels of digital transformation

When searching for a new business model companies often take the easiest way and copy the models of the most successful competitors or use digital business models that have already become a "standard" in the domain. To some extent, this reduces the company's risks and makes the transformation process more predictable, however, in the end, the company does not achieve the main goal – i.e., it does not get a significant competitive advantage, especially taking into account the market positions of such major players as MAANG. To start a new S-curve with respect to the business performance the company is to find an individual solution that gives a significantly better customer value and experience basing on understanding the customers and emphasizing the uniqueness of the company itself. This explains why there is no single recipe of successful digital transformation and why there are not so many companies whose digital transformation has really disrupted the market [5]. In turn, TRIZ offers a systematic approach to this challenge. TRIZ claims that when switching to a new operating principle of the system, a certain contradiction or several contradictions that limited the development of the previous system, i.e., the previous business model, are always resolved. Identification and resolving of such contradictions seem to be the main task for the use of TRIZ in relation to the processes of digital transformation.

TRENDS RELATED TO DIGITAL TRANSFORMATION

In most cases the development limit of the initial s-curve ultimately results from lack of information availability in the system. Digital transition allows the company to overcome the development limits of the legacy business model and technologies. Clear understanding of the nature and mechanisms of the development limit usually gives an insight regarding direction of a possible disruptive solution.

TRIZ suggests one of evolution trends as increasing in utilization of information flow [6–7]. Even though we do see such a trend in digital transformation, we cannot reduce digitalization just to increasing existing useful information flow conductivity and usability and reducing those for harmful or waste information flows. The effect of information flow is so significant that it results in complete reconfiguration of the functional architecture of the system. If we compare this to a technical system, it would be an equivalent of transition to a new operation principle. We observe such drastic change because in business systems the information is in the core of interaction between the system components. A jump in the amount of information available within the system and between the system and supersystem in combination with capabilities of deep and fast processing of this information using AI results in fundamental change in the customer experience, business models, business operation processes.

In [8], the authors describe the transformation of the system due to the information flows arising in it. According to this trend, initially information flows in a technical system are used in its control loop. As the technical system develops, information flows grow. At a certain stage, an information model of the activity of the source system is formed; and then such an information model is transferred to the level of the supersystem, where it begins to manage not only a separate system, but also all instances of the source system. Today one can see manifestations of this trend in the form of “digital twins”, IoT platforms and development of complex swarm-like systems.

In [9], the authors explain the relationship between digitalization and exponential growth of the company providing practical recommendations on the directions of digital transformation of the company to create conditions for exponential growth.

TYPICAL SCENARIO FOR TRIZ ENGAGEMENT AND CASE STUDY

Our extensive experience in digital transformation shows that most of our clients usually tend to primacy of the technology: the better technology they find the better solution they receive. They start with looking for a technology provider, who can offer the most advanced technology and can prove it applies well to their industry. When the technology is implemented, it turns out that even though the technology works the overall solution does not provide the anticipated business effect. The desirable disruptive shift has not happened, and the client needs to return to the starting point with wasted money and time. This means that the underlying conflict or contradiction has not been identified and resolved to form a new business model.

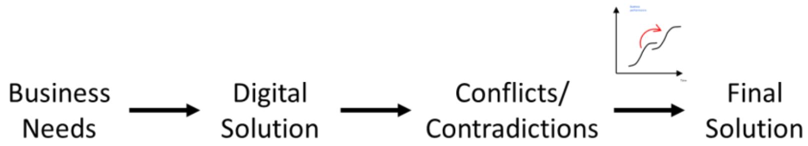

Figure 2. Typical scenario of TRIZ engagement for digital transformation

Let us consider a couple of examples from our practice (see fig. 1). In the first case we had an LPG company that fills gas in cylinders and sells them to consumers via a network of retailers. The company wanted to implement a solution for tracking gas cylinders. Each cylinder was equipped with an ID tag, which was scanned at key points of the distribution process. Tracking was expected to increase cylinder rotation rates, reduce cylinder losses in the supply chain, and reduce manual labor for inventory. Such a tracking solution provides a desirable effect only if the cylinders are tracked through the entire chain including retailers and consumers. The filling company faced an issue with engaging the retailers and their customers in a new tracking process. They did not see much value for themselves in doing extra work of tag scanning for the filling company. Analysis of retailer operation and consumer journey showed that there is another data, which is more critical for them: remaining amount of gas in the cylinder. Monitoring gas consumption would allow retailers to plan cylinder replacement process and provide a better service for consumers. It would bring consumers peace of mind as they do not have to worry about suddenly running out of gas. Knowing consumption data is important also for the filling company to predict demand and identify new opportunities for sales growth. Thus, the final solution combined gas cylinder tracking and consumption monitoring to deliver value to each stakeholder and motivate them to adopt a digital solution.

The second case is related to a producer of medical devices that are used for surgical operations. The company delivers its products to hospitals, where the devices are stored until the hospital uses them for operations. The hospital pays for a device only when the device is used. The hospital periodically informs the company about which devices have been used and the producing company issues an invoice. In the present process the producing company suffers loss through delays of the information from the hospitals. As a part of digital transformation, the company needed to develop a solution for automated notifying about product consumption. The technical solution was based on using a sensor, which was embedded into the product package to periodically send information about package integrity to the cloud. To reduce the sensor cost it was preferable to use an edge device that communicated to multiple sensors in the storage room and then sent aggregated data to the cloud. Such a solution required installation of those edge devices in the hospital. However, the hospitals usually refuse to install any additional infrastructure or do not allow using their own infrastructures unless it gives an essential value to them. As the initial issue of the information delays concerned only the producing company, one had to figure out how to make the hospital a part of the new value chain. One of the possible solutions proposed to use the same infrastructure to let the hospital track their medical equipment inside the building. Thus, a new value was created for the hospital to justify the efforts for installation of an extra infrastructure.

The above examples illustrate typical conflicts between the stakeholders during implementation of digital transformation. In both cases improving only technical parameters of the initial solution does not resolve the conflict. We need to look for a solution in the supersystem, i.e., to redesign our value producing system to include other stakeholders, who were a part of the supersystem of the initial solution.

CONCLUSIONS

In terms of TRIZ evolution laws digital transformation is a transition to a new s-curve for the company performance. This transition occurs due to resolving a certain contradiction that limits scalability of the previous business model. The new model is implemented with a set of digital technologies.

Application of TRIZ in digital transformation projects should primarily be aimed at identifying and resolving contradictions that limit existing business models thus providing fundamentally new value and new opportunities for scaling this value. Transition to supersystem seems to be the most effective approach to resolution of the above contradictions because they are usually associated with the large number of restrictions and limitations.

In most cases companies come to understanding the need to rethink the business model after trying to achieve significant improvements in performance by digitizing and automation of existing processes. Our study confirms that a more efficient approach starts with defining new value proposition followed by selection of the appropriate digital technologies.

ACKNOWLEDGEMENT

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TRIZ ontology: TRIZ model and its application

SUMMARY

TRIZ model includes fundamental notions of TRIZ and describes how these notions are interconnected and interact in the processes of system evolution and solving inventive problems within these systems. TRIZ model enables the classification of different methods, formulated both in TRIZ and in other fields of knowledge and their place in the system's development (evolution).

Preceding versions of the TRIZ model did not embrace specific methods and sections of TRIZ, such as flow analysis, analysis of processes, trends of evolution of technical systems (TETS), and tools for developing creative imagination (CID). On the other hand, several TRIZ tools, for example, failure anticipation analysis or «admit the inadmissible», were not contradictory to TRIZ Model.

The article describes a new version of the TRIZ Model. It was developed as part of the project «TRIZ Ontology».

A distinguished peculiarity of the proposed version of the TRIZ Model is that it enables to introduction into the general classification of such sections and methods of TRIZ, which it had been possible to introduce to the general classification in keeping with their initial meaning heretofore. Besides, it is shown in the article how a generalized Model of TRIZ is refined in other more particular sections in TRIZ tools: TETS (trends of evolution of technical systems), analysis of processes and flows, and Development of Creative Imagination (CID). Moreover, it enables to identify of common features in different methods and tools, unites them and augments them due to the transformation of approaches and notions from one particular method of TRIZ to another as part of the general group, the meaning of which is pre-determined by the classification of the TRIZ Model.

Keywords: *TRIZ model, TRIZ tools, trends of system evolution, Creative Imagination Development, flow model, process model, CID.*

INTRODUCTION

It is possible to identify three stages in the evolution of the notions of TRIZ:

- 1st stage – formation and description of basic notions of TRIZ by its founder G.S. Altshuller [1]

- 2nd stage – is a creation of a glossary of TRIZ terms and a unified system of TRIZ knowledge. [2]

- 3rd stage – improvement of the knowledge system on TRIZ based on the ontology of TRIZ [3].

Similar to the fact that a model of this sphere of knowledge operates in other spheres of knowledge [4, 5] as a foundation, TRIZ Model can serve as a foundation for creating a unified system of TRIZ knowledge. TRIZ Model includes fundamental knowledge of TRIZ and describes how these notions are interconnected and interact in the processes of system evolution and solving of inventive problems inside them. TRIZ Model enables to classify different methods both in TRIZ and in different fields of knowledge and their place in the process of system evolution.

Preceding versions of TRIZ Model, starting with 1994 [6] described in a generalized way the process of improvement of the system, also through solving inventive problems within it, and also application of individual methods and tools of TRIZ as part of this process.

Preceding versions of TRIZ Model did not embrace certain methods and sections of TRIZ, like flow analysis, analysis of processes, trends of evolution of technical systems (TETS), tools of development of creative thinking (DCT). Neither did a number of tools of TRIZ, for example, failure anticipation analysis or «admit the inadmissible» contradict TRIZ Model.

The generalized TRIZ Model, presented in this article, contains a description of the reverse use of the TRIZ Model in analysis of the systems. This innovation made the classification of TRIZ methods and tools based on TRIZ Model more complete, enabled to generalize of tools and methods of TRIZ, in which general characteristics had not been identified before, for example, reverse function-oriented search and the method of the «Goldfish», failure anticipation analysis and the method «A step back from IFR».

A high level of generalization of the TRIZ Model enables to analyze from the unified positions of the methods and the tools of systems evolution, developed not only in TRIZ but in other fields, for example, theory of constraints (TOC), Design Thinking, Lean Production, Six Sigma and other known methods for improvement of the system. It simplifies mutual penetration of different methods of analysis of systems with similar functions in keeping with the TRIZ Model.

Preceding versions of TRIZ Models [6] explained how individual models and tools of TRIZ could be used as part of processes for modifications of systems and/or solving inventive problems. A specific feature of proposed version of TRIZ model is the fact that it demonstrates how the trends of evolution of technical systems (TETS) work in process of variation of systems, where and how models and tools of DCP can be used as part of these processes, and also how new models and tools are integrated with these processes, for example, the model of flows and processes and tools intended for work with such models.

APPROACH TO DEVELOPMENT OF TRIZ MODEL

HISTORICAL ANALYSIS OF TRIZ MODEL

It is possible to single out 4 stages in forming and development of TRIZ Model:

1. 1988, textual description of the sequence of problem solving in ARIZ through creation of a model of the problem and model of solution in the form of IFR appeared, there was no visual presentation of this sequence at this stage [1].

2. 1994, the visualization of the pattern of solving inventive problems is proposed, which implies the use of models of the problem and models of solutions of these problems, but in this case not only for ARIZ, but also for TRIZ on the whole, for example, with the application of standards and Su-Field analysis [6], however, this pattern did not reflect any tools of TRIZ, directed at the development without formulation of contradictions, for example, trends and lines of system evolution, typical models of Su-Field structures evolution. Figure 1 presents the pattern of TRIZ model of 1994.

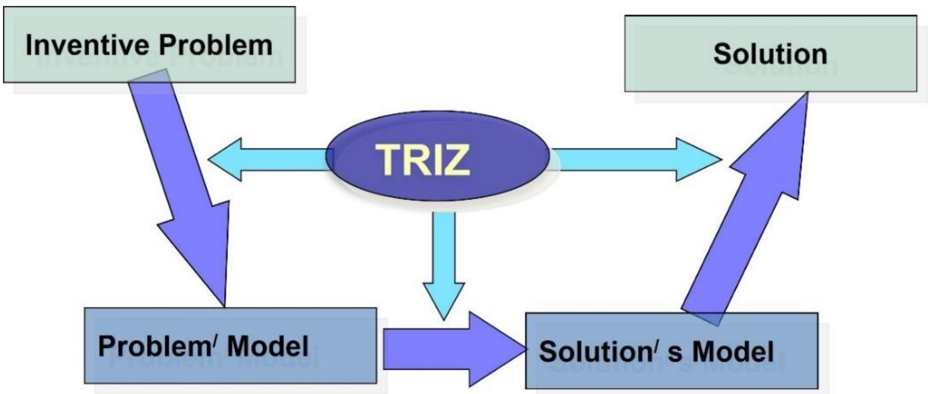


Figure 1. Model of TRIZ (1994)

3. 2011–2012, the pattern of solving inventive problems is augmented with the pattern of system evolution through the creation of a model and model of a new system. [7]. The pattern was augmented by the model of inventive thinking: analysis, synthesis, and evaluation [8]. The model of TRIZ of 2012 is presented in the figure below.

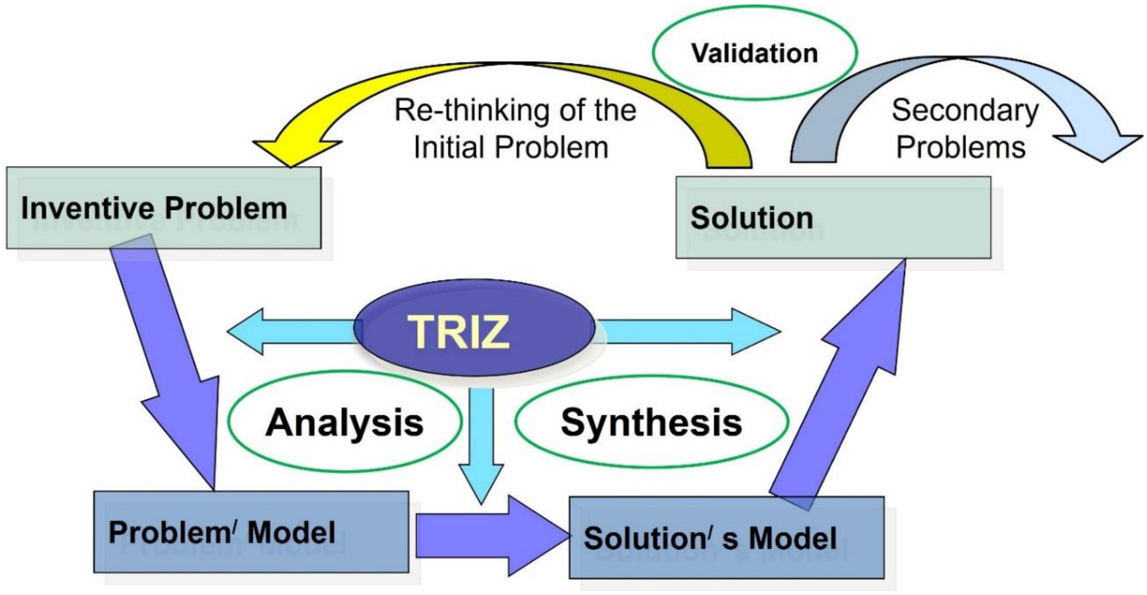


Figure 2. TRIZ Model (2012)

TRIZ Model of 2012 did not take into account certain methods of analysis of system and solving inventive problems, like failure anticipation analysis, step back from IFR, and other methods associated with reversion of analysis of systems and problems.

ONTOLOGICAL APPROACH

Analysis of the preceding version [9] and the development of a generalized TRIZ model was performed as part of the project on the development of TRIZ ontology. The research was based on the approach, described in [3].

TRIZ Model was presented in the form of an ontological diagram. The analysis of the ontological diagram of the TRIZ Model enabled to define missing and inexact bonds between notions, included with TRIZ Model.

Based on the results of this analysis, the ontological diagram of the generalized TRIZ model was developed.

Further on, for validation of the generalized TRIZ Model, the work was conducted on compiling ontological descriptions of basic tools and methods of TRIZ and their connections with the generalized model of TRIZ, i.e., the same approach to their formalized description was used for different tools and methods. As a result of this research work, described methods and tools were specified by the authors and also the used terminology of the very TRIZ Model was specified too. The results of the research are quoted in the present article.

GENERALIZED TRIZ MODEL

TRIZ Model is a schematic idea of transition from the system AS IS to the system TO BE through the TRIZ-model of the system, problem inside the system, and solving of the problem.

TRIZ Model includes main components of inventive thinking, which are necessary for forming and transforming models: 1) analysis, 2) synthesis, and 3) evaluation. TRIZ Model enables to systematize of all basic TRIZ TOOLS since they (according to their function) correspond to certain transitions in TRIZ Model.

A specific feature of the proposed generalized TRIZ model is the presence of 2 types of transition cycles: 1) external cycle of transition to TRIZ Model corresponds to direct application of TRIZ Model, 2) internal cycle of transitions corresponds to reverse application of TRIZ Model with the reversion of analysis of system or problem.

The generalized TRIZ model is presented in the next figure.

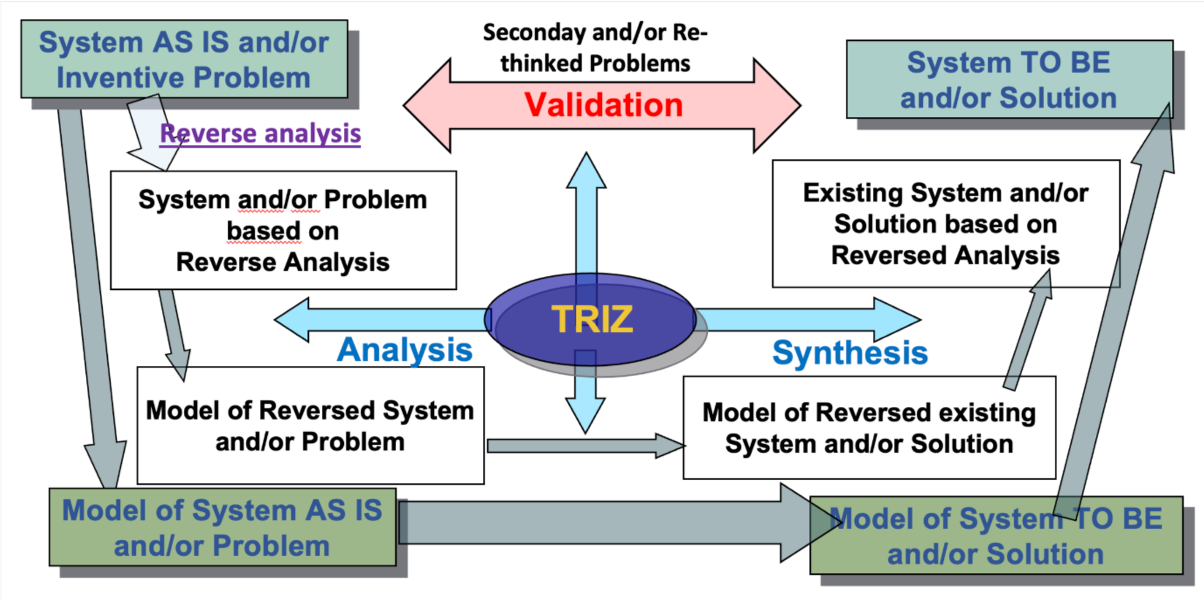


Figure 3. Generalized TRIZ model

In case with direct application of TRIZ model a transition from the system AS IS to the system TO BE and from the Problem to the Solution of the problem.

In case with reverse application of TRIZ model reversion of analysis takes place for the system or problem.

All transitions are carried out through corresponding models: model of the system (problem) and model of new system (solution).

Reverse use of TRIZ Model is associated with the reversion of analysis: instead of analysis of useful system – analysis of harmful system, instead of analysis of contradiction – analysis of IFR, etc. It is important to pay attention to the following: in this case we are not talking about the reversion of the system, but of reversion (change) of analysis being conducted. It is possible to single out two groups of reversion of analysis.

Reversion according to directions and goals of analysis:

- «Instead of a question why this or that phenomenon took place (CEA – cause/effect analysis) – a question is asked how to create this phenomenon» – this is research work based on failure anticipation analysis;

- «Instead of the improvement of the system – its deterioration» – this is failure anticipation analysis or analysis of a harmful machine.

- «Instead of eliminating a contradiction – creation of an image of IFR» – this is a Method of «Step back from IFR»;

- «Instead of improving the system – reconstruction of its state relating to the time, when it was improved earlier» it is a method for finding techniques and other tools for system evolution;

Reversion according to the object of analysis:

- «Instead of search for the tool – search for the product» is a reverse function-oriented search (reverse FOS)

- «Instead of creating a fantastic object from a real one – creation of a real object from a fantastic one» – this is a method of a goldfish, «Overton windows», etc.

TRIZ model enables to classify TRIZ tools according to their function.

Here are methods of analysis used for creation of a model of system or problem:

- Contradictions of requirements and specific features (technical and physical)
- Su-Field (El-Field) analysis
- Cause/Effect analysis
- Functional analysis
- FCA (function cost analysis)
- Flow analysis, analysis of processes
- Benchmarking of alternative systems for problem statement
- MPV-analysis

Analytical methods of problem statement, developed beyond TRIZ (theory of constraints (TOC), Design Thinking, Lean Production, 6Sigma and other methods)

Methods of synthesis for creating models of new systems or solving a problem:

- Ideal final result (IFR)
- Principles and techniques for resolving contradictions
- Indices of effects (physical, chemical, etc.)
- Benchmarking of alternative concepts for problem solving
- Lines of system evolution
- FOS (function-oriented search), alternative systems
- Analysis of resources enabling to conduct search for a solution

Complex tools of analysis of problems and synthesis of models for solving them:

- ARIZ
- Table of application of techniques
- Systems of standards for inventive problem solving
- Trends and tendencies of system evolution
- System operator

Methods based on reverse application of model TRIZ model:

- Failure anticipation analysis
- Analysis of harmful machine
- Step back from IFR
- Reverse FOS
- Goldfish
- Synthesis of a new system
- Method «Admit the inadmissible»
- Restoration of inventive technique
- Methodology of «Overton windows»

TRIZ model enables to structure and standardize the description of TRIZ tools methodology for using them in project activity, find general approaches to development and complex integration of different TRIZ tools.

CREATIVE IMAGINATION DEVELOPMENT (CID) TOOLS IN TRIZ MODEL

Until recent time tools and methods of CID occupied a special place in the body of TRIZ knowledge: on the one hand, CID is a part of TRIZ, while on the other hand these methods were used for elimination of psychological inertia and development of creative thinking, but not for solving problems or development of systems (with regard to particular exceptions). [10] As part of generalized TRIZ model, the tools and methods of CID are inscribed in the process of system evolution.

CID tools are intended to work with that part of TRIZ model, which describes the transformation of systems.

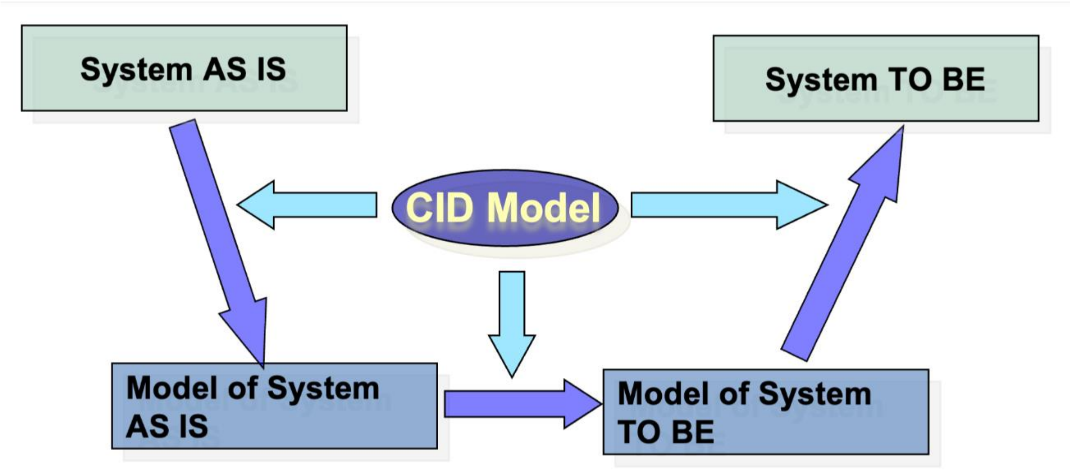


Figure 4. Model of application of tools of CID (model TRIZ-CID)

CLASSIFICATION OF CID TOOLS

At various steps of transformation of systems, they use different tools of CID. [11] Accordingly, the tools of CID could be classified in terms of type of transformation, which could be performed with the aid of this or that tool.

Table 1. Classification of tools of CID according to the type of transformation of systems

Group of methods intended for analysis and modeling of systems	Group of methods of synthesis based on the analysis of the system	Group of methods of synthesis of system
- System operator - Morphological analysis - Synectic - Smart little men - «Viewpoint» - Method of tendencies - Method of «Snowball» - Heurorhythm	- Morphological analysis - FOM (Focal Objects Method) - Synectic - Techniques of fantasizing - Size-Time-Cost Operator - Smart little men - Method of tendencies - Change of system of values - Method of «Snowball» - Heurorhythm	- Methods of creating plots of fantastic stories and tales - Techniques of art creativity

CID tools often contain several successive steps, which are related to different stages of transformation of systems, therefore, some methods got into two groups at once.

VARIANTS OF APPLICATION OF CID TOOLS IN TRIZ MODEL

Further on we shall consider several variants of using CID tools in TRIZ Model.

Variant 1. Obtainment of a fantastic idea (system) based on an actual system (prototype).

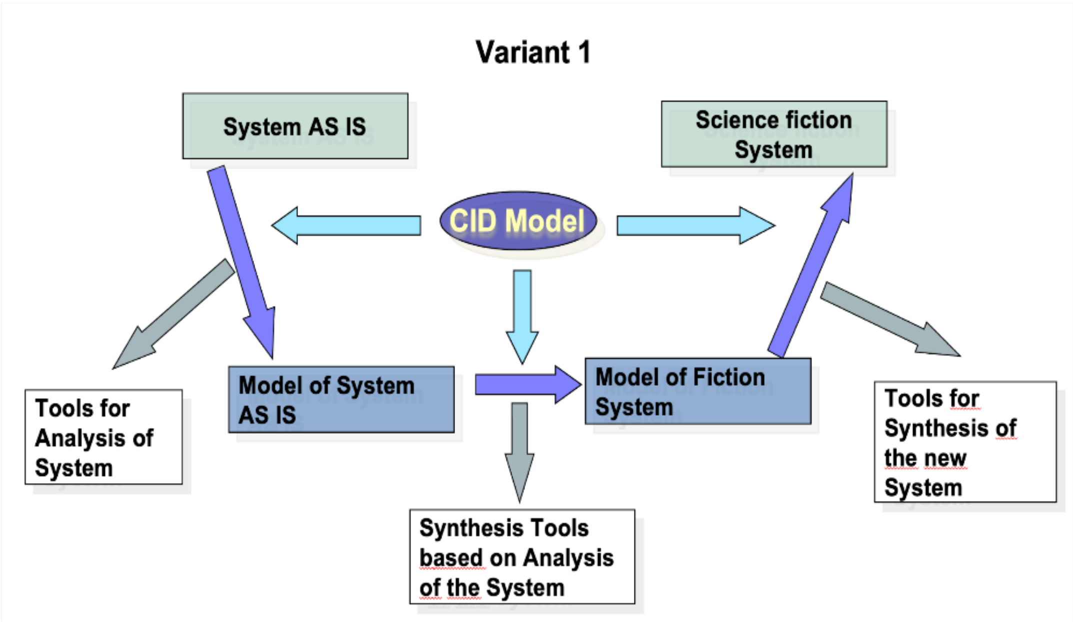


Figure 5. Obtainment of a fantastic idea based on an actual prototype

In direct application of TRIZ Model with the aid of CID tools a fantastic system is created, and problems are solved, which are associated with such a system.

Variant 2. Development of a fantastic idea (system) based on known (or synthesized) one.

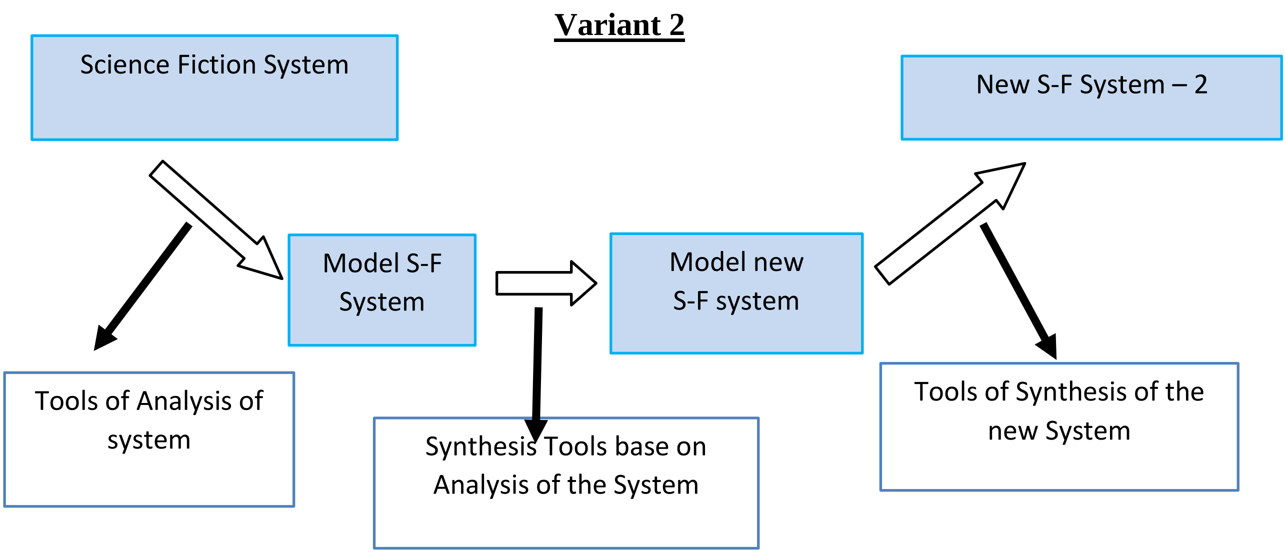


Figure 6. Development of a fantastic idea

Variant 3. In case with successive (cyclic) application of TRIZ Model it is possible to create several fantastic systems, which means, at bottom, to study the evolution of a fantastic system.

Variant 3

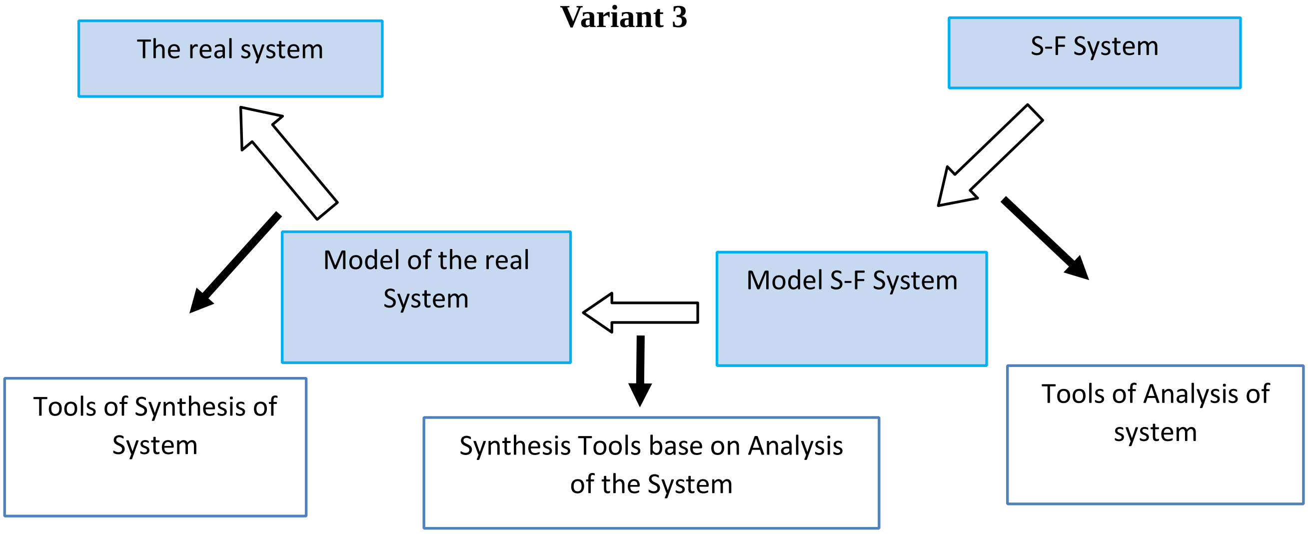


Figure 7. Reverse application of TRIZ model and tools of CID.

In case with reverse application of TRIZ Model due to reversion of goals it is possible to synthesize the SYSTEM-AS-IT-SHOULD-BE. The last circumstance explicitly points to the possibility to include the tools of CID with the processes of development of actual systems and solution of actual problems.

Let us analyze examples.

Morphological analysis – Variant 1 of the model TRIZ-CID [12].

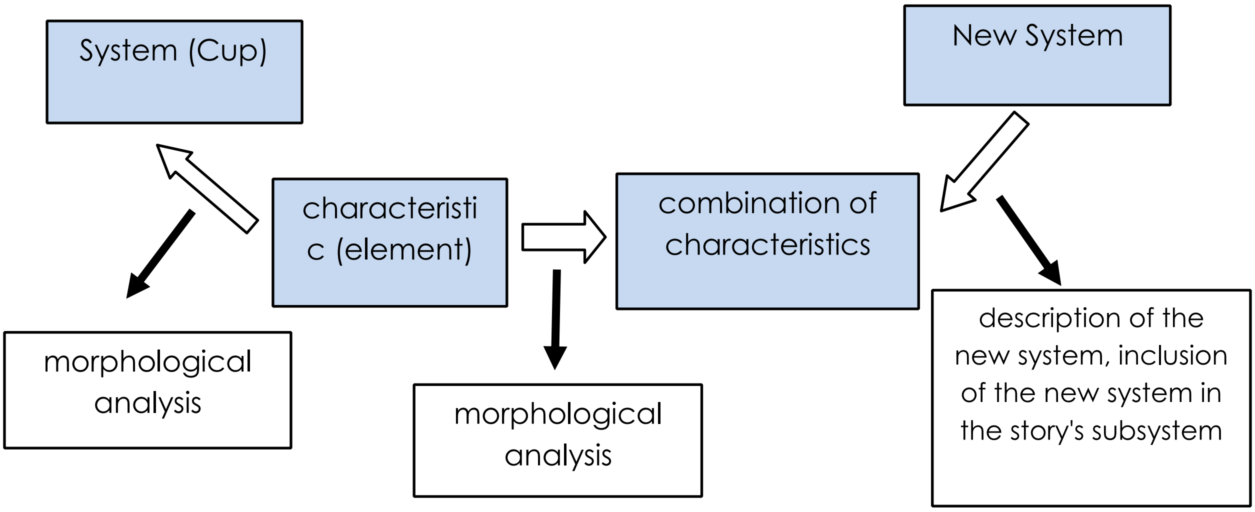
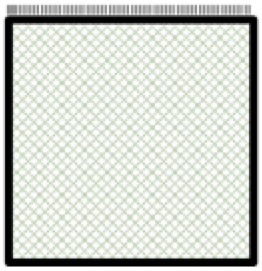


Figure 8. Model TRIZ-CID, variant 1. Example. Morphological analysis.

Step 1. Selection of the object. CUP.

Step 2. Creation of a morphological table. Identification of basic features (components) of the system and the variants for implementing them.

		1	2	3	4	5
A	vessel (shape)	round	square	Truncated cone	Flat	tube
B	Handle (shape)	No handle	ball	Continuous rectangular	tea cup holder	hem
C	bottom (add. function)	heating	cooling	insulation	Gassing	stirring
D	Hem (shape)	bell	narrowing	With fur	With filter	With a nose
E	picture	glazing	stickers	Thermo-paint	Hollows	Relief
F	material	Porce-lain	glass	plastic	Wood	eatable



Step 3. Selection of variants.

Selection of variants: A2; B1; C3; D3; E5; F5

Square cup, without a handle, with a heat insulation bottom, with furs on the hem, with relief picture, made of eatable material.

Step 4. Description of obtained idea.

Waffle cup, glazed inside, square-shaped (in keeping with the shape of waffles), without handle. Is intended for a small amount of hot drink.

Step 5. Use of the idea in a story.

In this case it might be an episode reflecting nature-saving approach.

«Snowball» method – Variant 2 of model TRIZ-CID. [13]

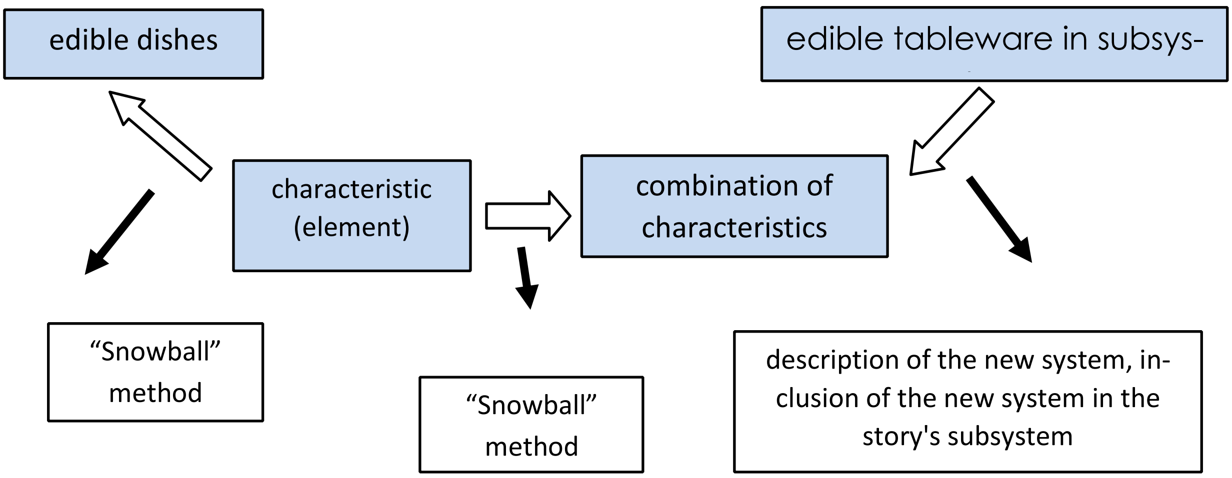


Figure 9. Model TRIZ-CID. Variant 2. Example. «Snowball» method

Step 1. Selection of fantastic object – eatable dishes.
Step 2. Short description of peculiarities of a fantastic object (in our case – from Variant 1).
Step 3. Identification of new mutual connections and interactions in different fields of activity.

FIELDS OF HUMAN ACTIVITY RECOMMENDED FOR ANALYSIS

Human lodging. House, flat, furniture, rooms, bathroom, human behavior in everyday life, etc.
Needs. Clothes, footwear, nutrition, sleep, etc.

Social life. Methods of human communication. Mass media. Means of management. System of education. System of health protection.

Family. Relations between husband and wife, children, parents, etc., how people get acquainted, how people part, etc.

Relationship at work. Profession, working milieu, labor operations.

Economy. Industry, Agriculture. Trade. Transport, Communication.

Politics. Geopolitical situation. Government, Parliament, parties, election, etc.

Arms and wars.

Art, culture, sports. How people spend their free time – hobbies and amusements.

Nature. Ecology. Animals and plants.

Planetary phenomena. Nature. Climate. Cataclysms.

Step 4. Inclusion of obtained idea with the supersystem of the story.

Edible dish is a disposable perishable product (which needs special conditions of storage). In this case the number of reusable dishes is reduced – the place for storage is free. In food stores the sets of dishes are on sale together with eatable dishes. The time for cooking is saved as well as for doing the house, etc. Sets of products and dishes could be accompanied by the information concerning the content of substances, calories, etc., i.e., recommendations concerning healthy nutrition. Changes of certain traditions –national cuisine, dishes cooked for holidays, may take place. Dinner break can be reduced by equipping the canteens (like shops) with ready sets of products in eatable containers. There is no necessity to locate kitchens in each canteen. It is necessary to grow special plants for production of eatable dishes and containers. International trade not in individual kinds of products, but in packing, probable, such a method of nutrition is more ecological.

«Goldfish» method – Variant 3 of Model TRIZ-CID. [14]

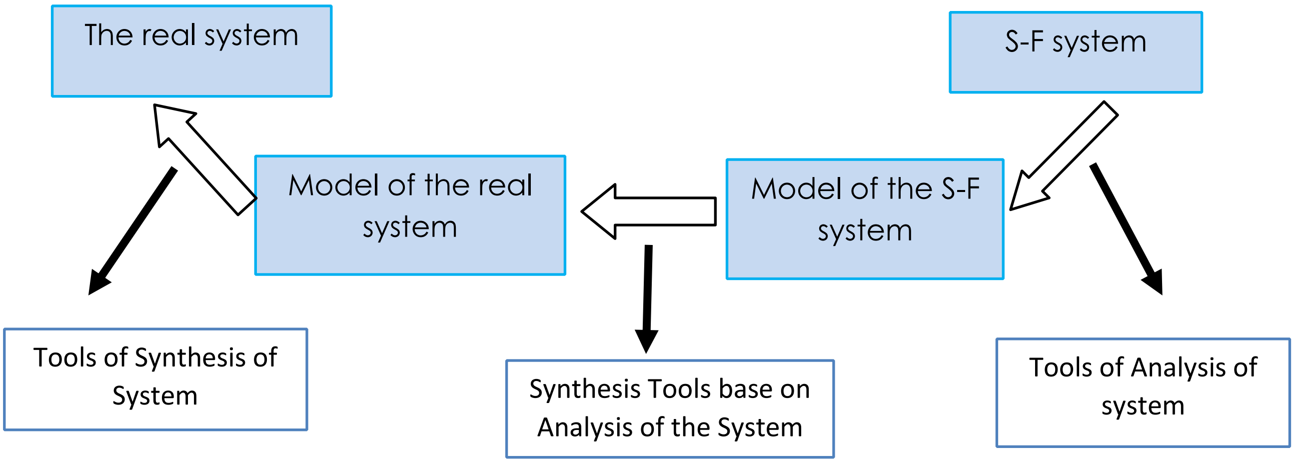


Figure 10. Reverse application of the model TRIZ-CID. Example. «Goldfish» method.

«Goldfish» method is the opposite of «Snowball» method. In order to work according to the method of «Goldfish», it is necessary to follow the reverse path: from fantastic idea (system) to actual prototype, «taking off the layers of reality», and, thus, reaching the «unexplainable residue».

«Goldfish» method proposes to analyze, of which components consists fantastic situation (or system). Classic example: talking goldfish – FS 2.

- What should a «talking goldfish» look like? The fish opens its mouth and the sounds of the human speech are heard – FS 2

- Can a fish open its mouth? Yes, especially if it is taken from water.

RS 1 – Real situation 1: the fish, opening its mouth. FS 1 – the sounds of the human speech are heard. It remains to explain, why the sounds of the human speech are heard at that moment (for example, somebody says something behind the back of the person, who extracted the fish from the water…).

CONCLUSIONS AND MODELS OF RESEARCH

1. The application of CID tools can be described with the aid of TRIZ model.
2. CID tools are an inseparable part of the body of TRIZ knowledge and could be used directly for development of systems and for solving problems within these systems.
3. TRIZ model enables to single out classification features for CID tools. Two classifications are proposed: based on the origination of tools (based on ontological map of «CID tools»); and according to the type of transformations of systems in TRIZ model.
4. 3 variants of functioning of CID tools according to TRIZ model are analyzed.
5. Proposed variants of using TRIZ tools can change the approach to teaching a course of CID.

OF TRIZ MODEL

We see how extensively today the model and the tools of TRIZ are used today for solving inventive problems in informational ([15, 16] and business systems [17].

Preceding versions of TRIZ model described the change of technical system, but did not embrace other types of systems.

In the proposed version of the model of TRIZ we widen the notion of the system including into it not only technical systems, but also flows and processes. It enables us to extend the application of TRIZ model, including other types of systems such as information systems and business systems as a mixes of engineering system(s), processes, and flows.

The diagram below presents the ontology, which widens the notion of the system in TRIZ.

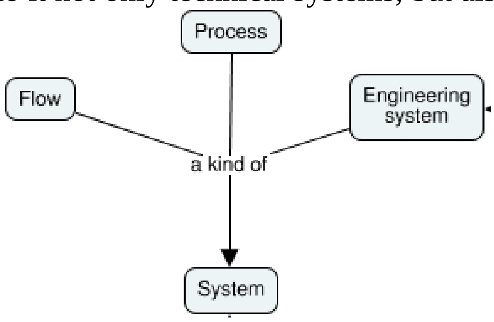


Figure 11. Widening of the notion of "system" in TRIZ

The diagram shows, in particular, that the technical system is an example of a more general notion of "system". Other examples of this general notion are "process" and "flow".

MODEL OF FLOW AND FLOW ANALYSIS

Model of the flow and flow analysis were derived from function analysis more than 20 years ago and it served as a separation point between these two tools. Further on, in spite of their logical connection, the development followed parallel ways, which, in its turn, led to difference of notions and of approaches.

In the process of using functional analysis a problem appeared concerning the description of states and requirements for systems consisting of flows – travels in space of material, energy or information particles. [18]. In order to broaden the potentiality of description and that is, to broaden the formulation of contradictions and solving of such problems, a flow analysis was additionally created as a specific case of function analysis.

Looking through the prism of generalized model of TRIZ at the flow analysis not only in that part, where it coincides with the function analysis, but in the optimized techniques and patterns of solutions, it is possible to surely say that the Generalized TRIZ Model is in full sense followed by the flow analysis, which is a derivative of function analysis, which, in its turn, also bears relation to TRIZ model. Therefore, TRIZ-based set of tools intended for work with flows is also well classified according to types: analysis, synthesis, evaluation and reversion of analysis of system/problem. In flow analysis the role of the system AS IT IS and AS IT SHOULD BE is performed by the system of flows. The described successive steps concerning the application of TRIZ tools for solving inventive problems and transformation of systems as appendix to flow analysis are shown in the diagram below.

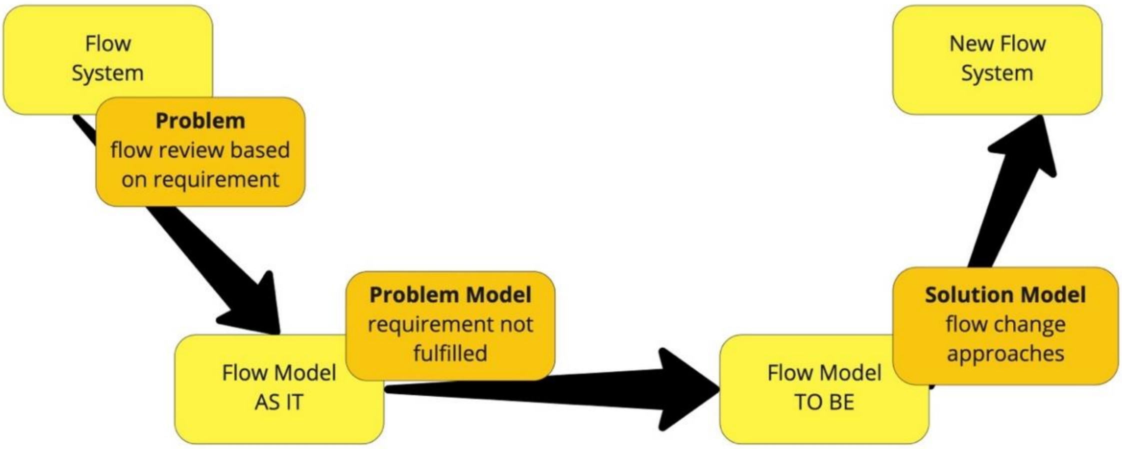


Figure 12

The diagram for application of flow analysis in keeping with direct model with two lines of transition: from the system of flows «AS IT IS» to the system of flows «AS IT SHOULD BE» and from non-compliance with the requirements to compliance to them. The transitions are performed respectively through the flow Model «AS IT IS» to flow Model «AS IT SHOULD BE».

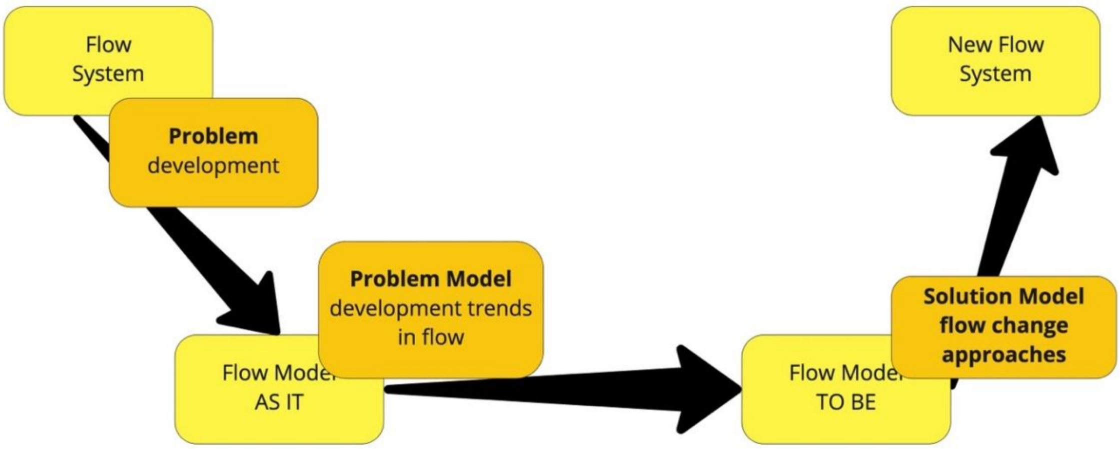


Figure 13

In this case the creation of a flow model is associated with the identification of necessary and sufficient characteristics and evaluating them in terms of compliance to the requirements. The obtained model of the system of flows «as it is» based on the «rules of creating a flow model based on non-compliance to the requirements» is transformed into a model of the system «as it should be». Working with such a flow model using the techniques of changing the flows, like, nevertheless any other TRIZ methods, a new system of flows is created, which corresponds to the requirements put forth.

The second way of application of the generalized TRIZ model in the system of flows will be like «Function-Oriented Search». Flow-oriented search does not imply any non-compliance with the requirements, however, uses «The rules of application of regularities of flow evolution in TS». Such application of flow analysis is similar to the first case; it requires the identification of characteristics and creation of existing model for the purpose of describing a system of flows.

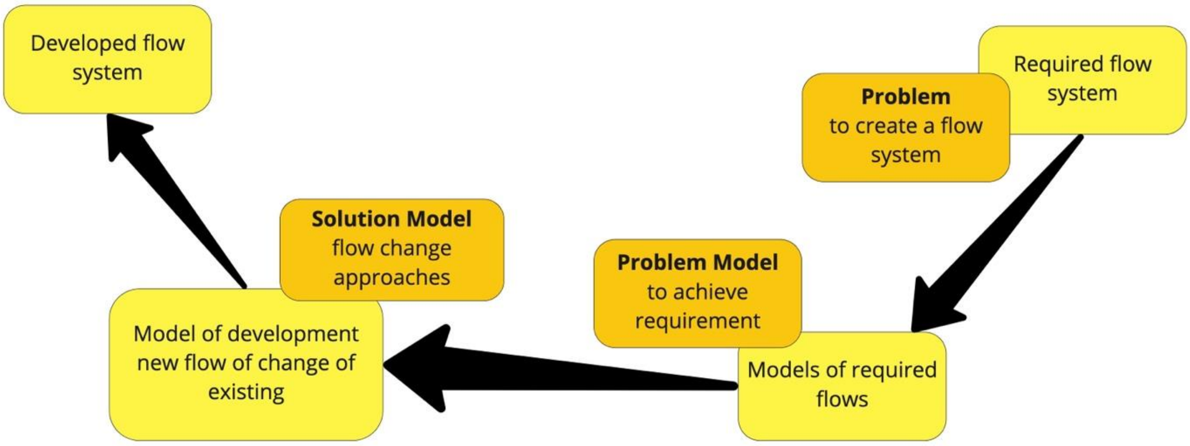


Figure 14

Described and characterized model of flow system can be changed by optimizing and developing the system, forecasting the next step in the development.

Generalizing direct analysis by:

Directions and goals:

o Elimination of disadvantages of the system of flows;
o Checking the flows for compliance with the requirements.
o Finding contradictions in the system of flows;
o Cause/Effect analysis of the flow system;

· The Object:

o Trimming the system of flows and increasing the ideality of flows

The reverse application of the generalized TRIZ model needs to be described in the case of flow analysis. Though in the statement of the problem concerning the reconstruction of factors and actions in case of non-obvious changes of the flow, or restoration of the changes which had taken place but not planned, it is necessary for flow analysis. Although when setting the task of restoring factors and impacts with no obvious changes in the flow or restoring changes that have occurred but not planned in the flow analysis, it is necessary. Completing the inventory of tools, they use the reverse application of the TRIZ model and the following diagram is obtained,

Generalizing the reversion (change) of analysis according to:

· Directions and goals:

o Failure anticipation analysis or analysis of harmful machines in the system of flows.
o formation of the image of ideal flow or component and application of the method "Step back from IFR";
o Restoring past changes as it was improved before
o Application of system of flows for the purpose of obtaining new goals

Object:

· «Instead of creating a fantastic flow from the real one – creation of a real flow from a fantastic one» – this is a goldfish method.

· Application of known systems of flows to new situations, in new systems

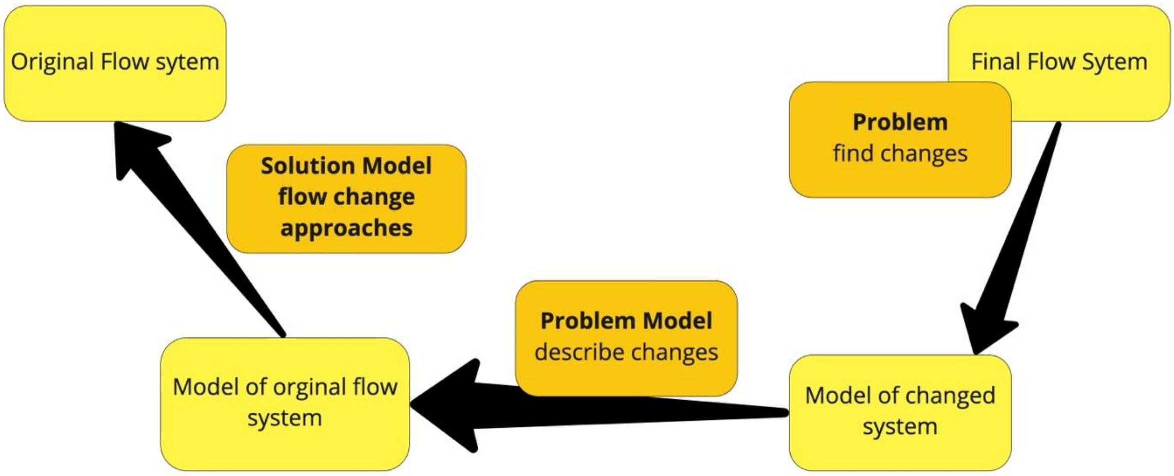


Figure 15

Examples of such use:

An existing system only suits us according to one or several parameters. Typical examples of the transfer of substance and rejection inside this flow are described in several analyses of the problems. Such approaches led to the use of FIFO in operations for storage of perishable goods, Just-in-Time chains of supplies, and the reject of this method in those very chains of supply. [19]

The application of reject analysis in information flow (described in less detail) and the analysis of information flows for non-compliance with the requirements is expensive, slow, and non-reliable. There may be distortions and other criteria are also noted. A less-described application is the analysis of defects in the information flow, and the analysis of information flows for non-compliance with the requirements – expensive, slow, unreliable, distortions and other criteria put forward. It is appropriate to mention the transfer of call centers to India and the necessity to solve another problem – returning them. [20] Lean transformation in the pure service environment: the case of the call service center. [21, 22]

Illustrating the next application of the generalized TRIZ model in flow analysis, we describe a normally working system, at which we want to look from the viewpoint of potential development. Then, accepting the trends and techniques and evaluating the obtained effect from the viewpoint of improving the system, it is possible to forecast or to create the following generations.

Often, if we don’t know, what method was used for developing this process, it is difficult to define, if it had been the solving of the problem or a targeted search for improvements.

Reverse application of generalized TRIZ model is associated with the exploration, research or restoration of flow changes, made within the system. In this case we have already a new system with changed characteristics, but we don't know the reason for that. It is necessary to state the (detailed) influence of external medium, super- or subsystems and other non-obvious changes. Establishing the influence of the (detailed) external environment, above or below systems, and other non-obvious changes. It also affects the exploration or research of actions of the competitor or the use of the technique “step back from IFR”.

PROCESSES IN MODEL OF TRIZ

As it is shown in Figure 16 (ontology of the system), the process is an example of the system. Respectively, model of TRIZ for processes can be obtained through incorporation into the source TRIZ model of the system of processes. Model of TRIZ for the system of processes is presented in the following figure.

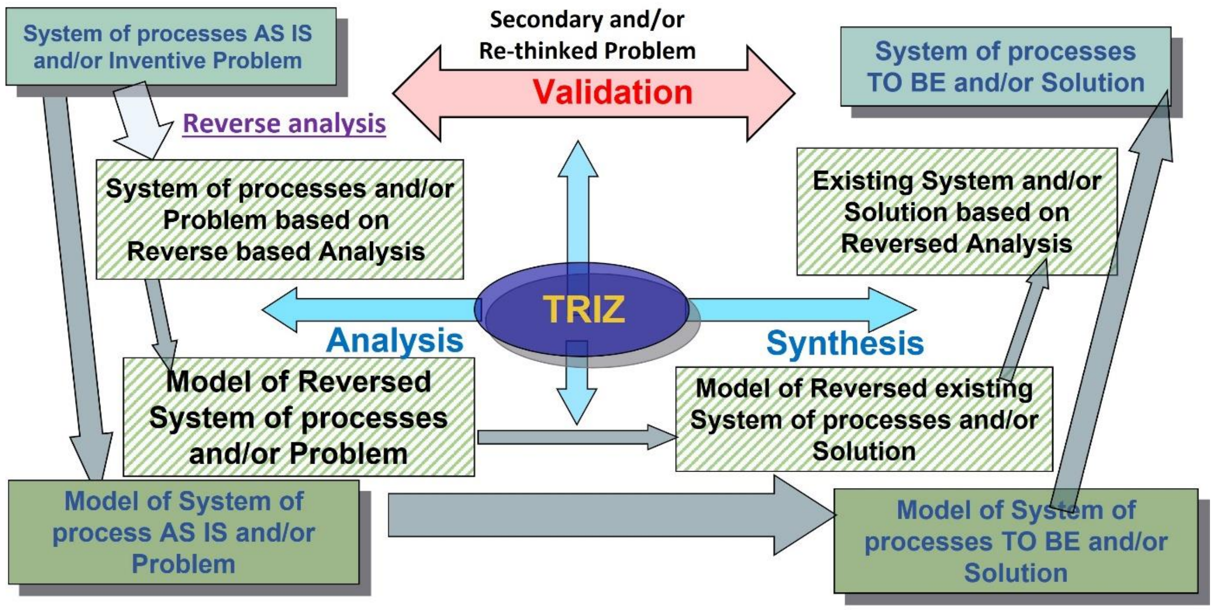


Figure 16. TRIZ Model for a system of processes

It is shown in the figure that TRIZ model in this case describes the transition from the system of processes AS IS to the system of processes TO BE, using the same ways, through which the transition is implemented in technical systems:

1) Through changing the system of processes according to the trends, lines of evolution or through patterns of transformation of systems, including techniques and inventive standards;

2) Through identification of an inventive problem and elimination of contradiction in the source system of processes.

In the future we are going to investigate how the reverse application of TRIZ model can be applied to the system of processes and to what results it can lead.

MODEL OF PROCESSES FOR TRIZ MODEL

To provide for a transition from the system of processes AS IS to the system of processes TO BE based on the trends of evolution and patterns of transformation it is possible to use the existing models of the processes and systems of processes. [23–25]

To provide for a transition through identification and solving of an inventive problem, the existing models of processes require optimization in terms of modeling the disadvantages (or negative effects – NE).

In order to describe the NE of the process as well as elements of the process, which are changed during solving the inventive problem or during transformation to the process TO BE, parameters are introduced for the operation and for the object. Such parameters enable to add to the model such information, which is necessary for formulation of inventive problems and identifying the changing elements of the process.

In order to create the ontology of the process different types of NE, which are encountered in the processes were collected and analyzed. A NE in the process could be related to one of 3 types: NE related to operation, NE related to object or NE related to the whole process.

The table below presents the types of NE in the processes.

Table 2. Types of disadvantages in the processes

Negative effect related to operation	Negative effect related to the object	Negative effect related to the whole process
Duration of the operation	Quality of the object (on the output of the operation), or reject	Repetitions
Cost of the operation	Cost of the object	Negative effects in ramification of the process
Operation, which does not add value	Negative effects of the plan (information object in the processes of management)	Negative effects in integration of the process
"Bottleneck"	Negative effects of the fact (information object in the processes of management)	Negative effects related to "feedback" (rate of reaction, dis-synchronization) in the management processes
	Negative effects of plan correction (information object in the processes of management)	

Types of negative effects in the model of the process (See Table 2.) allow to make a following steps: to define the typical patterns of contradictions in the processes and to systematize typical patterns for elimination of contradictions in the process.

CONCLUSIONS

1) A new version of TRIZ model is proposed, which unites practically all private models and tools of TRIZ, including the model of CID tools, which had not been included earlier.

2) New version of TRIZ model shows how the trends of system evolution are integrated into the process of changing the system and solving inventive problems.

3) New version of TRIZ model can be enlarged due to integration with other fields of knowledge. In particular, we showed how a new version of TRIZ model can be extended to model of flows and processes.

4) We regard the new version of TRIZ model as the ground for the database on TRIZ, a sort of link between already created and new tools and methods.

5) It has to be specially noted that the new version of TRIZ model shows the gaps in fields of TRIZ knowledge, which require filling. And consequently, TRIZ is waiting for new developers and for obtainment of results of their work in this direction.

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Laws of evolution: from technical to functional-and-targeted systems

SUMMARY

Laws of technical systems evolution (LTSE) are the main constituent and basis of TRIZ as a scientific discipline. In the present article the authors prepared criteria of scientific correctness of wording of laws of evolution and analyzed the complexes of laws of system evolution, which are already known in TRIZ. Based on this, the authors formulated dynamically developing complex of evolution's laws of functional-and-targeted system (ELFTS), which identifies the general laws of evolution both of live and social-and-cultural as well as social-and-technical systems. In particular, it became possible to show the common features of TRIZ and theory of creative personality evolution (TECP), based on the fact that the subject of both theories is the functional-and-targeted system – technical system and creative personality. The authors worded the unequivocal difference between the law of evolution and the line of evolution of functional-and-targeted systems. The scientific models of functional-and-targeted systems are based on the goal of the system, program of attaining it, operation principle of the system aimed at fulfillment of the programs and complexes of functions of the operation principle.

Key words: *theory of inventive problem solving (TRIZ), theory of evolution of creative personality (TECP), complexes of evolution laws of functional-and-targeted system (LEFTS), operation principle, lines and spaces of system evolution, evolution studies.*

INTRODUCTION

Laws of technical systems evolution (LTSE), developed by G.S. Altshuller in 1977 [1] became the basis for forming the theory of inventive problem solving (TRIZ). Even now LTSE remain constituent and basis of TRIZ. The laws allow us not only to research the process of technology evolution, but also to put forward the forecasts concerning the trends of this evolution. In spite of numerous developments in this field carried out by TRIZ specialists, still it is rather vital to proceed with research in this field. There are several reasons for that:

-TRIZ is actively used for development not only of technical systems, but also non-technical ones: information technologies, business, social systems, etc.

- known complexes of laws of technical systems evolution have insufficiently accurate wording, there are no unified ideas of LTSE, many researchers doubt the compliance of these laws to scientific criteria;

- there is no strict demarcation between the laws of development and lines (regularities) of system evolution.

In the present work the authors studied the criteria of scientific laws and, based on them, formulated the complex of laws of evolution of functional-and-targeted systems, which is extended not only to technical systems, but also to any functional-and-targeted systems: technical, biological, social, scientific and other systems, in which the complexes of functional connections between elements for the purpose of attaining a certain goal are formed.

1. SHORT ANALYSIS OF PUBLICATIONS ON THE TOPIC OF LTSE

It is possible to single out the following stages in the formation and development of complex of laws of technical systems evolution.

1. The first stage may be related to the end of the nineteenth century, when technology was looked upon as a secondary component of more important processes. Karl Marx, for example, was less interested in machines proper, paying more attention to their influence upon economy, society and capital formation. In 1867, in the first volume of «Das Kapital», describing the role of machines in formation of the capital and enhancement of exploitation of workers, Karl Marx remarked that «it is necessary to study how means of labor is transformed from a tool into a machine and how a machine is different from an artisan's tool». [2] Frederick Engels in his article «History of a rifle» [3] in reality wrote about popularization of articles of military technology, which were new at that moment. He concludes his article in the following way: «Not a single conscious soldier should be ignorant concerning the fact according to which principles the arms are created and how it should function…». However, these works contained the fundamentals of the evolutionary approach to studying the history of evolution of technology and the objective character of the processes, which form the basis for this evolution, though the trends or laws of technology evolution were not formulated. The transition processes from the first stage to the second one characterized by works of many researchers, who focused their attention mainly on technology and its evolution, formed classifications and worded separate regularities of technology evolution, for example, the works of P. K. Engelmeier and of other authors. [4, 5, 6] The tools used in creation of an invention (as a key object of technical systems evolution were never analyzed and the notion of a technical system as a key element of technology as a whole was never singled out.

2. The second stage of evolution of LTSE were the works of G.S.Altshuller, starting with the article written in 1956 jointly with R.B.Shapiro. [7] LTSE were first formulated by Genrich Saulovich Altshuller in 1977 and then published in 1979 in the book. [8] Table 1 quotes a complex of trends of technical systems evolution, proposed by G.S.Altshuller.

Table 1. Laws of technical systems evolution

Statics	Kinematics	Dynamics
1. Law of completeness of system parts. 2. Law of «energy conductivity» of the system. 3. Law of coordination of rhythm of system parts.	4. Law of increasing ideality of the system. 5. Law of irregularity of development of system parts. 6. Law of transition to supersystem.	7. Law of transition from macro-level to micro-level. 8. Law of increasing the degree of Su-Field feature.

Beside the system of trends G.S. Altshuller formulated several lines of technical systems evolution, for example, S-curve evolution line, line of transition to supersystem «mono-bi-poli», line of emptiness. [9, 10]

G.S. Altshuller singled out two approaches to search and specification of laws of technical system evolution:

- so called «patent layer» – analysis of hundreds or thousands of inventions from different fields of technology during 20–50 years;

- «patent hole» – analysis of history of development of inventions on an example of one and the same system during thousands of years or since the very beginning of its existence, for example, watch, arms, houses, etc.

3. The third stage of development of LTSE is associated first of all with the works of disciples and followers of G.S. Altshuller regarding the development of a complex of LTSE according to several directions:

- illustrations on examples of already formulated laws of technical systems evolution, for example, in the book; [11]
- specification of wording of trends and lines of technical systems evolution; [12]
- the addition of new and detailing of known trends of the evolution of technical systems; [13, 14]
- augmentation of new trends and refinement of known trends of technical systems evolution-application of LTSE as tools for forecasting of technical systems evolution and solving inventive problems, enhancement of instrumentality of LTSE complex application;
- extending the laws of technical systems evolution to other kinds of systems: biological, art systems, journalism and advertising, management, system of demands and many other fields; [15, 16]
- different methods of structuring, classification and grouping of laws in complexes of LTSE.

4. The fourth stage is associated with the formation of a more general (as compared to LTSE) complex of laws of evolution of any systems, not only technical ones. The present article also relates to this trend.

The necessity for developing a new complex of laws of systems evolution as compared to known complexes of LTSE is associated with a number of their disadvantages. Let us list out only some of them.

As of today, hundreds of works on laws of technical systems evolution have been published, in which dozens and even more than a hundred laws of technology evolution. Such profusion strongly complicates the application of these laws in practical activity. There are very many laws – dozens and hundreds. Detailed elaboration is superfluous. For example, such a wording of the law is proposed in one of the law systems: «The structure of a technical system should be organized in such a way that the interaction of the components should result in selection and singling out of only such information, which is necessary. Informational value of a technical system or processes depends not on the quantity of information contained in it, but on ways and methods of using this information».

The terms used in the wording of laws are often non-specified and non-formalized, which makes this or that wording unclear, difficult to use and difficult to verify. For example, one of the works proposes «The law of preserving complicacy», «The law of increasing systematicity», or another «The law of complex use of forms of substance motion for the purpose of implementing the functioning of a technical system». Among the notions, which remain non-formalized in TRIZ, we find such notions as complicacy of the system, degree of systematicity or forms of motion of substance, while the attempt to formalize them and to word them correctly might lead to encounters with serious scientific and methodological difficulties. The use of non-precise notions will inevitably lead to inaccuracy of laws themselves and the complex of laws on the whole.

Of course, it is possible to encounter simply incorrect wordings of the laws. For example, rather widely spread is the following wording of the law: «Each technical system should include four basic parts: motor, transmission, working member and control member». Elementary facts prompt that it does not correspond to reality. For example, a house, a chair or a spike have no motor, but they are evidently technical systems. Karl Marx, to whom the authors refer thereby, wrote not about the technical system in general, but about machines: "Each developed multitude of machines (Entwickelung der Machineries) consists of three significantly different parts: machine-motor, transfer mechanism, finally, the machine as an instrument or a working machine» [2]. Transfer of machine structure to all technical systems is not correct.

One more example is the formulation of laws, which stay in contradiction to themselves. For example, the law of tendency to ideality/anti-ideality, the law of stabilization-dynamization. [17] In the system of laws proposed by the authors further in this article such Contradictions will be excluded inside one law. It is also possible to trace certain discrepancy between laws and conclusions drawn from them, between laws and lines of evolution. The authors avoid this discrepancy in the proposed system of laws of development of function-and-targeted systems.

It is also possible to apply the word «incorrect» not only to the very wording of the laws, but also to the methods of composing them into complexes of laws and methods of classifying them. For example, in some works it is proposed to create the hierarchy of laws based on the dominance of «the law» of S-curve evolution though it is not a law, but simply a line of development, i.e., this is a derivative of several laws of evolution.

In the complex of laws of evolution of function-and-targeted systems the authors will also resign the dominance of the main function as the one, which entirely determines all hierarchy of system functions and will use a more general notion – operation principle of the systems.

In order to enhance scientific objectiveness of the proposed system of laws of evolution the authors analyzed possible criteria of correctness of wording of scientific laws.

2. CRITERIA OF CORRECTNESS OF COMPLEXES OF LAWS OF SYSTEM EVOLUTION

As of today, TRIZ is at bottom a theory of evolution, which acquires to a greater extent the traits, which characterize an actual science. This is true, since modern TRIZ actually possesses all main components, which are characteristic of science (*object*, *method*, *theory*, *law,* etc.) Thus, there are Laws in TRIZ (or complexes of Trends), there are structured databases of facts (for example, a database of physical effects, use of patents for inventions as databases, etc.), *hypotheses* are put forward and verified, specific methodologies and tools are formed, as well as models, analytical procedures, systems of notions, etc.

TRIZ is based on collection and analysis of information arrays dealing with inventive solutions, differentiation of these arrays according to levels of complicacy of contradictions being resolved, identification of techniques and methods for resolving contradictions, models of creative process and examples of developed methods for solving inventive problems and developing the systems. [18]

Theory of inventive problem solving (TRIZ) is the field of knowledge on laws, trends and tendencies of development of technical systems, methods and tools of forecasting, identification, analysis and resolving of contradictions of system evolution. TRIZ is based on *laws of dialectic,* and implies the use of evolutionary, system-based, functional, model-based and other fundamental scientific approaches. TRIZ model includes the bonds between models of inventive problems and the models of solutions of these problems as well as connections of system models with the models of their evolution. Regularities and methods of forming and development of inventive thinking are identified as well as methods of developing creative thinking. TRIZ methods and tools are applicable for solving inventive problems not only in technology, but also in non-technical systems. TRIZ is used in practice for development of creative personality, solving inventive problems in different areas in innovative enterprising, in solving problems at manufacturing plants. [15]

Basic theoretical *methods of scientific research*: induction, deduction, axiomatic method, analysis, synthesis. Main empirical methods of scientific research: monitoring, experiment, questionnaires, conversation (interview). Methods of scientific cognition can be classified in the following way: monitoring, comparison, measuring, experiment, abstraction. Key notions and terms used in science are: Hypothesis, Law, Regularity, System of law, Theory, Facts and other notions, for example, Monitoring, Experiment, Statement, Scientific notion, Scientific community, Tendency, Phenomenon, Mechanism of phenomenon, Rule, Principle. Based on facts, hypotheses are put forward, which are supported by facts. Hypotheses formulated in the form of trends, based on which regularities can be identified, as private cases or consequences of laws. The experiments enable to obtain new facts and to confirm formulated laws and regularities. System of laws includes interrelated laws of one theory. The theory is restricted by the area of application and contains a system of models (notions), laws and regularities.

Comparing this basic methodological and terminological paradigm, characteristic of science with similar methodological and terminological set used in TRIZ, it is possible to see that practically all these components of a scientific theory are present in TRIZ. For example, the facts in TRIZ are understood as arrays of inventions and multitudes of problems solved with the help of TRIZ. Hypotheses are preliminary images of tools for statement and solution of inventive problems, for example, five first experimental standards were formulated before creating a system of standards for problem solving. In order to identify new regularities in TRIZ so called united collections of cards were formed with a set of objects on this or that topic. In order to analyze the effectiveness of using TRIZ tools, like in any science, different *experiments* are also used. For example, statistics of solving an inventive problem in focus groups (without TRIZ) and in a group implying the use of TRIZ is collected. Another way of conducting experiments in TRIZ: solving an inventive problem first with one set of tools, for example, Contradictions and IFR and then with another set of tools, for example, standards for inventive problem solving. One more type of experiments is measuring the level of inventive thinking based on solving a set of problems or using other methods. Comparative experiments on measuring the level of physiological stress in solving inventive problems are also known: a person with zero TRIZ training experiences the stress of a higher level than the person, who is skilled in using TRIZ tools.

Like in other sciences, special role in TRIZ is performed by Laws and their components (or their predecessors): tendencies, rules, regularities. To begin with, let us recollect, for example, how physical principles are defined:

«*A physical principle is a quantitative ratio between physical values, which is identified based on generalization of empirical facts and expresses objective regularities, existing in nature*».

In reality such wording, which makes us reflect in Principles particularly quantitative relationships, is somewhat idealized even for physics. For example, Galilei stated that in vacuum all bodies fall down *similarly*, independent of their weight. And this statement is a principle, since it is unequivocal, it corresponds to the facts and there are no exceptions from it. However, quantitative relationships are absent her, they are substituted by the word «similarly». It is possible to give many similar examples, which show that in historical context not all principles (and not always) were formulated particularly in quantitative relationships. [19] Yes, the science *tends* to strict quantitative description, but it does not mean that it initially has it. Strict quantitative description is a result of long-term development. As of today, laws of TRIZ bear more phenomenological and less quantitative character, than the principles of physics, but this state is not final. At the same time in other sciences, for example, in biology or in sociology, the Principles are often devoid of quantitative character, but they reflect, for example, the sequence of certain stages of evolution or, for example, qualitative description of results of this or that process, etc. The most important in a scientific method is the fact that corresponding *models*, describing reality, are created and developed and further on science deals with these models for obtainment of new knowledge, formation of forecasts and performing the analysis. The law is also a certain model, since its formulation (wording) is based not only on objects of reality, but *model-based ideas* (material point, elementary charge, genome, social-and-economic system, etc.).

Consequently, it is possible to say that *the principles in science stipulate qualitative (and ideally also quantitative) relationships between the notions (values, objects), which correspond to existing sets of factors and express objective regularities, existing in nature).* This role is performed by TRIZ laws. However, the trends are not obliged *to explain* the phenomena that take place. They only record and reflect the main regularities. And the reasons why certain phenomena take place are, as a rule, stated by the Theory. The laws are part of the theory; however, the theory contains not only laws, but also phenomenological explanations of mechanisms for origination of such phenomena, with which this theory deals. Besides, the theory, as a rule, also contains the definitions of the terms as well as tools for analysis, rules, recommendations and methodologies.

Table 2. Criteria of correctness of laws and their projection on TRIZ

Criteria of correctness of laws	Comments for TRIZ
Being restricted by the field of law application.	With TRIZ the field of application is restricted by the analysis of system evolution in ontogenesis and phylogenies. This criterion does not allow to transcend the frames of the subject.
The law generalizes large number of facts (induction and deduction), related to the field of the law and possess forecasting qualities	With TRIZ these are information funds of inventions of high level and facts of evolutionary development of the system. The trends in TRIZ enable to obtain forecasts of behavior of objects in the future and/ or in case of change of external conditions. This criterion provides for high commonality of laws and prevents the uncontrollable growth of system of laws.
Law operates model objects and notions, defined in theory	Wording of law in TRIZ should contain at least one notion, defined in TRIZ. In the wording of the majority of version of LTSE this criterion was not always adhered to, since not all terms were introduced, while many introduced terms did not find an exact and unequivocal wording in TRIZ. In the system of laws proposed by the authors below, an attempt is made to eliminate these disadvantages. This criterion provides for standardization and non-ambiguity of notions.
Reproducibility of laws	In TRIZ there are no sustainably repeatable results, which are contrary to the law within the frame of the field of its application This criterion provides for compliance to pragmatically obtained facts.
Laws (complex of laws) should have a certain potentiality of development. With the appearance of new objects and theoretical processes the laws are grouped into a complex of laws.	A possibility of adaptation to new facts and new fields of TRIZ application should characterize TRIZ laws. Laws of TRIZ (complex of laws) should have the simplest possible wording of all possible ones. Maximum of laws and relations should be described through minimum resources. This criterion provides for potentiality of TRIZ evolution.
System of laws should be complete so that the entire cycle of processes in the given field of application should be described.	System of laws in TRIZ should contain the description of forming and evolution (progress and regress) of all stages of system evolution. This criterion provides for completeness of subject description.

Based on general scientific approaches, it is possible to formulate criteria, with which certain Laws should comply and to project these criteria upon the trends of TRIZ (Table 2).

It is possible to note that the system of TRIZ trends in its initial form does not as yet possess completeness. Thus, for example, the notion of *Contradictions* is extensively used in TRIZ. In fact, the formulation and resolving of contradictions is almost the strongest tool for solving problems, which we find in the inventory of TRIZ. However, to the surprise of the authors there is no, for example, *Law of origination and elimination of contradictions in systems* among the formulations of laws of technical system evolution. Neither do we find *anything reminding us of the content such law*. Though a law, which has approximately the same content, for example, in philosophy bears the name of «*law of the unity and struggle of opposites».*

Thus, it could be said that TRIZ moves along the way of evolution to the level of quite modern science, however, in terms of a number of parameters it stays at the initial stage of this process. First of all, its Laws are mostly devoid of quantitative character, and secondly, the formulations of these Laws need improvement, additional formulation or reformulation (rewording). Secondly, neither is the appearance of *new laws* excluded, since the system of Laws in TRIZ is probably incomplete.

In their significant part the Laws of TRIZ correspond to the described criteria, though at any new stage of development it is necessary to check them for compliance, since as the time flows, the volume of accumulated knowledge changes, the field of application is specified, new terms and notions are introduced, new connections are established, identified cases of incorrectness, inexactness and Contradictions are eliminated. It is natural that it leads to new wording of known laws, formation of new laws, development of structures of interconnections within the system of laws as well as to trimming (amalgamation, generalization) of laws. Below the authors quote a renovated variant of a complex of laws of system evolution, which takes into account the above-listed disadvantages and criteria of laws' correctness.

Here is the list of criteria of correctness of system evolution laws intended for forming a complex of evolution laws in TRIZ:

1. The notions and terms used in the wording of each law should be unequivocal in interpretation and characteristic exactly of TRIZ. The wording of a law in TRIZ should contain at least one notion, which is defined exactly in terms of TRIZ. It eliminates the ambiguity of interpretations and notions, which exist now.

2. The wording of each law should not transcend the boundaries of the field to which the law refers (for example, it should concern exactly the evolution of the system in phylogenesis and ontogenesis and not more than that), and shouldn't be narrower as compared to the phenomenon, which is actually being described (for example, there is no sense in being restricted by technical systems only in the formulations of laws, if the law describes a phenomenon, which is characteristic of a wider field). It eliminates the blurring of the subject of research, transition of the frame of the subject.

3. The laws and their complex on the whole should correspond to known facts of development of the system and contain prognostic features, which can be confirmed. It eliminates the non-compliance of the system of laws with the available pragmatic facts.

4. Each law separately should not stay in contradiction to itself. It does not allow any internal contradictions in wording of the laws and provides for their workability.

5. The laws and their complex on the whole should be compact and should thereby describe the entire life cycle of the objects, the description of whose evolution is the goal of the law. Maximum of regulations and connections should be described by minimum wording. This principle is called in science «Occam's razor» and does not allow scientific ideas to endlessly become more and more complicated.

6. Complex of laws should be dynamic and should imply the possibility of adaptation to new facts and new fields of application. It provides for the evolution of the system of laws.

7. Complex of laws should comply with its own requirements and regularities. It is a unique criterion, which is typical particularly for TRIZ. In natural sciences there is no such criterion, since they deal with the material constituent of Nature. At the same time TRIZ is applicable not only to material systems, but also to non-material ones, for example, to systems of notions, models and trends. Thus, TRIZ should be applicable both to itself and to other sciences.

3. BASIC NOTIONS AND TERMS

The authors of the present article propose a new approach to creation of Laws of technical systems evolution with regard to above-formulated criteria of correctness of system evolution laws. The essence of this approach could be formulated in the following basic assertions:

- the main object of description in the complex of laws proposed by the authors are not the technical systems and their evolution, but the evolution of functional-and-targeted systems;
- the key issue in the description of evolution of functional-and-targeted systems will be not the main useful function of this or that object, but its operation principle, which implies not one function, but a complex of functions, which is characteristic of this object
- complex of laws of evolution of functional-and-targeted systems (LEFTS) will contain laws, consequences from laws and the lines of development of systems.
- formulation of each law and of the consequence from it separately will not contain internal contradictions, but a complex of laws of evolution on the whole and the lines of evolution should contain dialectic contradictions
- it is proposed to use not only the lines of evolution of systems, but also the planes of evolution (combination of two lines of evolution as axes of the plane) and the space of evolution (combination of three and more lines of evolution as axes of space of evolution).
- since the complex of laws of evolution in itself is a function-and-targeted system, LEFTS can be used for checking and development of the same complex of laws.

These terms are explained in the present article.

Functional-and-targeted systems.

Many authors, including, for example, Pyotr K. Engelmeier [4,5], have to strongly broaden the usual understanding of technology (technique): technique of playing musical instruments, artificial systems, anthropogenies systems, etc. It is associated, admittedly, with a higher dependence of technical systems upon the human beings and the society. However, the attempts to generalize in TRIZ the notion of technical system have serious disadvantages. For example, a human being, born in a maternity house with the aid of the midwife: is it an artificial or a natural system? A giraffe in the zoo – is it an anthropogenies system or not? It is not possible to create scientifically grounded wording of trends based on suchlike proposals concerning the broadening of the notion of technical system.

Complexes of LTSE don’t possess the necessary level of generalization, however, there is considerable practice of applying them for development of technical systems and solving inventive problems. According to the opinion of the authors, it is possible to combine the generalization of laws with their instrumentality in formulating the laws of evolution as applied to function-and-targeted system.

Function-and-targeted system is a system formed for the purpose of performing a complex of useful functions and attainment of goals in keeping with the requirements of the supersystem and the operational principle of the given system. Functional-and-targeted system is formed based on self-organization, natural or artificial selection, or as a result of targeted actions of one of the super-systems. It is possible to relate the following systems to functional-and-targeted systems: biological systems, technical systems, social, economic, scientific and other systems.

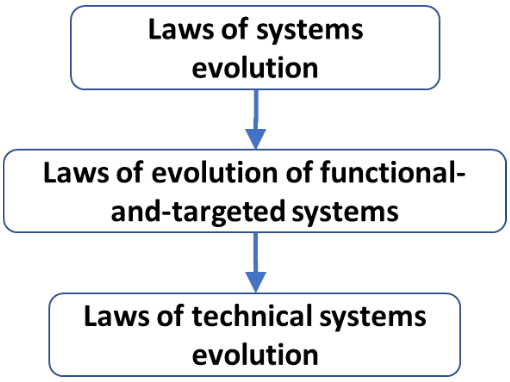
Theory of functional systems is a model, which describes the structure of living organisms, which was proposed by P.K. Anokhin in 1935 [20]. He singled out two types of functional systems:

- Systems of the first type provide for homeostasis due to internal (already available) resources of the organism, without transcending its boundaries.
- Systems of the second type support homeostasis due to changes in behavior, interaction with the external world and offer the basis for different types of behavior.

There is an obvious (though false) dissonance: the model is basically very close to technical systems, however, is formulated for living organisms, which are in no way like the technical systems. As a result, the theory of functional systems of P.K. Anokhin practically did not influence the evolution of TRIZ as a scientific theory.

The term functional-and-targeted system is used in describing social organizations, in theory and practice of managing organizations and projects, for living and social systems. One of the reports in 2020 [21] quotes the examples of functional-and-targeted systems: organism, population, system «nature-society-human being», family. In TRIZ the term of function-and-targeted systems was introduced in 2008. [22] In formulation of complexes of evolution laws the authors used (as an object of research) exactly the notion of function-and-targeted system as a more general and more exact for describing the laws of evolution than the technical systems. In this case the succession of LTSE and LEFTS (laws of evolution of functional-and-targeted systems) was preserved. It enabled on the one hand to procure a sufficient level of generalizing the trends and on the other hand – to preserve and even to enhance the instrumentality of complex of LEFTS as compared to LTSE.

It is possible to single out three reasons why it is necessary to use the term *functional-and-targeted systems*, not the term *functional systems*:



- the term «*functional systems*» with P.K. Anokhin and with TRIZ are a private case of functional-and-targeted systems;
- LEFTS describe evolutionary development of systems, not simply their functioning, which requires the inclusion of a notion of goal for this evolution;
- LEFTS embrace the evolution, including that of social systems, which are better matched with a tendency for attainment of the goal.

Figure 1. Interconnections of LEFTS with TSE and laws of system evolution [23]

Function-and-targeted systems were formed on Earth as a result of processes for self-organization of substance approximately 4 billion years before in the form of first one-celled anaerobic organisms and their communities. Later on, the evolution of these systems started and goes on till the present day: microorganisms, water weeds, plants and animals and their communities, people, technique, science, civilizations, states, economy, law – all this and many other things are examples of function-and-targeted systems.

Transition to function-and-targeted systems made it necessary to consider as the basic notion not the function, but the operation principle, in which the function is only one of the subsystems.

Operation principle of function-and-targeted systems.

Operation principle is the key model for describing function-and-target systems. Let us quote several examples.

Example 1. System «Planting hoe». If we assume that a technical system necessarily consists of an energy source, motor, transmission, working member and control member, a hoe is not a technical system at all [11], since it is devoid of both energy source and transmission. If we try to formulate the main useful function of the hoe, we shall also encounter difficulties. It is possible to describe fairly different functions of the hoe: to crush the clumps of earth, move the earth, dig out the plants, take away the weeds, form the earth, make beds in the earth, make small pits, etc. However, all these functions in reality don't define the essence of the hoe, all these functions could be performed, for example, be performed by a spade or a rake. An attempt to describe the operation principle will give us much more in terms of understanding. The goal of using the hoe is manual ploughing earth or digging it. The elements, shape and materials: metal or stone (in ancient times) blade of the working part, wooden handle. The working part can be narrow or wide, flat, curved or spade like. The functions were numerated above by us. One might add an instruction sheet to it: what kind of hoes could be selected for which kind of work, what soil or lawn is processed, etc. It is obvious that the operation principle describes the hoe in greater detail than simply a list of possible functions. Especially if we try to single out and to formulate one main function of the hoe.

In 1935 P.K. Anokhin formulated provisions of the theory of functional systems based on the research of function performance with the animals:

- The function is performed by the organism as a whole, not its separate organs;
- Motivation and stated goal are very important;
- A program containing a list of steps for attainment of the set goals;
- The micro-level (subsystems) is involved for fulfillment of the program;
- The implementation of the function is accompanied by monitoring of the result; feedback is introduced and decisions are taken for attainment of the goals.

All these provisions are in the fullest sense related to functional-and-targeted systems. Figure 2 shows the hierarchical connection from the Goal to functions of the system. Formulated goals of the system are attained based on certain programs with feedback for controlling the attainment of the goals and correcting the programs. The programs are performed due to implementation of operation principles of the systems, which include complexes of functions.

It is necessary to note that not every system if a functional-and-targeted one. There are so called resource systems, in which there is no action or the instances of action could be neglected, there is a self-regulating system, in which there are actions, but no functions and there are functional-and-targeted systems, in which a certain complex of functions is created for attainment of this or that goal. For example, the rocks somewhere in the mountains or the sand near the shores of the sea are resource systems, in which there is no action or this action is not significant. If we take into account that the action is the change of parameter of a certain object, then we come to a conclusion that the actions can be found in self-regulating systems. For example, galaxy, Solar system, climate of the Earth. No doubt, there are actions in these systems, there are variations of numerous parameters of a huge number of objects, however there is no «customer» and «designer» of these actions in the form of supersystems, as it is observed for complexes of functions. Solar system, for example, does not provide for existence of our galaxy.

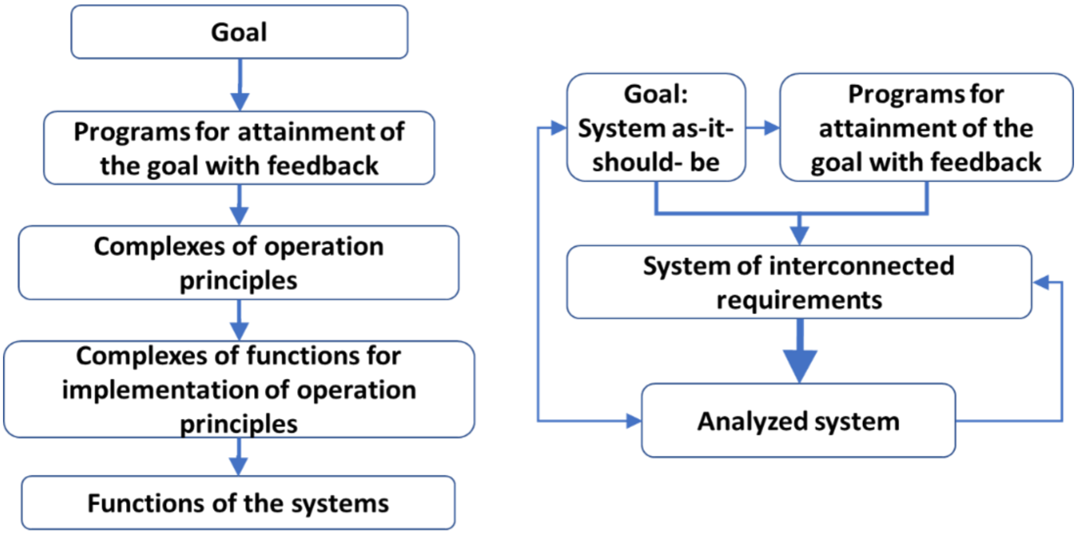


Figure 2. Interconnection between the Goal, operation principle and functions of the system. Formation of the set of requirements to the analyzed system

Another situation with living organisms is their existence and vital activity depends upon the functions of heart, kidneys, blood system, upon behavior, etc. Live organisms can be simultaneously considered to be both self-organizing and functional-and-targeted systems: in one aspect or at one level – these are self-organized systems (for example, a flock of migrant birds, a crowd of people), while in other aspect or at another system level these are functional-and-targeted systems (digestion, blood circulation, etc.). For example, it would be fairly complicated to provide a wording of a goal for an ecosystem, animals or humans – these are self-organizing systems. Living organisms can be considered to be a transition period in the evolution of systems from self-regulating to functional-and-targeted ones. For example, it would be fairly complicated to formulate the function, goal or meaning of existence of an ecosystem, animals or human beings. However, it is possible to formulate the goals and functions of breathing, nutrition, motion, reproduction and other functional-and-targeted components of living organisms. It is impossible to formulate a function or a goal of existence of the human being, however, it is possible to formulate the goals of a scientist, functions of a baker or a metallurgist.

Example 2. System «fishes with spawning migration». Spawning migrations are carried out by many kinds of fishes. An example of spawning migrations is migration of salmon fishes of the Far East: Siberian salmon and humped-back salmon. At a certain period of time these fishes in huge shoals consisting of myriads and hundred thousand species pass from the Pacific Ocean to the mouths of the rivers and move upwards along the rivers upwards at distances of hundreds and even thousands of kilometers. It would be impossible to describe such a system through the wording of the main useful function. It can be done only through the complex: «Goals – Programs for attainment of these goals – Operation principles – Functions of the systems».

Example 3. System «Alpinist». In the same sense it is impossible to describe the activities of the alpinists through one main function. It could be done through the same chain: Goals – programs for attainment of these goals – Operation principles – complexes of functions. The goals were clear – to attain the chosen top. There are also requirements in the form of restrictions – to get back intact, physical and financial restrictions of the alpinist himself and of his group. There is a whole set of programs for attainment of the goal: programs of preparation, program of expedition, climbing program, program for passing through rick and ice relief, program of getting down from the top, program of actions in case of emergency, program of communication with the basic camp and rescue team. With each program there are operation principles of the system, which are involved with the fulfillment of these programs. There is also feedback for correcting these programs with regard to particular situations: weather, state of the route, speed of passage, level of actual preparation of participants, available set of equipment and food products, etc.

It is proposed to use the following notions and definitions as the foundation of a complex of laws of evolution of functional-and-targeted systems:

Goal is an information image (model) of «System AS TO BE», which is capable to encourage the subject of the Goal to perform actions, which are directed at preparation and fulfillment of actions of programs for attainment of the Goal. The goal is formed by the system (subject of the Goal), supersystem or based on their interaction. The goal is attained due to realization of ready or formed programs of action and complex of interconnected functions.

Model system of System AS TO BE type is formed based on the model of the System AS IS by certain transformations: parametrical, structural, etc.

Operation principle is a description of the method for performing a complex of interconnected functions of the system, directed at the attainment of the goal and also including the description of its morphology, composition of elements and sub-elements, their interconnection as well as technologies for realization of functions.

The program of attainment (fulfillment) of the goal is an information image (model) of the possible sequence of actions (technologies) and intermediary results, which are necessary for the attainment of the Goal by this or that subject – carrier of the Goal. The program is fulfilled due to realization of operation principles of systems, which are required for that and contains mechanisms of correcting (adaptation) based on feedback.

Requirements to the system is a complex of functions, restrictions or interactions, which should necessarily be realized for supersystem, directed at this or that object. The requirement is formulated for the attainment of a certain goal, program of its realization or operation principle of this or that subject and directed at this or that system. The requirements could be grouped into systems of interconnected requirements, which form the foundation for forming and evolution of the system, at which these systems of requirements are directed. It is possible to single out goal-oriented (targeted) requirements and restrictive requirements.

Restriction (restrictive requirement) is a type of requirements, in which such functions, interrelations, components or parameters of components are described, which are obligatory for this operation principle or which are prohibited.

A technical system is a material functional-and-targeted system, the evolution of which takes place under the influence of requirements of a supersystem and target-oriented change (or application) of known system. Technical systems don't possess the feature of self-evolution in phylogenesis. It is impossible to identify a technical system without knowing, how it originated: based on active actions of supersystem or due to self-organization and self-development.

This complex of notions is the basis for forming and development of a complex of LEFTS.

Laws, evolution lines and complexes of evolution laws of functional-and-targeted systems

The laws of system evolution (LSE) are a complex of general, objective and internally non-contradictory trends of evolution of the systems, based on scientific approaches to system evolution. Among the scientific approaches used are dialectical approach, system-based approach, evolutionary approach, parametrical and model-based approach, basics of psychology of creative thinking.

Basic law of LSE: the evolution of the systems follows the direction of increasing the level and efficiency of capture and use of resources. The field, which deals with forming and development of LSE is called "System evolution studies" or "Evolutionology".

The law of evolution of functional-and-targeted system (LEFTS) is an objective law, in which the sustainable direction of evolution of a functional-and-targeted system is described, which enhances its compatibility at the level of system-based phylogenesis. The laws of evolution of functional-and-targeted system are internally non-controversial. Each trend can be specified by providing the consequences from this trend. Based on LEFTS the lines of evolution of functional-and-targeted systems are formulated, methodologies of analysis of functional-and-targeted systems and of forecasting their evolution are developed. Hierarchy of LEFTS complex is based on supremacy of the law of increasing ideality.

The lines of evolution of functional-and-targeted system are a description of this or that direction of system evolution based on a chain of transformations, which are in their turn based on a group of laws of evolution of functional-and-targeted systems. The description of evolution line include: the laws based on which the line of evolution is created, Contradictions of requirements of evolution line, IFR for formulated contradictions, no less than three steps along the evolution line (fulfillment of one of the requirements, fulfillment of the contrary requirement, a step towards IFR). The combination of two lines constitutes a plane of development, while a combination of three and more lines of development constitute the space of system evolution. The lines of system evolution are included with the systems of standards for inventive problem solving and are used in forecasting the system evolution.

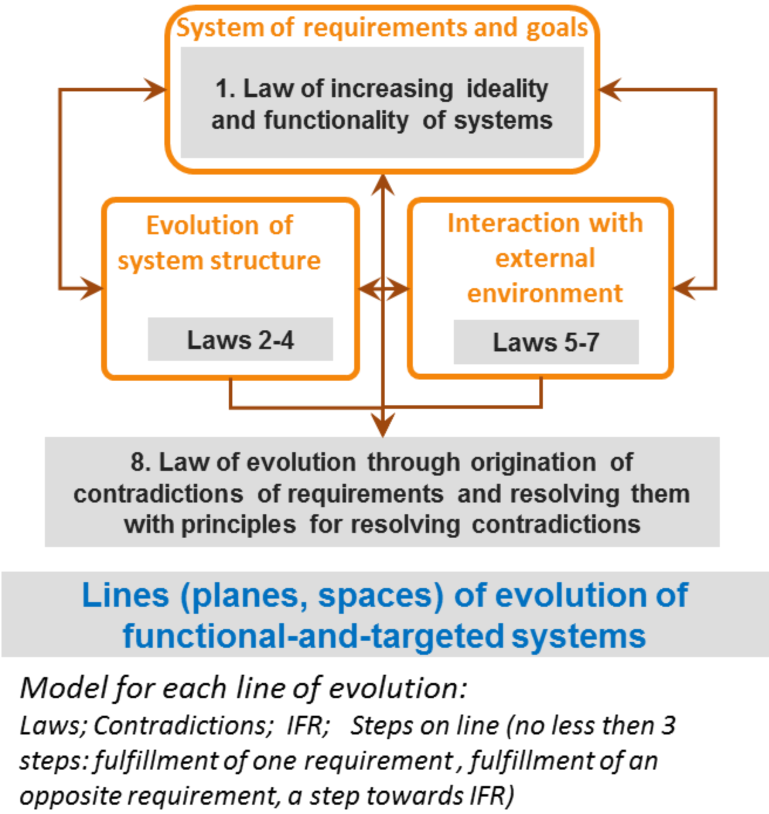


Figure 3. Structure of LEFTS: Laws and lines of evolution of functional-and-targeted systems

Complex of LEFTS is a complex of interconnected laws and lines of evolution of functional-and-targeted systems, describing the entire life cycle of forming and evolution of functional-and-targeted systems. The complex consists of 4 main parts:

1) Law of increasing ideality,

2) Group of laws of evolution of system structure,

3) Group of laws of interaction with external environment and

4) Law of evolution through origination of contradictions of requirements and resolving these contradictions.

Laws of complex of LEFTS can enter into a dialectic Contradiction in contrast to each trend separately. Resolution of this Contradiction is pre-conditioned by the law of evolution through origination of contradictions of requirements and through resolving these contradictions. The complex of LEFTS in itself is a functional-and-targeted system and can evolve due to new consequences from laws, lines of evolution, new laws and the interaction between them. The structure of LEFTS complex is shown in Figure 3.

The law of increasing ideality of functional-and-targeted systems is a sort of translator of system of requirements: requirements should be adhered to at minimum or absent expenditures and harmful functions.

System of ideal requirements is implemented due to two groups of laws: a group of laws of system evolution and a group of laws of interaction with external environment. Since the requirements of laws can enter into Contradictions, the law of evolution through origination of contradiction of requirements and resolving these contradictions using the principles of contradiction resolving is included with the complex for the purpose of resolving them.

Since the complex of LEFTS in itself is a functional-and-targeted system, this very complex of trends should be used for its evolution.

4. LAWS OF EVOLUTION OF FUNCTIONAL-AND-TARGETED SYSTEMS

Figure 4 shows the hierarchical structure of a complex of laws of evolution of functional-and-targeted systems: the laws, consequences from laws and lines of system evolution.

Let us analyze these laws, consequences from them and lines of evolution in detail.

4.1. Law of increasing ideality of functional-and-targeted systems.

The law of increasing ideality of functional-and-targeted systems: evolution of functional-and-targeted systems follows the direction of increasing ideality (ratio of complex of useful functions to expenditures on fulfillment of these functions increases). Complexes of useful functions of the system operation principle are firmed in keeping with the requirements and goals of the system.

This law is a kind of a conductor of system of requirements and goals, which are given to the system. In keeping with the law of increasing ideality these goals and requirements should be realized at the minimum of expenditures.

Let us quote the examples characterizing the functional-and-targeted systems of three types:

- for technical systems
- for biological systems
- for creative personalities as a functional-and-targeted system.

Example 4. For a technical system. Tendency to ideality. Efficiency of motors grows in the process of evolution: steam engine – 1%, carburetor engine 20-30%, steam turbine – 35-46%, electric motor – more than 97%.

Example 5. For biological systems. Tendency to ideality for living substance on the whole: the efficiency of using available energy in biosphere is constantly increasing. «The meaning of evolution is the deceleration of entropy as related to the source of life – the sunbeam». [24] All variety of organic forms is but a peculiar method of complication of cycles of energy transformation on Earth and increase of energetic efficiency of living beings, which manifests itself in the formation of stable energy systems».

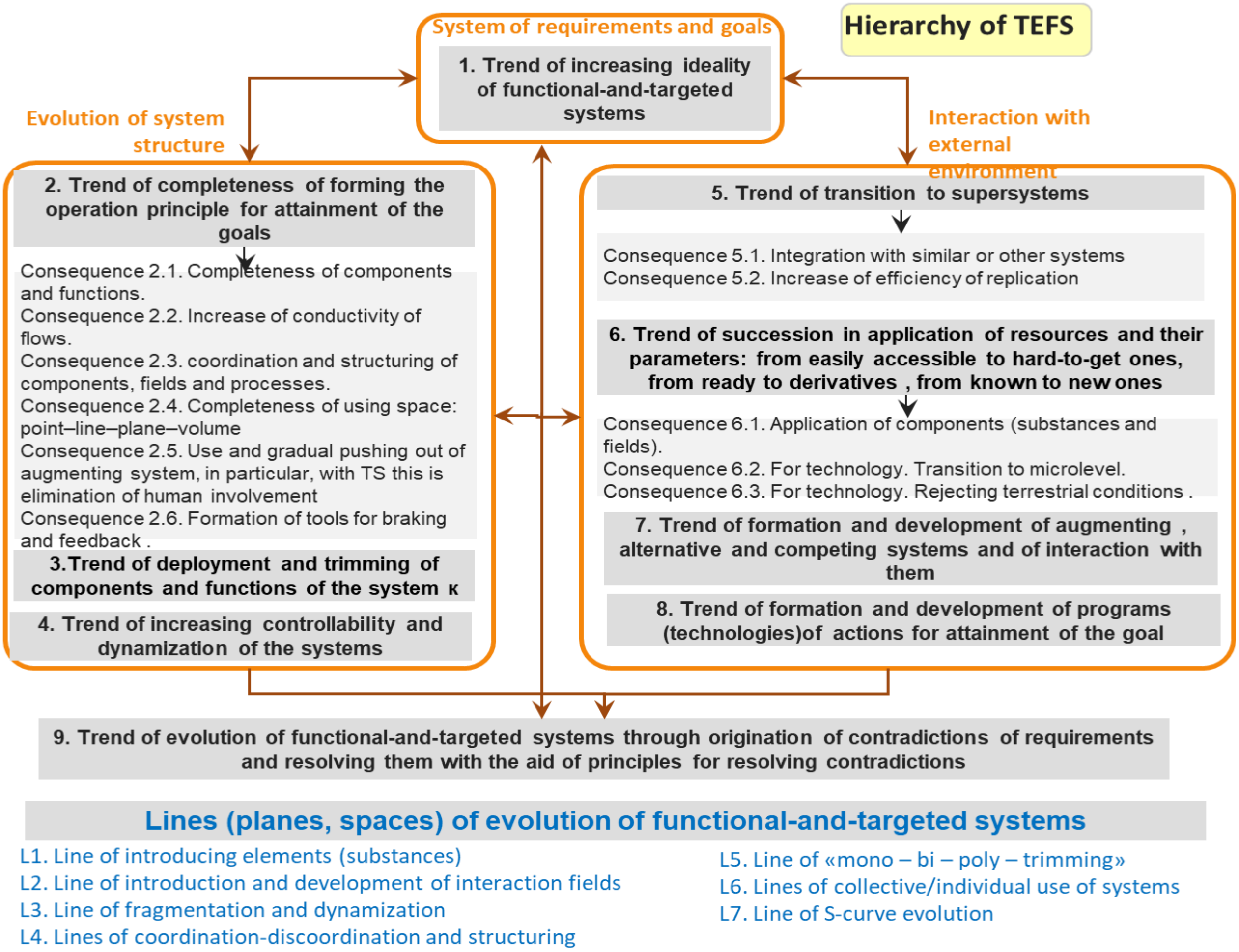


Figure 4. Hierarchy in complex of laws of evolution of functional-and-targeted systems.

Example 6. For the development of creative personalities. Tendency to ideality. During the Middle Ages (11th – 14th centuries) in Central Europe the percentage of science-intensive products can be evaluated approximately in the amount of 0.5%. Because of illiteracy in England King's autographs date back to the 13th century, while the ladies' signatures appeared one hundred years later. In Germany even the poets first dictated their songs to the clerks. Currently in Germany the portion of science-intensive products in gross domestic product constitutes more than 60%. The time between evolutionary events in the development of civilization decreases according to exponential rate: in ancient times it constituted 8000 years, in the Middle Ages more than 100 years and currently – less than 10 years. The volume of information in the world since 1500 till the present time has increased billion times. If recalculated for each citizen of the Earth, the increase of information amounts to 55 million times. It means that the scientists should process a volume of information, which is many times higher and the resultativeness is increased: important evolutionary events take place more often and the number of science-intensive products is increased.

4.2-4. Laws of evolution of structure of functional-and-targeted systems

A group of laws of evolution of structure of the system consists of three laws and several consequences from these laws.

4.2. Law of completeness of forming the operation principle for the attainment of the goals

Law of completeness of forming the operation principle for attainment of the goals: a necessary condition of forming and improvement of the operation principle is arranging for completeness of fulfillment of operation principle of functional system, conductivity of its flows and coordination of rhythms of its parts.

The definition of the notion of operation principle was given above in this article.

The law of forming and improvement of operation principle provides for interconnection between components, processes and flows within the system. Several consequences follow from this law.

Consequence 2.1. Completeness of components and functions.

The necessary condition for fulfillment of operation principle of functional-and-targeted system is the presence and minimum fulfillment of functions of the main components of the given system. The component is understood either as an element or the field of interaction (mutual relations) of the elements.

Consequence 2.2. Increase of conductivity of flows.

The condition for fulfillment of operation principle of a functional system is the presence of certain necessary bonds between the components of the system, including the flows of substances, information and energy between them, which are necessary for fulfillment of operation principle.

Consequence 2.3. Coordination and structuring of components and processes.

The necessary condition for fulfillment of operation principle of a functional system is coordination of all parameters of bonds (including flows) between the system components, including their variation in time. To achieve the target-oriented braking of the system functioning it is necessary, on the contrary, to reduce or to completely exclude the coordination of bonds between the system components.

Consequence 2.4. Completeness of using space.

Completeness of fulfillment of operation principle of the system is provided for, in particular, by the completeness of using space, which leads to transitions from point to line, from line to plane, from plane to volume of the entire available space.

Consequence 2.5. Use and gradual elimination of augmenting systems, in particular, the humans.

Completeness of fulfillment of functions of the system is provided for, in particular, due to the use of other augmenting systems, which replenish the missing components and processes. For example, the plough is augmented by the horse, the sail ship – by the wind, and the first textile machines – by the humans. With the growth of the source system augmenting systems are eliminated, while the source system becomes more and more self-contained, independent of necessity to use external systems: the horse, the wind, the human.

Consequence 2.6. Forming the tools for braking and feedback.

With formed functional-and-targeted systems a necessary component is a set of mechanisms for braking and feedback, which are necessary for control of attainment of the set goal and dynamic adaptation to the changing external conditions.

4.3. Law of deployment and trimming of components and functions of the system.

In evolution of functional-and-targeted systems the growth of new useful and controlled functions outpaces the growth of new elements (deployment), while the decrease of the number of elements in a system (trimming) outpaces the decrease in number of useful functions. The processes of trimming and deployment could interact one with another (some elements stay at the stage of deployment, while others – at the stage of trimming), and the periods of trimming and deployment could alternate.

4.4. Law of increasing controllability and dynamization of the system.

In the process of evolution components of the systems, their mutual bonds and the system on the whole enhance the potentiality of controllable change of their parameters for the purpose of adapting them to the conditions of external environment. For this purpose, the system should contain the elements, which provide for controllability and the elements, which are capable of changing their parameters.

4.5-7. Laws of evolution of interaction with external environment.

The group of laws of evolution of interaction with external environment consists of four laws and several consequences from these laws. The laws of this group are interconnected with the laws from the group of evolution of the internal structure of the system.

For example, consequence 2.5 from the law of completeness of forming the operation principle concerning the elimination of augmenting systems is interconnected with law 7 concerning the formation and evolution of augmenting systems.

Law 4 concerning the enhancement of controllability and dynamization of system is interconnected with law 8 concerning the formation of programs for attainment of the goals.

Law 6 concerning the transition from easily available to hard-to-get resources is associated with law 2 of completeness of forming the operation principle of the system: the systems evolving based on this law can become new easily available resources for other systems. For example, the coach became a convenient resource for first cars, microorganisms became a resource for origination of plants and animals.

4.5. Law of transition to supersystems.

Supersystem is a system, which includes the analyzed system as a constituent part. Supersystem is a multitude consisting of systems and possessing the features of a new system.

The law of transition to supersystem proclaims that the evolution of any system, including functional-and-targeted ones, can be continued by formation of or inclusion with a supersystem. Supersystem can also be formed from the system itself, for example, a double-barreled gun is formed from a one-barreled gun, or the system might be included with a ready system. For example, a trolley-bus can be included with a supersystem of city transport. The system, included with a supersystem, becomes more stable and efficient. For example, a pride of lions is more efficient than a lonely lion, the tribe is more efficient than a single family.

Consequence 5.1. Integration with similar or other systems.

Supersystems can be formed by integration of similar systems, transformed systems, anti-systems or systems with other operation principles and goals.

Consequence 5.2. Increase of efficiency of replication and scaling.

One of the methods for forming supersystems is the replication of the system. The processes of replication form the foundation for creating similar or transformed systems. In order to form a copied system, there is no necessity to exactly copy the entire evolutionary pattern, which was needed for creating the original system. There are always mechanisms of replication and their efficiency in the process of phylogenesis is increased. For example, it is easier to replicate a machine, than an animal; it is easier for a computer to copy information, than for a painter – to make a copy of an original oil painting. External connections of the systems being copied, which form a supersystem, become internal connections for a supersystem.

Scaling is understood as a proportional increase of system parameters without any functional distortion of proportions and with retaining of operation principle. Increase of the picture, increase of productive capacity, increase of dimensions, increase of clientele – all these are examples of scaling. Replication can be understood as a private case of scaling, for example, creation of a network of similar shops is a method for scaling business. Scaling can lead to forming a supersystem. For example, scaling of a village can lead to formation of a city or a megapolis. Scaling of a squad leads to formation of a squadron, regiment or army. It means that scaling is also one of the methods for forming a supersystem. Internal connections of the scaled system are the foundation for the formed supersystem. Systems develop in the direction of increasing efficiency of their scaling. For example, the growth of a logarithm of weight as a result of the increase in length with cars is 1.4 times less than with animals [25], i.e., in technology the scaling is more efficient than with animals.

4.6. Law of transition from easily available resources to hard-to-get resources.

Any system can originate and develop exclusively due to the environment. In this case there are always mechanisms, enabling to use resources of environment for formation and development of internal structure of the system. The wording of the law implies that first of all the systems use such resources, which are easily available for them, and then hard-to-get resources are used, first they use ready resources and then their derivatives. In this case the very mechanisms of converting external resources into the system proper are improved: resources, which were unavailable earlier become available, the expenditures on their conversion are also reduced in the process of evolution of functional-and-targeted systems.

For example, during the Archean era, 4 billion years ago the atmosphere of the Earth had low density, consisted of ammonia, hydrogen, methane, sulfureted hydrogen, water vapors, oxide and dioxide of carbon, oxygen was absent, as well as continents. [26] Strictly speaking, blue-and-green seaweeds had nothing else for their origination and evolution. Solar light was added to it – that is all, from what the blue-and-green seaweeds created themselves and create until now. The eukaryotic green seaweeds, which appeared later, exhausted free oxygen into the atmosphere, which was poisonous at that time. Gradually this «poison» became a ready resource, which was used by bacteria, capable of living in an oxygen medium. Currently there is 21% of oxygen in the atmosphere of the Earth and we use it every day, like all the rest of the animals.

Another example is the opportunity to use huge resources of mineral wealth's in which – 4880 minerals are present (beside oxygen). Living organisms cannot make use of these wealth's, however, the minerals are actively used in technical systems. For example, live substance appeared on Earth approximately 4 billion years ago. During this period the overall weight of biomass on Earth constituted approximately 2.4 trillion tones of living substance. Instruments of production are improved and developed approximately 2.5 million years, while the overall weight of technical substance (techno-sphere) already constitutes according to different evaluations from 3 to 30 trillion tones. One can form the opinion on the rates of growth of anthropogenies mass on Earth by the fact that at the very beginning of the 20th century it constituted only 3% of weight of biomass of living beings on Earth, and now it exceeds the weight all living beings on Earth. [25]

Consequence 6.1. Application of components (substances and fields).

External environment first offers for system formation 1) available elements (substances) and 2) fields of interaction (See also consequence 2.1 from trend 1).

For example, water, carbon, oxygen, gravitation, electricity and magnetism, which are available on Earth as well as other substances and fields are first used for live and technical functional-and-targeted systems. Pyramids of ecosystems are built according to hierarchy of resources, which are available for nutrition, for example, plants, herbivorous insects, raptorial insects, birds. Each of them creates a resource for further sub-chain in this ecological chain. Similar bonds can be observed in industry: branches of mining industry, power industry, processing industries, power engineering, production of goods and services.

Cars and airplanes use the available resource – oxygen in the atmosphere. Spaceships have no such ready resource; they have to carry oxidizer on board.

Consequence 6.2. For technical systems. Transition to micro-level.

Sequence in the use of resources affects their size as well. For a human being the ordinary dimensions from several millimeters to several hundred kilometers are usual. In this range of dimensions, the traditional technology develops. However, as the time flows, the human being manages to transcend the boundaries of usual dimensions. Microscopes enable to pass over to angstroms and nanometers, while telescopes are associated with light years and parsecs. New ideas of dimensions enable to pass over also to creation of technical elements of such dimensions. For example, typical is the transition to microlevel for technical system: from hammer to sandblaster, from sandblaster to laser, from bulb calculators to notebooks, from old telephones to mini-telephones and smartphones.

As an example of this consequence from the law it is possible to quote the evolution of Computer Numeric control (CNC) of a machine intended for cutting different materials (from plywood to metal). In the middle of the 20^{th} century the working member of this machine was a milling cutter, which takes away the material of the object being processed. Nowadays the working member is the laser beam, which processes the object throughout the area of processing amounting to several micrometers, which yields a more exact result of processing.

Consequence 6.3. For technical systems. Reject of terrestrial conditions.

One more consequence of law of transition from easily available to difficult-to-get resources (as applied to technical systems) is the reject of terrestrial resources in case of using substances and fields. For example, a transition takes place from the usual atmosphere either to purely oxygen medium or to inert medium. From the usual pressure equal to one atmosphere, they pass to the using either of vacuum or very high-pressure values. The same is true temperature values, which are usual for the Earth, composition of the atmosphere and composition of the Earth crust, gravitation and other terrestrial characteristics. From the use of usual values of these parameters the technology gradually passes over to their highest values. Accordingly, other parameters will be usual at other space objects and the tendency will take the form, corresponding to these conditions.

4.7. Law of forming and development of augmenting, alternative and competing systems and interaction with them.

For each system augmenting systems are always formed in the external environment, as well as alternative systems performing the same functions, but in a different way, as well as competing systems. Competition can take place not only in terms of functions, but also in terms of used resources or in terms of a possibility to enter this or that supersystem. Interaction with these systems can be both a source of system evolution and a source of breaking this evolution.

Example of augmenting system. There is a whole network of repair shops and filling stations for cars. For aviation the corresponding infrastructure of overland transport is created.

Example of alternative system. An automobile always has an alternative in terms of being transported to another place: tube, trolleybus or an electric car, bike, cutter, aircraft, helicopter and other means of transport. Alternative systems can be additional and competing and can be grouped into supersystems. [27]

Examples of competing systems in terms of functions. Many alternative systems can be competing, for example, railway transport and aviation transport. Diesel motors compete with motors on gas, pens with pencils, linoleum with parquet, etc.

Competition affecting resources. The wolves have many competitors with those, who eats hares and hoofed animals: panther, fox, polar fox, raccoon dog, jackal, wolverine, badger, brown bear, wild pig. In industry there is competition for energy resources, industrial areas, areas for burying wastes.

Competition for markets and integration into business processes. For example, competition for state orders, competition of business models (earning money through services and goods, now or with delay of payment), etc.

4.8. Law of forming and development of programs (technologies) of actions aimed at attainment of the goal.

To attain the goal, functional-and-targeted systems form programs of action and realize them based on such operation principles, which are typical of them. In this case also the image of anticipated result of performing the program of action is formed, while the feedback enables to correct the program of action based on comparing this image of anticipated result with the actual results of the action.

The notions program of action and expected result of performing the program of action (acceptor of the result of action) are a part of the theory of functional systems set forth by P.K. Anokhin. [20] With animals, for example, a program of action is found and the expected final image in hunting, in protecting animal cubs, for continuation of the gender, in case of fire or flood, etc. It is obvious that the programs are different with each animal, since all of them have different potentiality in keeping with their «operation principle». These programs are corrected during the process of their fulfillment depending upon the actual result of actions performed. Similar programs for acting are created in all functional-and-targeted systems, for example, in preparation of business-plans, in constructing buildings and edifices, in formation and development of the cities, etc.

4.9. Law of system evolution through forming and resolution of contradictions.

Evolution of system components and of their parameters takes place irregularly, which leads to the violation of trend of sequence (coordination) and to origination of contradiction in system evolution.

Law of irregularity in the evolution of components of the system can be traced in systems of many authors, for example, [11]. In spite of that many authors mention this law in the proposed systems of LTSE, the connection between this law and other laws of system evolution was never defined explicitly. Ontological approach to study of LTSE enabled to demonstrate this connection explicitly. Its existence shows that in the process of evolution the system is transformed under the action of certain trends. Such transformations lead to generation and aggravation of contradictions, the resolution of which, in their turn, lead to irregularity of development of system components.

4.10. Operation principle of a complex of LEFTS.

Development of the complex of LEFTS, like any other functional-and-targeted system, should be described by this very complex of laws. In particular, it is possible to describe the operation principle of a complex of LEFTS.

The goal of a complex of LEFTS consists in the creation of a model of evolution of functional-and-targeted systems. The complex consists of four constituents:

- law of increasing ideality
- group of laws of evolution of the system structure
- group of laws of evolution of interaction with external environment
- law of evolution through formation and resolving of contradictions.

All laws and groups of laws are interconnected. Formed complexes of requirements to the system through the law of increasing ideality leads to gradual formation and evolution of internal structure of the system based on operation principle, which is necessary for realization of the requirements. Internal structure develops in the direction of increasing completeness, the evolution is accompanied by alteration of trimming and deployment in the system, increasing controllability and dynamization of components and processes.

Evolution of the system takes place not in the interaction and mutual influence of the system and external environment. On the one hand, the system takes from the external environment all necessary resources for development and on the other hand – changes this very external environment and matches the requirements of the external environment. Interaction and mutual influence between system and external environment takes place due to the formation of a supersystem, use of available resources and competition or interaction with other competing and augmenting systems. With regard to available structure and operation principle of the system as well as conditions of changing external environment, the programs are formed for attainment of set goals and for fulfillment of available requirement.

Described processes and formed requirements to the system due to objective reasons leads to formation of contradictions, which are solved by the main principles of resolving contradictions of requirements: in time, in space, in relationships, system transition.

5. LINES, PLANES AND SPACES OF SYSTEM EVOLUTION

While laws of evolution of the system should not contain any internal Contradictions, the evolution line should necessarily contain a Contradiction. Here is a model of description for each of the lines of evolution:

- Laws on which the evolution lines are based;
- Contradictions of requirements in the evolution line;
- IFR for evolution line is the direction for resolving Contradictions;
- Steps on the line (there should be no less than three 3: matching one requirement, matching the second requirement, step towards IFR for resolving Contradictions of requirements, logic should be traced in the selection of succession of these steps).

The planes of evolution can be formed out of two lines of evolution. For example, Line of fragmentation and dynamization with the line of collective-and-individual use. Should one more line be added, for example, Line of S-curve evolution, and we get the space of system evolution. The idea of line, plane and space echoes the structure of evolution trees of N. Shpakovsky. [13]

L1. Line of introducing elements (substances)

Contradiction: If we introduce a new element, THEN it is possible to increase functionality or eliminate the non-desirable effect. BUT the system will be made more complicated and additional resources will be required.

IFR: Absent additional element ITSELF increases functionality or eliminates non-desirable effect.

Key steps: Emptiness – Modification of resource – Field – Small doses – For a period of time – Copy – disappears after use

Logic of steps. Emptiness is the introduction of an element «from nothing» which is close to IFR. If it cannot be achieved, the modification of available resource – small deviation from IFR. The use of the field can increase the degree of IFR, like the introduction of element in small doses or the use of copies, if it is possible.

L2. Line of introduction and evolution of interaction fields

Contradiction: If we introduce a new field, THEN it is possible to increase functionality or eliminate the non-desirable effect, BUT the system will become more complicated and additional resources will be required.

IFR: Absent additional field ITSELF will increase functionality or eliminates non-desirable effect.

Key steps: Modification of available resource – Fields from accessible external environment – Use of controllable fie fields – Introduction of field temporarily – The field vanishes after being used.

Logic of steps. Similar to logic in L1.

L3. Line of fragmentation and dynamization

Contradiction: If we fragment the system or its element and connect these parts in this or that way, THEN it is possible to increase dynamicity and controllability of the system. BUT, in this case the system will become more complicated and additional resources will be required.

IFR: The system without fragmentation ITSELF will provide for a possibility of dynamization and increasing controllability.

Key steps: Fragment the system into two parts – Fragment the system into many parts – non-flexible integration of fragmented parts – Integration of parts by flexible connections – Integration of parts by fields – The separated parts are flexible themselves – Flexible elements integrated through controllable fields – The entire system is flexible – Instead of elements there are controllable fields of interaction. The sequence of steps can vary.

L4. Lines of coordination-discoordination and structuring

Contradiction: If we coordinate and structure the system and its elements, THEN it would be possible to enhance the efficiency of the system, BUT, in this case, the system will be more complicated and additional resources will be required

IFR: The System ITSELF provides for coordination and structuring without any additional expenditures.

Key steps: Forced coordination of parts – Buffer (by special element, field or subsystem) – Self-coordination of parts without introducing elements and fields – Temporary coordination and structuring – Coordination of rhythm – Use of capillary-and-porous system for structuring – Use of effects and local active additives for coordination of necessary features. The sequence of steps can vary.

L5. Line «mono – bi – poly – trimming»

Contradiction: If new systems are added to the system, THEN it is possible to increase functionality and opportunities of a new complex, BUT the complex will be still more complicated and additional resources will be required

IFR: Absent new additional system will ITSELF increase its functionality and enhances new opportunities of united complex of systems.

Key steps: Add to the system another system of this type (bi-system) – Add to the system many similar systems (polysystem) – In similar integrated systems some characteristics are made different. Instead of integrating similar systems different systems are integrated. – Systems and antisystems are integrated. – Many similar parts of different systems are integrated into one element (partial trimming) – Bonds between integrated systems are developing – Trimming of bi- and polysystem into a monosystem with possible repetition of a cycle of origination of a polysystem.

L6. Lines of collective and individual use of systems

This line is a private case of evolution of a bi-system, in which one of the systems is the analyzed object, while another is a consumer, user of this object (human, group of persons, team). Line relates to social functional-and-targeted systems.

Contradiction: If the system is created for individual use (possession) by one subject (human being), THEN it is convenient and does not create any conflicts with other subjects, BUT, this is expensive and requires additional resources.

If the system is used for collective use (obsession) by many subjects (team), THEN it reduces expenditures, BUT, creates inconvenience in use and conflicts between the members of the users' team.

IFR: Collective system with low expenditures ITSELF provides for convenience and absence of conflicts of individual use.

Key steps: Collective use – Individual use – Part of the time is a collective one –Part is an individual one – Part of the system is a collective one – Part is an individual one – In one place it is collective, while in another place it is collective-and-individual system.

L7. Line of S-curve evolution

It is possible to identify five characteristic stages at the S-curve line of system evolution. Each stage will have its characteristic Contradiction, IFR and corresponding steps of evolution.

1. 1st stage (beginning of evolution). Contradictions are associated with the low functionality and bog specific expenditures. Wording of IFR are directed at forming the operation principle and enhancement of efficiency of functioning, at the use of ready resources for the system. Recommendations are as follows:

• It is necessary to maximally use already existing infrastructural resources and demands;

• It is recommended to integrate the system with the systems, which are leading at the present moment;

• It is recommended to develop the system in a particular field, in which its advantages surpass its disadvantages.

2. Transition period from stage 1 to stage 2.

• It is necessary to maximally speed up the implementation.

• It is required to attain the least possible admissible value of basic parameters and dramatic overtaking in terms of at least one of them.

• TS should be implemented in one field, where the ratio of its advantage sand disadvantages is most appropriate and demanded for.

• The system should be adapted to existing infrastructure and resources.

• Serious changes within the system and its elements are admissible. Operation principle of the very TS (its core) should not be changed.

3. 2nd stage, active evolution.

• It is recommended to adapt the system to new kinds of application;

• To adapt the available infrastructure resources to the needs of the system.

4. 3rd stage, stabilization, cessation of growth.

• Problems should be solved in the near and nearest future concerning expenditures and development of service functions.

• For the distant future it is necessary to foresee the change of operation principle of the TS or of its components, resolving Contradictions, breaking the evolution of the system.

• Very efficient are deep trimming, integration of alternative systems and other methods of transition to supersystem.

5. 4th stage, oscillations or decline.

• In the nearest future it is necessary to solve problems on decrease of expenditures and development of service functions.

• In the near and distant future, it is necessary to foresee the change of operation principle of TS, which resolves the Contradictions, which break the evolution.

• It is necessary to look for local fields, in which the system will still be compositable.

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Table 3. Connection between laws and lines of evolution.

…… **Laws** / **Lines of evolution**	1. Increase of ideality	2. Completeness of operation principle	3. Deployment and trimming	4. Increase of controllability	5. Transition to supersystem	6. Transition to application of resources	7. Forming and evolution of alternative systems	8. Origination of contradictions
L1. Line of introduction of elements	√	√	√			√		√
L2. Line of introduction and evolution of fields	√	√	√			√		√
L3. Line of fragmentation and dynamization	√			√	√	√		√
L4. Lines of coordination and structuring	√	√						√
L5. Line of transition to supersystems	√		√		√		√	√
L6. Lines of collective and individual use	√				√			√
L7. Line of S-curve evolution	√	√	√	√	√	√	√	√

Since there can be many combinations of laws of evolution, the number of lines of evolution can also be higher than that of above described. Besides, there may be evolution lines for special fields or systems. For example, in business it is possible to form an entire complex of evolution lines, for example, Line of formation of chains of creating values, Line of forming the structure of organization, Line of business objects, Line of price and payment, Line of assortment, Line of market development, Line of customer evolution.

As an example, let us quote the description of a Line of evolution of the product assortment.

Contradiction of requirements of the line. The assortment should be wide in order to provide for the needs of the customer and to foresee them and should be narrow in order not to distract large resources of the manufacturer and seller.

IFR 1: Wide assortment of products ITSELF creates an opportunity not to distract large resources of manufacturer and seller.

IFR 2: Narrow assortment of products ITSELF provides for fulfillment of wishes of the customer and provides for foreseeing these wishes.

Use of trends and lines of development: line L5 «Mono – bi – poli – trimming» and Line L1 of introduction of elements (substances).

Here is a possible variant of sequence of steps of lines of evolution of assortment:

• single product, no assortment
• Products with «shift» of characteristics and price. Assortment groups.
• Increase of number of assortment groups and their price range.
• Saturation of assortment. Full coverage of assortment niche.
• Partnership of suppliers and manufacturers for regulation of assortment.
• Formation, structuring and dynamization of assortment policy depending upon the territory, place in the shop, season and time of the day.
• Instead of part of the assortment – copies of specimens of goods, analysis of assortment of competitors. [28]
• Use of Internet-technologies for independent formation by the user of necessary set of goods (assortment).

Table 4 quotes an example of plane of development, for which two lines of evolution have been chosen: «Line of fragmentation and dynamization» and «Line of collective-and-individual use». For the sake of simplicity only part of steps of these lines are quoted. As an object let us quote, for example, a bus. Then a private individual bus can be placed in the cell 1–2 of this space of development. Two or more buses (trailers, half-trailers), attached one to another for collective transportation of passengers. Cell 5–4 could take the form of a bus fragmented into parts (sections) with flexible bonds and with a private (individual) driver, however intended for collective use by the passengers. Or another variant – the tractive vehicle is private, while flexible buses-half-trailers are of collective use. Cell 6–5 – it could be individual private buses without drivers, which can be grouped on the road (through city information system) into a collective train, if their routes coincide art least partly. Cell 9–6 – it could be flexible buses with completely changeable geometry. In case of individual use, it is «compressed» to small size, while in collective use it can be stretched to big dimensions.

Table 4. Example of plane of development: «Line of fragmentation and dynamization» and «Line of collective-and-individual use». Only part of steps of these lines is quoted

Line of collective-and-individual use Line of fragmentation and dy-namization	1.Collective use	2.Individual use	4. Part of the system is collective – part is individual	5. In one place it is collective, in another place	6. Collective-and-individual system
1. Monolith system		1 – 2			
3. Many parts	2 – 1				
5. Flexible bonds			5 – 4		
6. Connecting parts by fields				6 – 5	
9. The entire system is flexible					9 – 6
10. System is created of fields					

6. APPLICATION OF COMPLEX OF LAWS OF EVOLUTION OF FUNCTIONAL-AND-TARGETED SYSTEMS

The complex of LEFTS proposed by the author has several directions and a rather wide sphere of application. It is possible to single out five directions of application and development of a complex of LEFTS:

1. Forecasting of development of functional-and-targeted systems. It is possible to use lines, planes or spaces of system development. It is possible to use trends themselves directly.

2. Statement of inventive problems. Based on the forecast it is possible to state a problem, associated with the transition of a particular functional-and-targeted system.

3. Application of a complex of LEFTS for creation and specification of complexes of laws in different functional-and-targeted systems.

4. Development of a complex of LEFTS. Complex of LEFTS needs to and should develop. For this purpose, it is possible to use different approaches:

- accumulation and analysis of collections of cards of inventions («patent layers») and histories of system evolution («patent holes»)
- mutual adaptation of trends from different areas
- specification of a complex of LEFTS for a particular narrow field, for example, metallurgy, medical science, jurisprudence, theory of values (axiology), etc.
- application of complexes of LEFTS to the evolution of the very complex of LEFTS (complex of LEFTS is in itself a functional-and-targeted system and laws and line soft development of a complex of LEFTS can also be applied to it).

5. Accumulation of collections of cards with examples confirming or violating the laws of evolution of functional-and-targeted systems.

Transition from analysis of technical systems to functional-and-targeted systems as an object of TRIZ study, enables to significantly widen the circle of system, evolution of which TRIZ is able to study and describe. In particular, LEFTS enable to unite TRIZ and theory of evolution of creative personality (TECP). Let us quote only several examples of TECP compliance with the complex of LEFTS. In TECP, for example, there are analogs of law of increasing ideality: Great Dignified Goal, tendency to Ideal Creative Personality, tendency to realization of Ideal Creative Strategy. Completeness of operation principle in TECP is, for example, a complex of features of creative personality and formation of it. [15]

A group of laws of evolution of the system structure and a group of laws of interaction with external environment correspond in life strategy of creative personality (LSCP) to interaction of Creative Personality and External circumstances. Law of increasing controllability and dynamization in LSCP is a regular change of specialization, change of Goals, change of program of actions, change of disciples and own schools. Transition to supersystems is presupposed by the concept of maximum motion upwards, generalization of stated goals and application of obtained results, transition of personal work to a School of disciples, creation of institutions. No doubt, LSCP presupposes maximum use of resources and preliminary steps made in advance. The presence of partners and competitors, formation and development of programs for attainment of the set goal – all this is characteristic of LSCP and is described in LEFTS.

All activity of creative personality is permeated with Contradictions and the necessity to solve them. The Choice of a Dignified Goal, creation and realization of plans concerning the attainment of this goal, getting necessary education and search for required information, protection and saving of obtained results, avoiding the pressure of external circumstances and betrayal of colleagues and disciples – all this requires the skill of overcoming the encountered Contradictions.

7. ANALYSIS OF PROPOSED COMPLEX OF LEFTS FOR COMPLIANCE TO REQUIREMENTS TO A COMPLEX OF LAWS OF EVOLUTION

The table quotes the comparison of a complex of laws of functional-and-targeted systems evolution developed by the authors with developed criteria applied to this complex of laws.

Table 5. Comparison of a complex of LEFTS with criteria of requirements to it.

Criterion	Compliance with the complex of LEFTS
1. Use of TRIZ terms	Each law and line of evolution in complex is worded based on the terms, notions and phenomena, described in TRIZ
2. Compliance with the field of laws application	All laws and lines of evolution in a complex of LEFTS correspond to and are restricted by the area of functional-and-targeted systems. Thereby they don't contradict more general laws of evolution of the systems and narrowest laws of evolution of technical systems
3. Confirming through facts and prognoses	Complex of LEFTS corresponds to arrays of inventions and evolutionary development of functional-and-targeted system from fairly different fields. The complex of laws possesses large prognostic potential
4. Laws are not contradictory	Each law of the complex of LEFTS separately is non-contradictory
5. Laconic character of wording at the completeness of descriptions	At significant increase of area of application and introduction of new laws of evolution the number of laws was reduced to eight. Ideality of complex of LEFTS grew
6. Dynamicity and possibility of adaptation of a complex of LEFTS	As a result of retaining the general structure of a complex of LEFTS, the number of laws, consequences of these laws and lines of evolution can also change
7. Compliance with own requirements and laws	The directions of evolution of a complex of LEFTS corresponds to laws and lines of evolution of the same complex: ideality and completeness of laws have increased, the complex underwent the stages of deployment and trimming, its ability to undergo dynamization and adaptation, there is a supersystem in the form of laws of system evolution

Developed complex of laws of evolution of functional-and-targeted system corresponds to criteria of requirements to complexes of system evolution.

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CONCLUSIONS

1. The authors performed the analysis of known publications on the topic of laws of technical systems evolution in TRIZ, identified their positive and negative features and formulated criteria for correctness of complexes of laws of system evolution.

2. Based on the analysis of large array of facts and publications on the topics of evolution of functional systems the authors developed a complex of laws of evolution of functional-and-targeted systems, which corresponds to criteria of correctness of complexes of system evolution laws.

3. Complex of LEFTS is dynamically developing, able to be adapted to new fields of knowledge and specialized in narrower directions of application, and is based on the notion of completeness of operation principle of functional-and-targeted systems.

4. Complex of LEFTS enables from standardized positions to analyze the system of TRIZ-TECP, since the strategies of creative personality evolution are also functional-and-targeted systems.

4. One of the directions of evolution of a complex of LEFTS is the transition from the lines of evolution to surfaces and spaces of evolution of functional-and-targeted systems.

5. Next steps of presented research are associated with refinement of the complex of LEFTS, its application for development and forecasting of functional-and-targeted systems.

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Analysis of density problem as a tool for ranking a complex of problems

SUMMARY

Relevance and practical demand for methods for decision-taking is preconditioned by the restriction of resources irrespective of the kind of activity. The presence of a simple and objective method for selecting one option out of several ones enables to concentrate the effort in required direction without any quality losses. The present article is focused at disclosure of the essence of the method developed by the authors and consisting in simple and objective ranking of problems and tasks, based on the new notion of problem situation density. In order or the method to be practically used by other users the authors developed an algorithm for ranking problems and tasks, which was many times verified in the process of practical activity. This algorithm and some of the cases offered by the authors are also quoted in this article. The review of the existing methods for ranking concepts, problems and for decision-taking has been made for the purpose of identifying disadvantages, hindering the practical use of these methods, by the broad circle of users.

INTRODUCTION

The overwhelming majority of modern production facilities in this or that way include a number of different interrelations, which exist between machines and mechanisms, tools and materials, human being and equipment.

The authors noticed in the course of their practical activity that at such variety of system elements it is difficult to select a correct and vital problem. However, after selecting the problem, one cannot be always sure that the solving of this problem will lead to attainment of the goals, set before the enterprise. However, it is not possible and not feasible to get scattered between all problems.

The authors singled out at least three reasons:

• Restriction of resources of TRIZ-specialists and participants of project teams at industrial enterprises;

• Degree, rate and complicacy of implementing the solutions, obtained during the process of project performance at the functioning batch and serial productions;

• Loss of reputation of project team participants.

"Selection of the problem largely preconditions the fate of the invention and the inventor".[1]

In problem ranking such problems should be certainly selected first, which more than other problems influence the hindrance of enterprise development and the solving of which could bring the highest economical effect. Such logics could lead to erroneous selection of priority directions in project development.

In order to enhance the objectiveness of this process, parametric landmarks are introduced – consumption factor, time parameters, economic criteria. However, such logics could fail in selecting the problem. For example, based on their experience of project activity the authors noted that if the overall amount of consumed electric energy dominates over other kinds of energy, however, at the same time the number of different consumers of this energy is very large, it will be necessary to solve many problems associated with each consumer, not one problem. Therefore, according to the opinion of the authors of this article, the issue of methodology for selecting correct problems is also vital and open as of today.

In such situations interviewing the owner of the problem or the problem-setter and contiguous departments could partly eliminate this problem, however, in this case the risk of adding subjective opinions; it has to be borne in mind that for the problem owner his problem is the most important and significant, which does not add any objectivity to the process of problem ranking. Similar situation could be encountered as a result of addressing the experts, since their prognoses come true with such probability, which is no higher than random guessing. [2]

In the course of practical introduction of TRIZ at production facilities of aluminum industry the authors discovered the demand for a tool of objective selection of directions for search and subsequent ranking of identified problems.

In order to solve this problem, the authors of the article introduced the new notion of «problem situation density», developed the method for analysis of problem density, based on this notion and developed an algorithm for using this method, which was tested on several cases from the project activity of the authors.

REVIEW OF REFERENCE SOURCES

The problem of correct selection of tasks was stated by G.S. Altshuller back in 1961. "Each of these machines could be improved and in each of them new inventions could be made. It is also possible to create other machines – completely new, such that don't exist. But where to begin? Which problem should be solved first?" [1].

In TRIZ the ranking elements are found, for example, in benchmarking, value engineering analysis (VEA) and flow analysis.

The goal of VEA is the lowering of expenditures per unit of useful effect. [3,4] However, this approach could yield erroneous conclusions in such cases, when the analyzed technical system has complicated incorporated structure of subsystems and formation of expenditures is not restricted by one element. At the same time the creation of a precise value engineering model requires a higher number of resources and the result can be improbably cumbersome, which would hardly simplify the identification of problems, which are necessary to solve. [5]

Similar situation could be encountered in performing flow analysis. For example, identified leak of useful flow at the upper level of the system, if it is analyzed at the lower system level, will appear to be scattered throughout the multitude of elements of subsystems. And the answer to the question, with which element of the subsystem it is necessary to interact further, unfortunately could be less definite as we might wish.

It is necessary to note that outside the ambience of TRIZ the necessity for problem ranking is also vital and the ranking methodologies, which are verified and workable, are in no lesser demand. In the article «Methodology for quality problem ranking…» it is said that «…elimination of failures, which were observed in a complicated technical object, should be regulated in terms of labor intensity and expenditures. …As the practice shows, the ranking of quality problems based on one feature only (for examples, massive scale or expenditures) is not efficient. It is necessary to perform corrective action both as applied to mass, but insignificant defects and as applied to significant (expensive) defects, discrepancies or breakdowns. …In order to define the priority for elimination of this or that problem, it is necessary to determine a complex indicator, which would include at least the evaluation of mass involvement and evaluation of significance». [6] The methodology proposed in [6], is applicable for selection of priority problems, but has a specific applicable character and requires the accumulation of statistical data regarding failures. The tool becomes cumbersome and labor intensive.

Moreover, the problem of selection and ranking of problems at an enterprise is a private manifestation of a broader problem of decision-taking. Therefore, it would be a disadvantage of the authors not to take into account the achievements of the theory of decision-taking.

In the article by the Nobel-prize winner G.Symon and his colleague A.Newell [7], the authors single out so-called well-structured and poorly structured problems. Well-structured problems are understood as those, which can be expressed in figures and symbols, i.e., have a parametric form of expression. Poorly structured problems, for their part, have no parametric expression and the decision is taken based on subjective preferences of the person, who takes the decision.

The increase in the degree of the problem being structured is possible due to the enhancement of decision-taking criteria. At that both classical methods of solving a multi-criteria problem [8, 9], and the modern methods based on these above-mentioned previous developments exist. [10]

However, the application of support system based on these methods is rather labor consuming. These methods and systems are most often applied for solving such problems, in which the expenditures on development and implementation of these systems are compensated. To these problems refer, for example, the problems for planning the activity of the corporations, design of complicated technical systems, selection of variants for operation of expensive equipment, etc. Application of complicated mathematical models is first of all economically feasible in such cases. [11] However, with systems, which are less equipped with resources the problem of decision-taking is less vital due to such a simple reason that they are less tangible to wrong solutions against the background of costs incurred on taking this decision. Therefore, the demand for a simple and objective methodology for selection and ranking is vital.

THE BASIC PART

As it was marked in the reference review, the existing methodologies can either lead erroneous conclusions, or require significant preliminary preparation and creation of information structure on gathering various data.

In order that the problem stated in this article should be clearer, let us quote an example. There is a technical system, in which the overall amount of expended energy dominates over other kinds of energy used. However, the technical system consists of a large number of different users, who use electric energy and the statement of problem of energy saving will lead to the fact that it will be necessary to solve not one problem, but many problems at once applied to each consumer, while taking into account the restrictions, mentioned in the introduction to the present article, the feasibility of such approach is problematic. In order to avoid such mistakes, the authors of the article stated the goal of developing such a method, which would enable to take feasible decisions regarding the selection of this or that direction and the task for decision-taking. The method is based on the notion of problem situation density (problem density).

The density of problem (of problem situation) is a numeric indicator of a problem situation, which shows specific value of this or that characteristic of the object. The characteristic could be understood as consumed (or generated) energy, expendable materials, amount of reject, labor payment fund, number of failures, expenditures on operation, maintenance and other parameters, which numerically characterize this or that analyzed object and the problem situation associated with it.

The specific value of this parameter could be reduced to the area, at which the cumulative value of this parameter is formed, to the unit of the overall amount of equipment, overall number of steps or elements, to the unit of time, to the overall number of operation and servicing personnel, etc. Based on the value of problem situation density, it is possible to rank different problem situations and stated problems. The higher the specific density of the problem, the more vital could be the analyzed problem and the more promising could be the solution of it for the implementation of the project or for the improvement of parameters of the enterprise as a whole.

The authors also noted that in problem ranking one can use not only the density of problem characteristic, but also the density of useful characteristic.

The following algorithm was developed in order to formalize the method and to obtain a possibility to transfer it for future application by other users:

• Select a complex of objects or processes for analysis. Selected objects or processes should have one measurable parameter, which should be common for all of them (physical, economic, social, etc.). For example, equipment or technological process of a particular manufacturing plant is selected as an object.

• To define the goal of analysis: ranking of objects or processes for the purpose of singling out problems and placement of tasks; defining the potentiality of certain concepts or known solutions. For example, to decrease the expenditure of energy, increase productive capacity, decrease the violations of discipline, define the potentiality of the energy source, etc.

• To define the parameter values, according to which the ranking will take place. On the one hand, they should embrace all objects or processes chosen for selection, while on the other hand they should match the selected goal of analysis. Selected parameter values should correspond to system level of TS. For example, the selected parameter values can take the form of energy consumption or energy production, expenditures or profits, number of violations of law or of prizes, expenditures on operation, repair or maintenance, etc.

• To select the parameter values of objects and processes, the measuring unit of which will control in defining the density. It could be presented in the form of spatial, temporal and quantitative characteristics. For example, the area of a workshop, the length of a pipeline, the number of energy consumers (in units), changes in sales volume in time, number of personnel, etc.

• With characteristics selected in item 3 it is necessary to calculate specific characteristics (of density) per unit of characteristics selected in item 4. If we are talking about the distribution according to the number of units, it is necessary to take into account if they belong to the same type or not (i.e., if we shall have to solve the problems separately). For example, the specific expenditure of gas with each workshop per year averagely or in each season. Or the amount of reject at similar products made with the aid of similar equipment.

In case the selected analyzed object is the process with processing stages (steps) or the flow, it is necessary to take into account the influence of cumulative effect of expenditures in the flow upon the density of the problem.

• In order to compare several characteristics (densities of characteristics), benchmarking should be used.

• To analyze the results of ranking from the viewpoint of correspondence to problems stated in item 2. If the goals are not attained, it is necessary to pass over to item 1.

EXAMPLES OF APPLICATION OF THE METHOD

The method was tested on practical examples from the experience of project activity of the authors.

One of the products of the plant was selected as the object for analysis. In the course of analysis of the enterprise the data was obtained on costs for manufacturing this product, while the characteristic was understood as energy expenditures on the manufacturing of the product. The distribution of energy expenditures is presented in Fig. 1

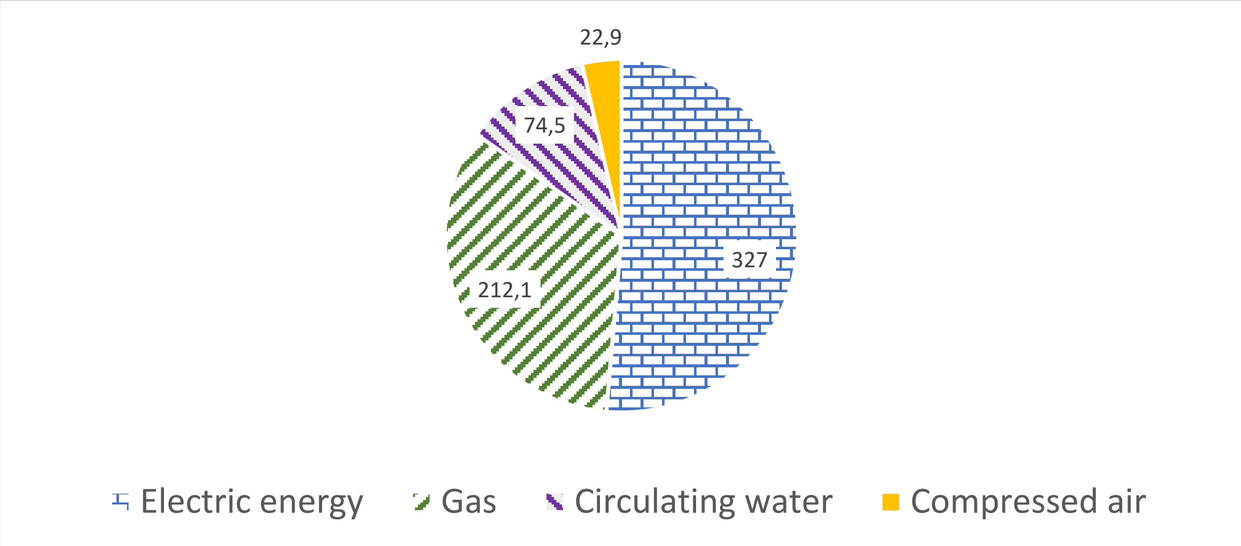

Figure 1. Distribution of energy expenditures Rbs/t

Based on the diagram presented in Fig. 1, it is possible to make a conclusion that first of all it is necessary to deal with issues of energy saving. Having recorded this conclusion, let us pass over to problem density analysis and after that we shall compare the conclusions obtained.

In order to perform the analysis, the authors received from the enterprise not only the data on product costs, but also process design, which characterizes product manufacturing and includes the list of equipment used. The number of energy consumers was selected as a characteristic, the unit of which will define the density in the course of further analysis. Table 1 quotes the obtained data and the results of calculating density values with regard to similar equipment:

Table 1

Type of energy	Cost, Rbs/tonne	Number of individual consumers, units.	Problem density, Rbs/tonne*unit.
Electric energy	327	12	27.3
Gas	212.1	1	212.1
Circulating water	74.5	2	37.3
Compressed air	22.9	2	11.5

As it is seen from the Table 1, the introduction of specific value redistributed the priorities from electric energy in favor of gas and circulating water.

Similar approach could be used in the analysis of losses in water pipeline networks. The situation is worse not in the water network, in which more water is lost, but in that one, with which the relative parameter value of water losses per length of the water network or per overall volume of water consumption in this network is higher. Let us consider it on example of two cities – Lisbon and Tokyo.

In terms of absolute parameter values the situation with water losses in Lisbon is much better – the number of losses is 9.3 times less than in Tokyo. However, if we include the specific characteristic with our analysis, the situation fundamentally changes – the losses per 1 km of network are 70 % higher than in Tokyo (see Fig. 2)

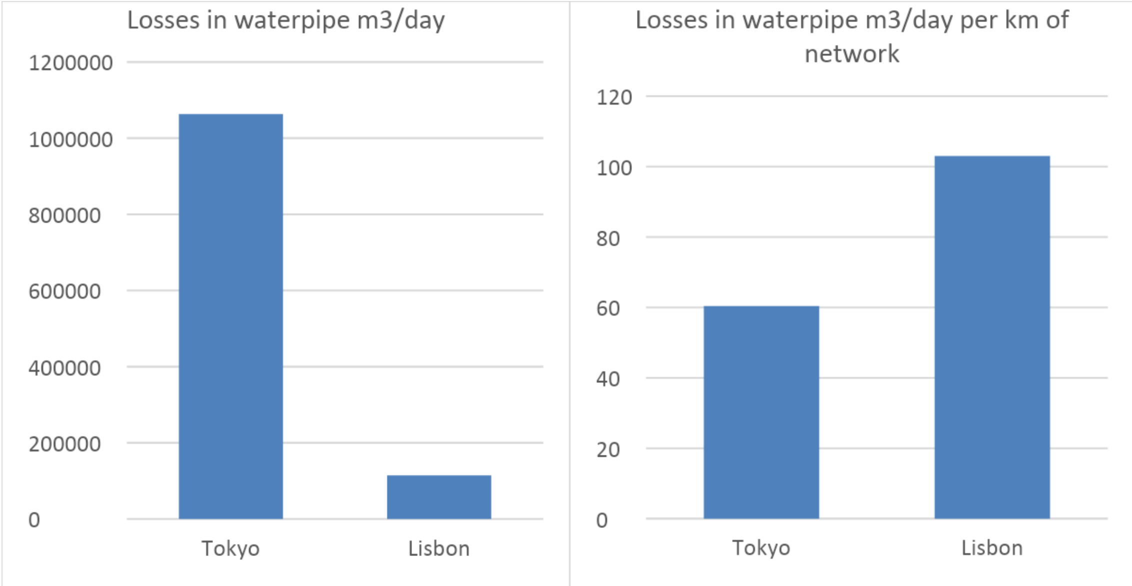

Figure 2. Comparison of absolute and specific characteristics of losses in water network in Lisbon and Tokyo

Another example is proposed for analysis: data on technological waste in manufacturing of a certain product. Fig. 3 shows the expenditures incurred by the manufacturing plant at each of the alterations of the technological sequence of manufacturing as well as normative percentage of technological wastes remaining after each step of manufacturing.

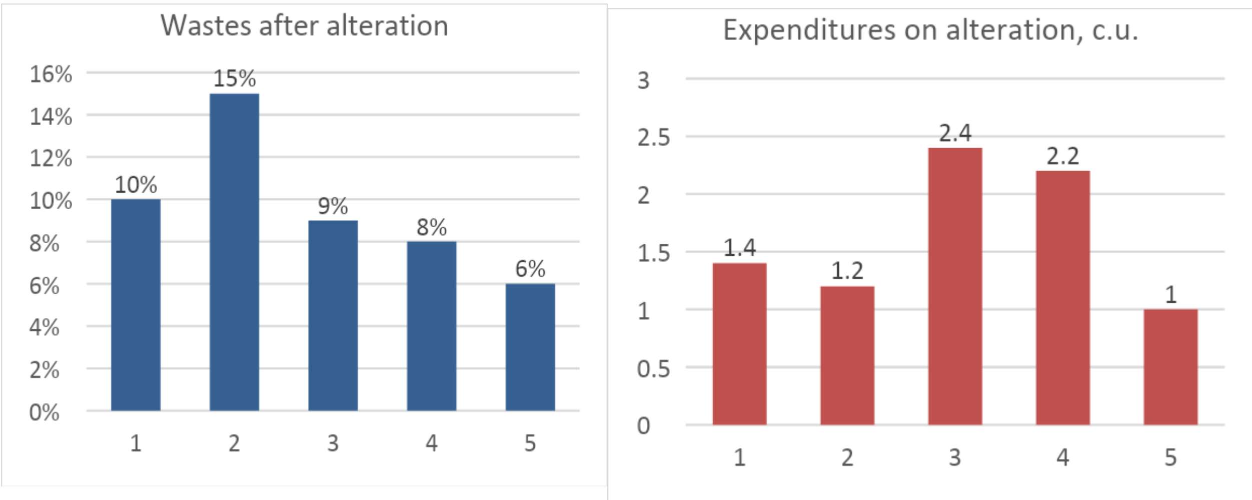

Figure 3. Comparing the expenditures due to manufacturing alterations with the amount of obtained technological wastes

A conclusion could be drawn from the quoted diagrams that the efforts first of all should be directed at the work with alteration 3, since the highest expenditures in conventional units are concentrated there, or with alteration 2, since there we have the highest percent of obtained technological wastes. But what alteration shall we begin with?

If we address the characteristic of problem density, which takes into account the expenditures of all previous alterations, we shall obtain a different result, which will certainly direct us towards the top-priority direction of work:

Table 2

	Alteration 1	Alteration 2	Alteration 3	Alteration 4	Alteration 5
Expenditures on alterations	1.4	1.2	2.4	2.2	1
Waste after alteration	10%	15%	9%	8%	6%
Cumulative expenditures on wastes after altera-tions	0.14	0.39	0.45	0.58	0.49

Thus, it is possible to draw a conclusion that the most «morbid» alteration is exactly the alteration 4, in which based on the parameter of problem density, the greatest losses of the enterprise are concentrated. Let us note that before introducing the notion of problem density we never spoke about alteration 4 and the choice was made between alterations 2 and 3.

In the course of developing and practical testing of this methodology the authors noticed that in calculating the problem density (the density of useful characteristic) it is also necessary to take into account the effect of replication – expenditures on the search of solution are not multiplied by the number of similar or identical objects. Let us quote a practical example.

Table 3 quotes the structure of expenditures on the manufacturing of products according to the type of expenditures. It is seen that after introducing the notion of problem density with regard to the number objects, the structure underwent changes: the transition was from the concentration of attention on consumers of electric energy to users of crude oil.

Table 3

	Percentage of expenditures in rubles, %	Number of sites according to these characteristics	Index of characteristics with regard to density
Gas consumers	18%	5	26,2%
Electric energy consumers	**57%**	21	19,7%
Crude oil consumers	12%	2	**43,6%**
Compressed air consumers	8%	7	8,3%
Cooling mixture consumers	5%	17	2,1%

Now let us introduce a correction regarding the effect of replication.

Table 4

Characteristics of objects	Identical objects from the viewpoint of planned analysis	Groups of identical objects	Index of density with regard to replication
Gas consumers	5	1	**56.9%**
Electric energy consumers	4	18	2.4%
Crude oil consumers	0	2	31.6%
Compressed air consumers	4	4	4.5%
Cooling mixture consumers	17	1	4.6%

It is to be seen from Table 4, that with regard to identical objects the priority of directions also changed – first of all it is necessary to deal with gas consumers. The consumers of electric energy were practically devoid of attention due to a great number of various consumers, they should be the last consumers to deal with.

As it is seen from the quoted example, the method, which is rather easy to master, enables to precisely define the priority directions, which are characterized by maximum potentiality of efficient use of resources for solving problems.

CONCLUSION

• The authors identified and formulated the reasons, due to which the identification of problems and setting the tasks at the enterprises is a key issue and preconditions both the future of individual projects in particular and the tempo of implementing TRIZ at the enterprise on the whole;

• It was shown by the authors that the existing methods for decision-taking and for selection of directions could either yield erroneous conclusions or require significant preliminary preparation, creation of information infrastructure, involving the gathering of comprehensive data and use of complicated mathematical apparatus, which significantly reduces their application in practice;

• For the first time the authors introduced the notion of problem situation density (problem density) and the density of a useful characteristic;

• The authors developed the method and the algorithm for using this method based on the notion of problem situation density and the density of useful characteristic for ranking the directions for improvement as well as task ranking;

• The authors demonstrated the practical use of newly introduced notions and the developed algorithm for analyzing the density of problem characteristic for obtainment of results, which are unexpected and different from those results, the obtainment of which is based on standard logics for task selection;

• The authors noted, that in calculating the density of problem situation (useful characteristic) it is necessary to take into account the number of identical objects, with which it is possible to replicate the found solutions;

• The authors noted, that in ranking according to several characteristics with regard to their density it is possible to use benchmarking or other known methods for ranking according to several characteristics.

The authors suggest the following directions for further research of developed method and its optimization:

• Testing the analysis of problem situation density (useful characteristic) on a large number of cases, formulation and formalization of constraints of this method;

• Improvement of algorithm of using the method involving the formalization of selection of typical sets of characteristics depending upon the field and kind of activity;

• Enhancement of precision of the method through introduction of corrective multipliers of the lifecycle stages of a technical system with the further optimization of algorithm for using this method.

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Characteristics Dissonance Analysis as a Methodology for Statement of Tasks

SUMMARY

In the present work, the authors disclose the essence of the method developed by them, which got the name of Characteristics dissonance analysis. This is a method for analysis of different characteristics of one system, which are interconnected by one model or another, or of similar characteristics of different systems. This method found extensive use in practical activity of the team of authors and is directed predominantly at identification of problem situation and statement of «correct» problems. The novelty of the work consists in the complex research of the nature of dissonances, as well as in the algorithmizing of work with the emerging dissonances for the sake of formulating the tasks for future projects. The article will contain the analysis of such aspects, which prove the efficiency of the authors' developments, will show the actual examples of using the method for stating the tasks at manufacturing plants of various branches of metallurgy. Also, further steps for developing and using of this method will be briefly described.

INTRODUCTION

The development of science and technology leads to the appearance of still more approaches to solving the problems of various level of complicacy and corresponding methodologies. However, with the development of solving tools the issue of «What problems should be solved? » becomes more acute. As the practice shows, the identification and statement of «correct» is often more important than the ability to solve these problems. S. Litvin writes: «According to our statistics, vast majority of source, target-oriented problems need not be solved at all». [1]. The basic problem consists in the fact that in practice it often happens that the effect of solving the problem, even if the solution does not cause questions, is significantly lower than the resources consumed for obtainment of this solution.

Currently there are such TRIZ tools, which enable to identify and state the problems. There are tools, which are both more known and widely spread in practice, like, for example, value engineering analysis (VEA) [2, 3], Flow analysis [4, 5], Failure anticipation analysis, and less known: Modeling the scheme of causality of interactions (SCI), TRIZ-analysis of social-and-technical systems [6] etc. The method of Main Parameters of Value (MPV) Analysis [7, 8, 9] is used for statement of problems with regard to the requirements of the market. However, the use of above-listed tools, from the viewpoint of the authors, does not always enable to attain the required result – to identify and to state the «correct» problem.

The method for Characteristics dissonance analysis is, on the one hand, the generalization of existing methods for identification and statement of problems and on the other hand, the widening of the area of using analytical tools and approaches of TRIZ beyond the limits of exclusively technical systems.

This method started to develop based on quite a number of existing tools, directions and methodologies. In the analysis of dissonance of system characteristics, it is possible to find the elements of theory of cognitive dissonance of Leon Foestinger [10], the elements of above-mentioned value engineering analysis [2, 3] and parametrical analysis, sociometry, etc.

Thus, having amalgamated many useful features of different methodologies, the analysis of dissonance of system characteristics could be considered to be all-embracing for identifying possible problem directions, which is expressed in the fact that on the whole the method could work with absolutely any system (all-purpose character according to the object), thereby using the same algorithmized steps (all-purpose character according to method). The advantages of this methodology also include its relative simplicity in application as part of problem statement, when it is not required of the manager to have deep and detailed knowledge of specific features of system functioning, which was several times checked by the authors based on actual business cases.

Significance of the issue of problem statement

According to the opinion and experience of the authors many managers often encountered such situations, when the solution of the stated problem did not bring desired results, or the expended effort was much greater than the effect from solving the problem. Nevertheless, as part of the present article the authors think it to be necessary to quote the examples of such situations in order to supply additional illustrations of the idea, what incorrectly stated problem could lead to.

Example 1. To begin with, let us consider the situation, when a problem stated on one system level did not take into account the supersystem requirements. A project team at one enterprise faced the problem of increasing the productive capacity of the equipment. The problem is important and did not cause doubts with anybody. According to the results of project performance, it became possible to increase productive capacity by 9.7%, which was a good result for this category. However, the growth of productive capacity did not entail the increase in demand for products of the manufacturing plant and, consequently, the profits from selling these products. This example shows that in stating the problems it is necessary to focus not only on the system being changed, but also on what surrounds this system.

Example 2. Another example is dedicated to the search of methods for reduction of costs in producing metallurgic products. The project team performed the analysis of electric energy consumption and the analysis showed that one of the highest parameters of consumption per ton of product is concentrated at the section of anodizing. Preliminary economic effect from decrease of electric energy expenditure in this section appears to be rather significant and the project team directed their effort exactly in this way. The technological chain of this section was analyzed in greater detail, problems and losses of electric energy were identified, concepts for eliminating them were implemented. However, only in calculation of actual economic effect it became clear that the area is significantly underloaded because of the absence of orders, it operates 1 day a week. Many consumers did not buy anodized products and nobody expected that «breakthrough» solutions would lead to the increase in the number of orders particularly for anodized products.

Example 3. Let us analyze the situation, when the economic (or any other) effect of solving the stated problem is dramatically less than the number of resources expended on solving it. A problem of reduction of product cost had been solving at an industrial enterprise. The project team contracted for solving this problem consisted of 7 persons. Eight months later the problem was completely solved and the concepts obtained were implemented with the production process. However, after the analysis of the solution it appeared that the direct economic effect from the solution of this problem was more than two times lower than the salaries of the project team during this period. I.e., the resources spent on solving this problem appeared to be greater than the result obtained.

Encountering such negative results of work, when time and resources are spent and even there is an implemented solution, but the actual effect is not attained, the team started to develop methodology, which would be able to assist in significant simplification of search and selection of «correct» problem, thereby retaining its simplicity and all-purpose character for broad range of application in different systems (from complicated social-and-technical ones to purely utilitarian ones).

As a result, the work on identification of problems in different systems, which are located at different system levels, rich experience was accumulated, which enabled to pass over to formalizing of achievements, which finally found its reflection in the generation of such a method as Characteristics dissonance analysis.

DESCRIPTION OF THE METHOD «CHARACTERISTICS DISSONANCE ANALYSIS»

Characteristics dissonance analysis is a method for analysis of different characteristics of one system interconnected by one and the same model or similar characteristics of different systems for the purpose of identifying problem situation and stating the tasks. In order to perform the Characteristics dissonance analysis, it is possible to use the same characteristic of one and the same system, but measured at different time or at various stages of the system lifecycle. Dissonance in TRIZ is a violation of concord (harmony) in interconnected characteristics of one or several similar systems. The wording of characteristics could be different – from "good/bad" to graphic rendering of functioning range. At any rate these are certain evaluations of behavior or state of object/process/system [11]. Characteristics dissonance analysis is the generalization of a complex of types of analysis, connected by a similar approach: value engineering analysis (VEA), sociometry, analysis of limits of development, theory of cognitive dissonance, function analysis, etc. These kinds of analysis can be considered as a private case of dissonance of system characteristics.

Characteristics dissonance analysis enables to identify the most general and often non-obvious problems in the systems. The method could be applied to any systems: material and non-material. The identified problems could also have a large spectrum of variety: from purely technical to financial-and-economic and organizational problems but the approach in the analysis will be the same.

It is possible to identify the following sources for analysis of characteristics:

- Different source data;
- Distorted model;
- Distorted image;
- Incorrect comparison;
- Wrong evaluation of comparison;
- Dissonance in the object proper;
- etc.

In graphic form the dissonance of characteristics of the system could be presented in the form of the model developed by the authors (Fig. 1), reflecting the main essence of the dissonance.

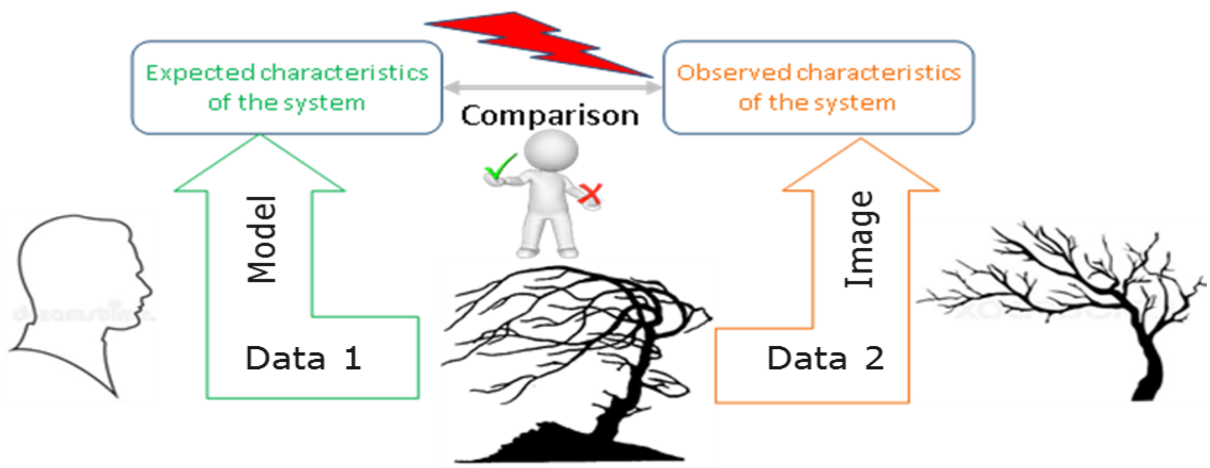
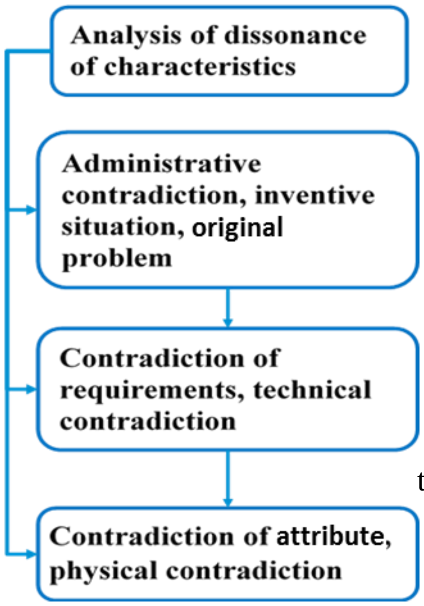


Figure 1

In spite of the commonness and in contrast to other methods for search and statement of tasks, characteristics dissonance analysis of system immediately leads us to those measurable characteristics and parameters, which enable to transfer the identified dissonances to objective contradictions of requirements of supersystems and the features of system elements. Thus, Characteristics dissonance analysis could be a kind of «start» before the transition to the classic triad of contradictions (figure 2), which was many times verified by the authors in different cases.



In order to formalize the work and to structure the information the authors developed and currently offer for use the morphological box of obtained «dissonances». The authors propose the following definitions and abbreviations for working with the morphological box:

• Characteristic 1 and characteristic 2 are different analyzed characteristics, however, one and the same characteristic should be similarly understood within different systems or at different time;

• System 1 and system 2 are, respectively, analyzed systems (objects or processes); at that it is important to understand that System 2 is not a System 1 or a subsystem (supersystem) of a system;

• Symbols -1, 0, +1 is a specific feature of analyzing the system in the past, present and future respectively.

Figure 2

Table 1 contains a possible form of a matrix of such a visualization.

Table 1. Morphological box of dissonance of characteristics.

		Past				Present				Future			
		X1C1_-1	X2C1_-1	X1C2_-1	X2C2_-1	X1C1_0	X2C1_0	X1C2_0	X2C2_0	X1C1_+1	X2C1_+1	X1C2_+1	X2C2_+1
Past	X1C1_-1												
	X2C1_-1												
	X1C2_-1												
	X2C2_-1												
Present	X1C1_0												
	X2C1_0												
	X1C2_0												
	X2C2_0												
Future	X1C1_+1												
	X2C1_+1												
	X1C2_+1												
	X2C2_+1												

For example, X1C1_0 will mean that the Characteristic 1 of the System 1 at present is being analyzed and it can be compared with X1C1_+1 – the same Characteristic 1 of System 1 in future. Or this characteristic is compared with System 1 on the one hand and System 2 on the other hand, etc. Based on the results obtained from the results of analysis, it will be possible to speak about the possible problem directions, in which it is possible to find the problems to be stated.

In order to search for more complicated dissonances, it is possible to analyze the cases, when a system or its supersystem or subsystem is used for comparison, which enables to observe the existing process or technology in greater detail, however, within the frames of this templates such variants are not reflected.

It is obvious that the morphological box can be increased in proportion to inclusion of new systems and characteristics with the analysis, however, based on the experience of the authors, it is sufficient to use no more than 2-3 systems and 2-3 characteristics for attainment of the goal concerning quick search and selection of potentially vital problem.

In order to work with the Characteristics dissonance analysis, the authors developed the following algorithm, which they currently use:

- Select a complex of systems (objects, elements or processes) for analysis. For example, equipment or technological process of a particular plant is selected.
- Define the goal of analysis: search for problem directions for future projects; ranking objects or processes or identification of the problems and statement of tasks. For example, reduce gas consumption, enhance product capacity, etc.
- Select the characteristics, which could be characterized by dissonances. For example, expenditures and productive capacity could be selected, of labor payment fund (LPF) and added value, number of processing operations and their cost, quality and rate of processes, etc. It is allowed to quote characteristics of derived values, obtaining two characteristics instead of one or forming complicated characteristics. For example, LPF and cost for an operation could be presented as one derived characteristic, which is numerically expressed as the ratio of LPF to operation.
- Define the time periods needed for the search of dissonance in system characteristics. It could be the data characterizing preceding periods, which are compared with the present period or between themselves, etc.
- Process the information in a convenient way: in the form of sector diagrams, linear charts, tables, etc.
- Define the identified dissonances. As a rule, from the very beginning, it is possible to discover dissonances, if necessary, it is possible to pass over to item 3.
- Analyze the results from the viewpoint of correspondence to goals, stated in item 2. If the goals are not attained, pass over to item 1.

The identified dissonance of characteristics is an important element for stating cause/effect relations, which lead to identified dissonance. In its turn, it enables to formulate the contradictions of requirements and to find methods for eliminating them.

EXAMPLES OF USING THIS METHOD

4 examples are presented in this section, selected by the authors from the set of resolved cases dated 2021.

Example 1. As a first example let us analyze the technical system at the level of an enterprise. Of course, there is no expecting a certain particular formulated task at such a high system level. This example is an illustration of how the analysis of characteristics helps to decrease the area of search for problems and tasks.

Added value, formed during the alteration, was taken as the first characteristic. The second characteristic is the labor payment fund. The dissonance is visible at figure 3. Calcination complex forms the minimum added value, however, in this case the expenditures on labor payment fund are maximum. A conclusion can be drawn therefrom that first of all one should solve the problems associated with the calcinations complex. These disproportionately high expenditures could be associated with:

- manual work of low productive capacity;
- complicated and labor-intensive operations;
- large number of alterations;
- highly skilled unique personnel.

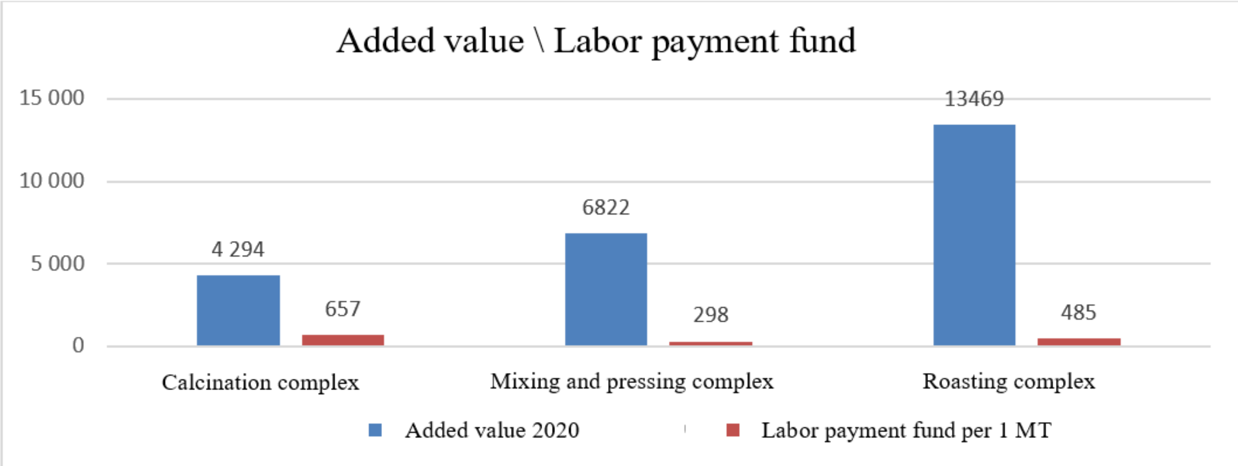


Figure 3

And each of these reasons could contain a contradiction. Which of these reasons (or a set of several reasons) are a ground for the emerging dissonance is an object for further research of TRIZ specialist at the enterprise? However, at this stage the operational zone of search for problems became at least 3 times narrower.

Example 2. The next example is destined to demonstrate the applicability of Characteristics dissonance analysis in non-technical systems. An inquiry was carried out in a certain social group. The participants were asked only one question: with whom out of the members of the group would they like to perform a common project and with whom would they like to go to the pub in the evening? After processing the results, a diagram was obtained, which is presented in figure 4.

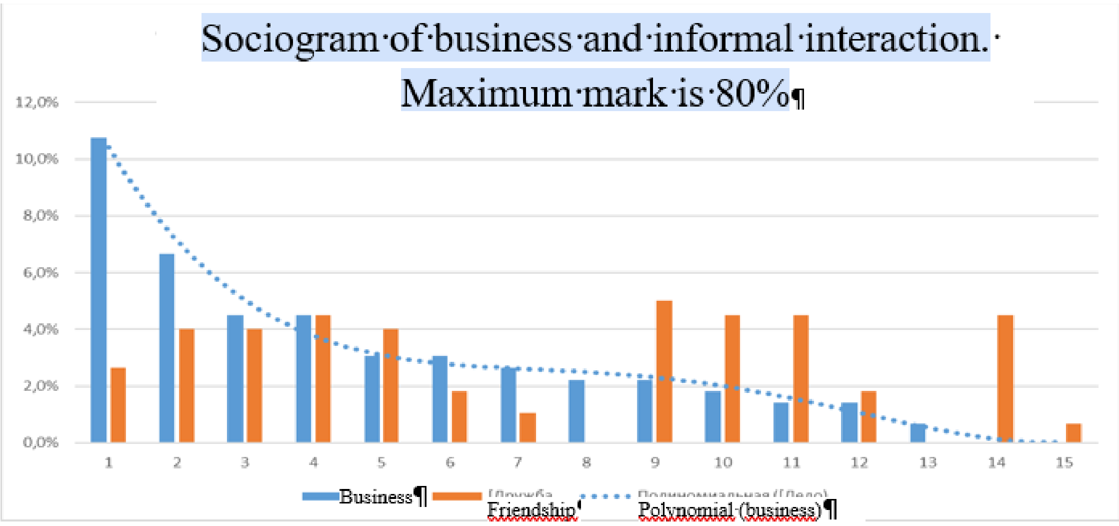


Figure 4

In the diagram it is possible to identify the dissonance of characteristics with the participants «1, 2, 9, 10, 11». In forming a project team out of the participants of this social group the leader will encounter a number of contradictions. For example, the colleagues would prefer business contacts with the first participant, however, at the same time they don't want to establish informal relationships, though all kinds of connections are equally important for an efficient team work.

Example 3. In order to analyze example 3, we propose to address allied methodologes.

Introducing of lean production, TPM, 6 sigma, TQM and other methodologies offers valuable data to TRIZ specialist, which are at bottom characteristics of certain production systems.

Figure 5 presents diagrams of productivity coefficients and quality coefficients of a casting aggregate built based on the data of production systems.

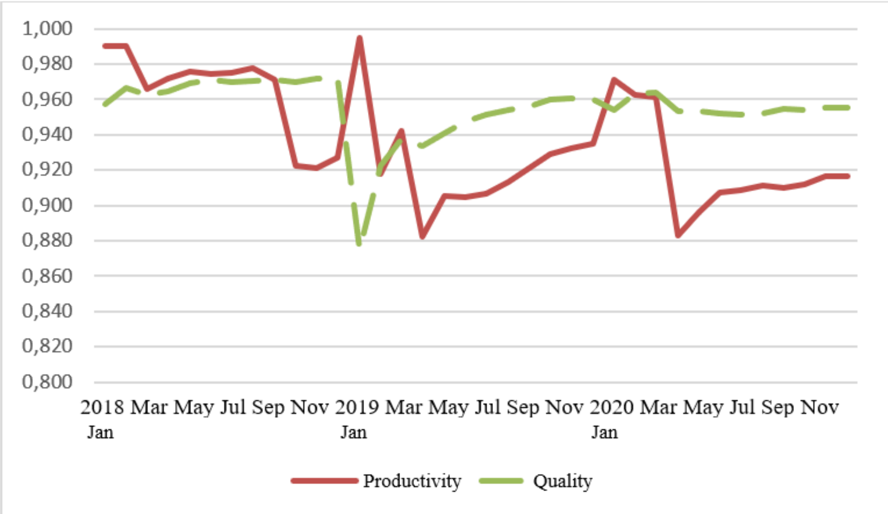


Figure 5

The dissonance dated January 2019 catches the eye first. The increase of productivity is accompanied by the decrease in quality at the given casting aggregate. What is this non-desirable effect associated with? This is an object of a separate research. However, at this stage the image of the would-be important task is quite understandable.

Example. 4. One more proposed example is the case, which was put into effect in the course of a project session for leaders at one of the big enterprises of non-ferrous metallurgy.

In the course of preparation an inquiry was sent to the manufacturing plant asking for information, which could be generalized in the form of 5 topical groups: Structure of the enterprise, financial characteristics, Competitors, Problems (quality), Implemented projects.

Several dissonances were identified as a result of the work performed:

Dissonance 1: Productive capacity/marginality according to fractional composition. High productive capacity with large fractions combined with their relatively low marginality (Fig. 6) Dissonance of the type *(X1C1_0) -(X1C2_0).*

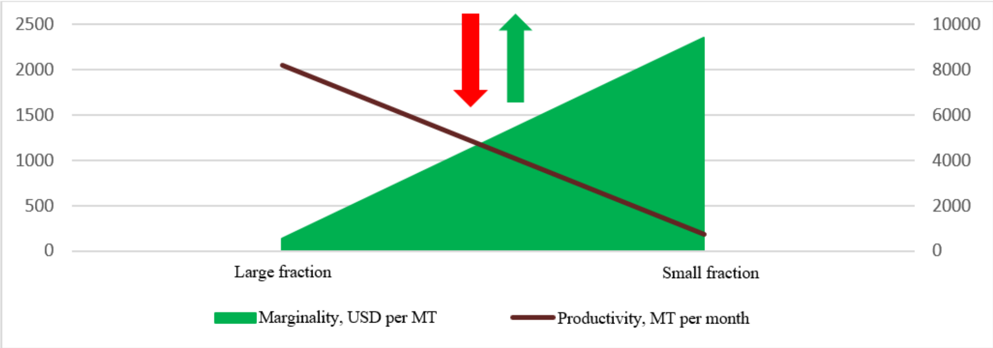


Figure 6

Dissonance 2: Additional alteration «3» adds less value than «1» and «2» (figures 7 and 8). Dissonance of the type (X1C1_0) – (X1C2_0).

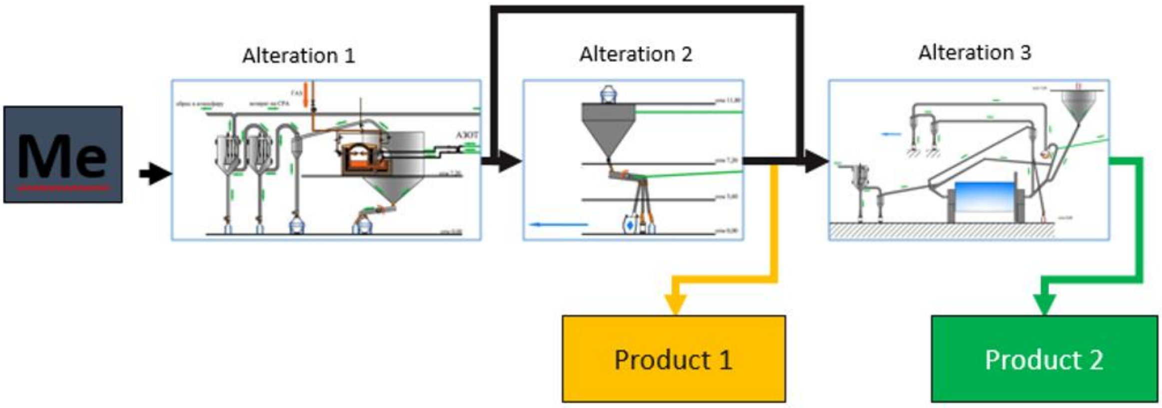


Figure 7

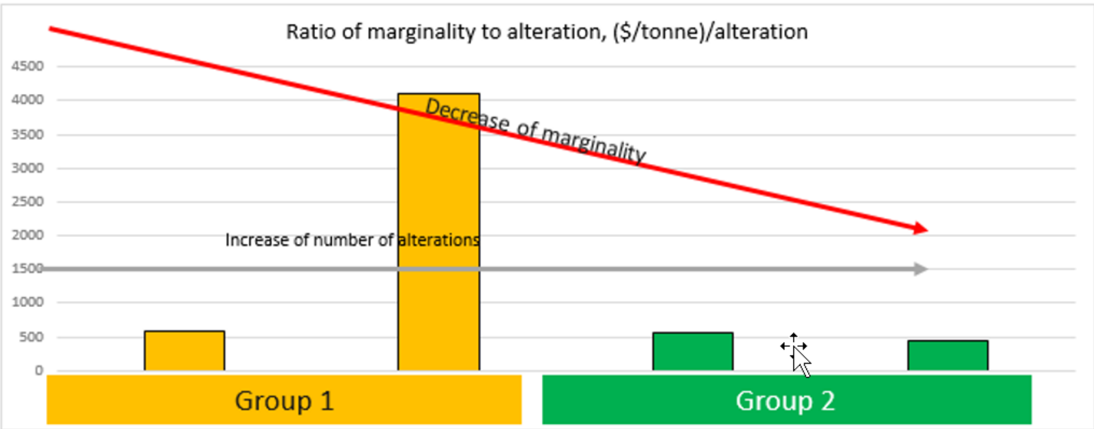


Figure 8

According to the results of work with identified dissonances, potential direction was defined for further penetration into the world market. After several months, the idea found its implementation in placed contracts and plans for further cooperation.

CONCLUSION

Stating problems is an important topic and, according to the opinion of the authors, exactly the statement of the problem, not its solution in many respects predetermines the future result of the project.

The method «Characteristics dissonance analysis» developed by the authors embraced the approaches of several TRIZ tools: parametrical approach, comparison of numeric characteristics of process/product with itself and with analogous processes/products, etc. and generalized them for the sake of joint use. Besides, due to generalization the analysis of dissonance of characteristics enables to work almost with any system (technical, social, organizational), which, by all means, makes it one of the universal methods in TRIZ.

As of today, Characteristics dissonance analysis is used in manufacturing companies of various technological orientation.

The plans for the future of the authors' team are as follows:

• Use of the method for statement of tasks at the enterprises of various sectors of economy;

• Generalizing of experience for applying this method and identification of «grey» zones for using this method;

• Correcting/augmentation of algorithm for using the Characteristics dissonance analysis.

The authors will be thankful for a feedback and criticisms regarding the use of method «Characteristics dissonance analysis».

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TRIZ and Production system: Methodological and Organizational View of their Interaction

SUMMARY

The methods of TRIZ and the Production system *differ in properties and opportunities, despite some similarity in their primary function while their application on production sites (search/solution of problems and shortcomings). This distinction is caused by the difference of classes and the nature of the studied problems. The experience of the implementation of TRIZ at the enterprises, where rather a wide experience of the implementation of the **Pro**duction system has already been accumulated, shows both advantages and shortcomings of the interaction of these two concepts in the uniform space of resources and restrictions.

There is a set of viewpoints on how tools of these two methodologies must/can be integrated. Their review is presented in publications written by numerous authors. The aim of this research is the presentation of orderly theoretical and practical data on the integration perspective. In this article there was performed a task to suggest an updated approach based on the experience of the existence of **two methodically aimed infrastructures** (TRIZ and the Production system) at domestic enterprises.

* *The Production system is a concept of lean production management at domestic enterprises, derivative from Lean manufacturing*

Keywords: *TRIZ, Lean, Production System (PS), Project, Project stage, Business Process (BP), Life cycle*

INTRODUCTION

The aim of this research is the presentation of orderly theoretical and practical data on the integration perspective. In this article there was performed a task to suggest an updated approach based on the experience of the existence of **two methodically aimed infrastructures** (TRIZ and the Production system) at domestic enterprises. The authors investigate the questions of the search and use of potentially significant aspects of the integration in practical conditions of conducting a project activity. The perspective of the implementation of one infrastructure or a technique when there already exists and is being successfully applied another one is **vital** for innovative development.

SHORT SUMMARY OF PUBLICATIONS ON TRIZ AND PS INTEGRATION

The subject of the combined application of TRIZ with various techniques of product or production process (such as Lean, Six Sigma, TQM and etc.) development for the purpose of quality and production efficiency improvement is not new. **However, the research results on this problem from various points of view have been published for two decades. The reason is that experts and departments of the available infrastructures on the well-known methodologies of change and improvement management at large companies not always well understand where to move further. Similarly, it unclears sometimes where and how to implement the methodology of innovative development and TRIZ, which are gaining the increasing popularity.**

To understand what is lacking in understanding of the status and the research results of such an integration it is necessary to classify them by the directions and to get acquainted with the materials of the publications devoted to the matter.

In this article, the consideration of the problem is narrowed down to the issue of integrating TRIZ with PS (localized version of the lean production[1] concept introduced at Russian enterprises). A practical approach to their methodological and organizational interaction is also presented. This issue is debatable and there is no unambiguous opinion about the way to coordinate the implementation.

*[1] **Lean production is lean production**. The system of the organization of production developed by Japanese automobile giant Toyota.*

The first direction is a review of conceptual properties of each methodology of TRIZ and Lean, their similarities and distinctions as well as ideas of their potential combination [1, 2, 3, 4, 8, 16, 17].

The second direction is the adaptation of the concepts and purpose of the tools in order to ensure their general perception by different methodologists. A detailed studying of the fields of method crossover is available here. [1, 2, 10, 11, 13]

The third direction is a process integration of the TRIZ and PS methods in design and innovative activity. [5, 9]

The fourth direction is an experience of the combined use of these approaches in applied tasks of production process, the review of integration opportunities through a prism of examples and cases. [6, 11, 15]

The fifth direction is a narrow-purpose integration application (**on** the industry, **on** the purpose). [7, 14, 18]

In their publications the authors pursued different aims while investigating the issue. At different stages of the TRIZ and Lean bi-system development it is possible to notice the domination of one of the component concepts (when it is offered that the tools of one of the techniques become optional or an integral part of the other's roadmap).

The authors want to note the qualitative review of a wide range of publications and cases of tasks under consideration on the matter in question. [12]

METHODOLOGICAL AND ORGANIZATIONAL ASPECTS OF TRIZ AND PS

Although the purpose of TRIZ and PS may outwardly have some similarities and differences in the terminology of the methods used (identification and elimination of shortcomings), there are several features and differences that guide each of them into different implementation areas, which does not reduce but rather emphasizes the importance of their smart combination.

Let's consider some of these differences. The PS clearly determines the main and **derivative values** as well as the ways of their creation, which is the guide to the methodological procedure organization. In TRIZ, the values of the object under consideration and the subject area can be different and specific, which makes it possible to set a variety of tasks with different levels of complexity. There are three of the common values for PS and TRIZ, namely, cost reduction, productivity growth and quality improvement.

In the PS, the effectiveness of each tool is determined by the built-in process measurement mechanism for the proposed improvements or changes. **For example, the Kaizen[2] forms specify the target and actual cost-effectiveness calculation.** However, the specified limitations of the PS tools do not allow considering the issue more broadly, in terms of other systems and components. For example, in PS stream analysis is considered from the flow organization perspective whereas in TRIZ it is carried out systemically to identify 'bottle necks', flow-riders, gray zones and resource optimization**.** The use of TRIZ roadmaps and tools provides a large degree of freedom for the researcher, but on the other hand, this property complicates the assessment of their activity effectiveness.

A careful quantitative calculation of losses (**Muda**[3], which is provided in PS, is a private vector to ensure the ideality of the systems provided for in TRIZ, which offers a comprehensive qualitative assessment of the parameters (useful and harmful functionality (functions), costs and etc.).

More detailed information about the characteristics of the two concepts that are important while analyzing the ways of their combining and role distribution comes as follows:

Table 1. Comparison of Characteristics of TRIZ and PS concepts

	PS	TRIZ
Task Type	identification and elimination of losses (**unnecessary motion, overproduction, waiting, overprocessing and defects)** - quality and safety improvement in work areas - standardization of works	- identification and resolution of key issues - technical and design tasks - management tasks - patent strategies - technology forecasting - production cost reduction - productivity improvement - product quality increase
Problem Class	Problems that can be solved promptly and easily. There is no problem complexity classifier	Solving complex inventive problems that have not been solved by applying the well-known methods and knowledge in the domain. There is a problem complexity classifier
Objects of change	Production site and personnel actions. Flows of goods and services. Processes with the biggest waste. Logistics. Documentation	Technical systems. Products and technologies
Nature of changes to objects	Reduction of the number and time of operations. Reduction of defects and material losses in the production process. Optimization of work zones and personnel actions. Creation of favorable working conditions	System components collapse. Reduction of harmful functions. Implementation of new technologies and effects. Systematization and globality (changes in supersystem components). Implementation of a new operating principle and radical system changes
Methods of scanning and handling problems	Regularity and fixation of observations on **Gembe**[4], loss measurement and change result control. Staff survey. Documentation change. The methodology has a fixed set of standard calculation and analytical procedures.	Identification of key issues. Analysis of consumer values. Comparative analysis of systems and technologies. System resource analysis and development. The methodology does not provide for a continuous process of data collection and analysis at production sites.
Peculiarities of	Workshops and activities for site monitoring. Calculation of the	Analytical steps to identify and address key issues.

	PS	TRIZ
Project Activity	specified data forms and using the reporting document templates. Presentation of **Kaizens**[4]. The implementation process generally does not require additional infrastructure and management resources.	Verification of solution directions with the stakeholders. The process of implementing TRIZ solutions requires additional infrastructure and management resources.
Standardized Work	Continual monitoring of work to add a value or business need.	One-off evaluation of functional model for functional and system component optimization.
Quality Control	Improvement effectiveness control through comparative measurements before and after changes are implemented. An additional business process is required to interact with quality assurance services.	Quality control is not provided by TRIZ measurement tools.
Tool implementation principles	1- 'Think about the customer' 2- Personnel are **the most valuable** asset' 3- 'Culture of continuous improvement – Kaizen' 4- 'All attention is directed to the production site – Gemba'.	1- Identification and resolution of key issues (through the target analysis) 2- Summary of problems and ways to resolve them 3- Achieving system ideality
Creative stage	External design of Kaizen lists when presenting the initial situation and the situation after the changes have been implemented.	At each of the design stages, it is possible to realize the creative potential of the performer of a particular analytical tool, both in the way the data is presented and in idea generation processes for solving primary and secondary problems
Key performance indicators – KPIs	Direct linkage to methodological tools. The tools are oriented towards economic impact	Their performance depends on the setting of tasks. It is necessary to establish links between KPIs and the TRIZ project activity (the actual economic effect obtained, the number of the projects completed, the innovative component of the implemented solutions and etc.)
Automation	Processes and tools are easy to automate. Software and hardware solutions for monitoring and fixation make it possible to apply PS in the background without compromising the main working process	There are significant limitations in the automation of the methods and road maps for a large number of typical tasks

[2] *'Kaizen' is a Japanese philosophy or practice that focuses on the continuous improvement of production, development, auxiliary business, and management processes as well as all aspects of life (Wikipedia).*

[3] *'Muda' is a Japanese word that means loss, waste, i.e., any activity that consumes resources but does not create value.*

[4] *'Gemba' is a designation of the approach characteristic of Japanese management practice kaizen, according to which for a full understanding of the situation it is necessary to come to the **Gemba**, which is the place of the work process execution, collect the necessary information and make a decision right on the spot.*

AREAS OF FRUITFUL COOPERATION OF METHODS

In one of the studies [5], a comparative analysis of the volume of the solved problems was carried out in five TRIZ complexity classes in two situations: (Fig. 1 (a)) without TRIZ integration with PS and (Fig. 1 (b)) with a combination of the two methodologies.

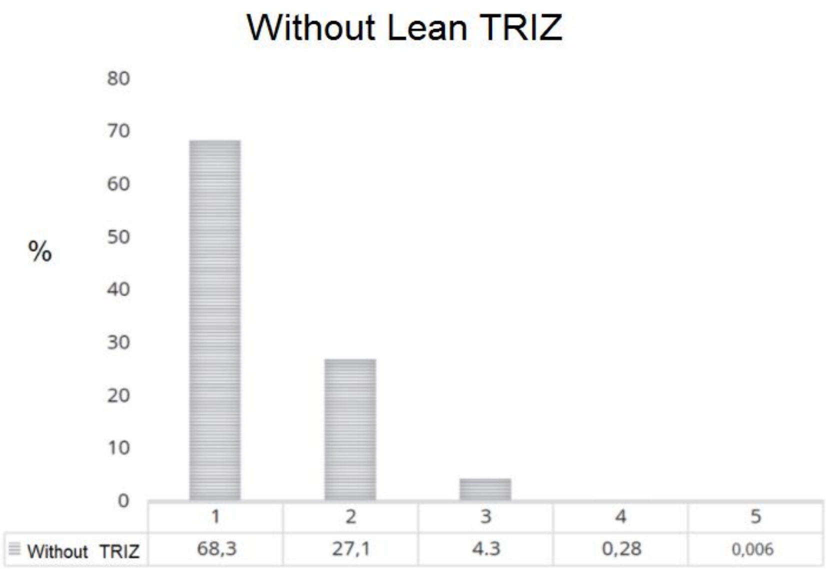

Figure 1 (a). Comparative analysis of the solved problems

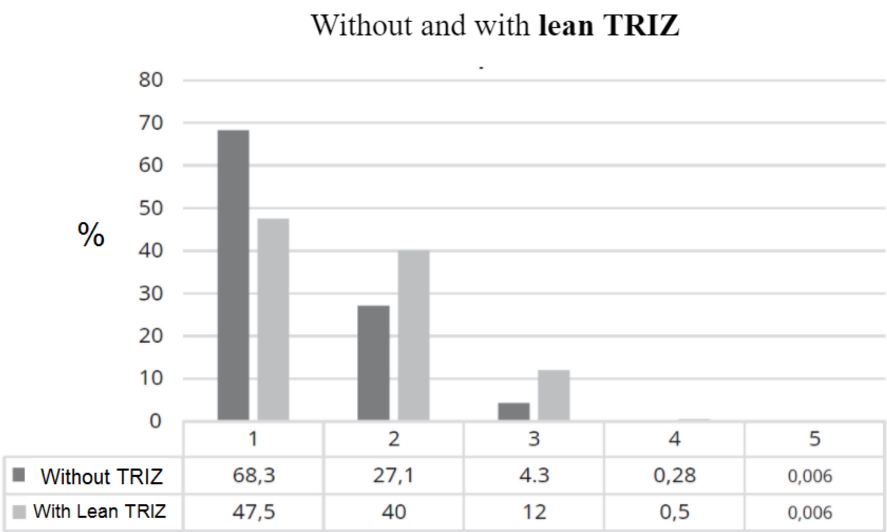

Figure 1 (b). Comparative analysis of the solved problems

According to the study, the following changes were noted in the second situation:

• Level 1 – obvious solutions: − 30%
• Level 2 – minor improvements: + 48%.
• Level 3 – main improvements: + 179%.
• Level 4 – new paradigms: + 78%
• Level 5 – opening: 0%.

Thus, the number of obvious Level 1 solutions fell by 30% using the joint methodology. This is the desired effect as the Level 1 reduced solutions move to more robust solutions at Levels 2, 3 and 4. This often leads to the organization releasing a new product line that is one or two levels higher than the one of its competitors.

When combining the two methodologies, you need to reorganize **their** business processes (BPs). Such a reorganization can be achieved through the following steps (1 or 1 + 2):

1) *Adaptation of two different BPs:* Reorganization of BPs of one infrastructure so that at certain stages of the project activity it is possible to attract participants and the methods of another infrastructure. This means preserving the lifecycle of the two business processes. This process can be lengthy and last from one to five years depending on the scale of implementation (enterprise department, business departments and corporation). Without a period of successful project execution in the context of role switching, it is impossible to proceed to the next step and achieve sustainable integration.

2) *Combining **BPs** into one:* When it becomes clear which methods and resources can be effectively used at which design stages the transition to activity planning to merge the two BPs into a single process starts to be available, which can mark the transition to an innovative and streamlined process that requires fewer management resources and gives transparency to the role interaction as well as helps to avoid duplication of functions and project tasks.

Since **the PS is more on Gemba than TRIZ**, the obvious solution is that **TRIZ can more efficiently** use the PS to collect input (primary) data at the analytical stage of solving the problem as well as at the most important stage, which is the implementation of TRIZ solutions into the production since PS is closer to production and production personnel than TRIZ, with regard to and due to the fact that PS had been implemented for many years before TRIZ was. TRIZ can also, at the analytical stage, very successfully, use data from standard PS forms, for example, timing forms and movement trajectories etc.

Other positive features of PS that can and should be developed and implemented in TRIZ in order to successfully compete in large-scale production:

1. Creation of mass corporate TRIZ culture. Development of team spirit.
2. Continuity of implementation, use and development.
3. Use of gaming techniques.
4. Creation and use Standard Operation Procedures (SOPs).
5. Development of typical TRIZ forms for data collection and solutions (analogue of PS forms).
6. Simplification of learning, i.e., creation of more effective TRIZ training materials.

CONCLUSION – PENDING A BREAKTHROUGH

In this article, approaches on the optimal and effective way of integrating two methodically directed infrastructures (TRIZ and Production System) are presented to specialists in the field of methodological development. These approaches, on the one hand, are based on the theoretical and practical experience of previous studies, and on the other hand take **into account the achievements and challenges of practical implementation of the ones at national enterprises**. Thus, the set target tasks of the authors' research have been solved and are available to the interested parties and organizations.

There is a wealth of experience in the practical development of PS at our national enterprises where the pace of TRIZ implementation is also increasing. **Despite a limited set of tools,** the PS model is being improved**, namely the transfer of properties from one development concept to another is being carried out [19].** The presence in the modern TRIZ of roadmaps and tools for forecasting business development and functional search for technologies allows approaching this integration systemically and innovatively when solving problems and management tasks.

Disadvantages and a small number of PS methods are striking (for example, timing, analysis of movement trajectories), and the authors suggest that TRIZ should soon be forced to add PS methods to the system level, using the concepts, principles and approaches of TRIZ, and, as a result, a TRIZ version will appear, which will be more targeted at production rather than the theoretical solution of problems, namely the production TRIZ, or lean TRIZ. TRIZ experts predict that refined PS methods using the TRIZ methods will be much more effective than the existing ones. This will bring production closer to the innovative development of large production.

The hopes and expectations placed on the combination and interaction of the elements of the two concepts under consideration, each of which individually has great potential for continuous improvement and innovation, can be realized under the condition of a competent and diligent organizational and methodological process. Literacy comes with experience and the conducting of a lot of integration tests and pilot sites since this area is still considered to be a new one, and the localization of the application of each of the methods has its own individual infrastructure circumstances and opportunities.

It would be naive to believe that leading experts in any field of PS or TRIZ will be able to go through a long and effective path of integration **without 'trial and error'** as well as without developing the potential of methodologies and not expanding the horizons of their application. It is also very important to understand that the key success factor is the spread of a culture of thinking patterns in terms of both PS and TRIZ among all the employees of an organization, starting from production and servicing to managerial and expert capacities**.** It is important for the management to understand that the lack of correct practical understanding together with the division of values of one of the development concepts leads to imminent failures in the pace of reaching breakthrough success stories.

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Approaches to Applying System Operator for Solving Organizational and Management Tasks

ABSTRACT

In this article, the case of applying System Operator (System Operator (SO) – the way of depicting the object of analysis on a time scale as part of system hierarchy. Synonymic terms which may also be found in reference literature include "multi-screen analysis", "talented thinking matrix", "nine screens") to solving organizational and management tasks is described. Also, the algorithms of applying SO to developing strategies of a company or a product (or another system) are offered.

Keywords: TRIZ, TRIZ instrument, *System Operator, SO, Management tasks, Organizational tasks, SO application algorithm, Catch the Flow, Realize the Potential, Uncover the Possibilities, Back to the Future.*

INTRODUCTION

From the first glance SO seems to be one of the most illustrative and simple TRIZ instruments. Undoubtedly, however, this approach to analyzing a system has a huge heuristic capacity for solving both engineering and organizational and management tasks.

1. APPLYING SO TO SOLVING ORGANIZATIONAL AND MANAGEMENT TASKS

In 2018–2019, several alternative algorithms of applying SO to defining the strategies of development of analyzed systems were defined and elaborated during the process of SO application to solving business problems of various companies.

These algorithms make up a clear-cut sequence of mental operations, the performing of which decreases the impact of psychological inertia and leads to new ideas creation.

Let us describe their application with the below examples.

2. SO APPLICATION ALGORITHM

2.1. The "Catch the Flow" Algorithm

This algorithm is based on two principles:

1. Every technical system (TS) is a response to the requirements of a supersystem (SS).
2. Some trends of an SS development may be observed distinctly enough in contrast to feasible directions of the development of the system under immediate analysis.

The inner imperative of a problem solver using this approach may be described as follows: "I will analyze the main trends and follow them (I will be able to understand today what the requirements will be like tomorrow)".

The following sequence of actions to realize this approach may be considered:

1. Define the system for analysis.

Document the main function and the key parameters of the analyzed system.

2. Analyze the main trends of the supersystems.

Define which supersystems are reasonable to be analyzed with regards to the given task and which change trends of these supersystems are known.

E.g., if the task is to find the ways of development of a certain product, various systems which it interacts with on different stages of its life cycle may be treated as supersystems: how will the sales formats change (e.g., it is clear today that most sales will take place online tomorrow)? How will logistics change (we may observe a trend of reduction of the minimum order quantity with consequential decrease of the weight and the size of cargo for a single delivery)? And so on.

1. Define the requirements which will become relevant in the planned future.

How will the defined trends change the supersystem in the planned future? How will the requirements of the SS to the TS change? Which new requirements will arise?

E.g., we may confidently assume that, when sales become online based, the requirements to the package will change. It will no longer perform the function of attracting customers' attention (an eye-catching package is no longer needed).

2. Adjust the parameters of your system according to the requirements.

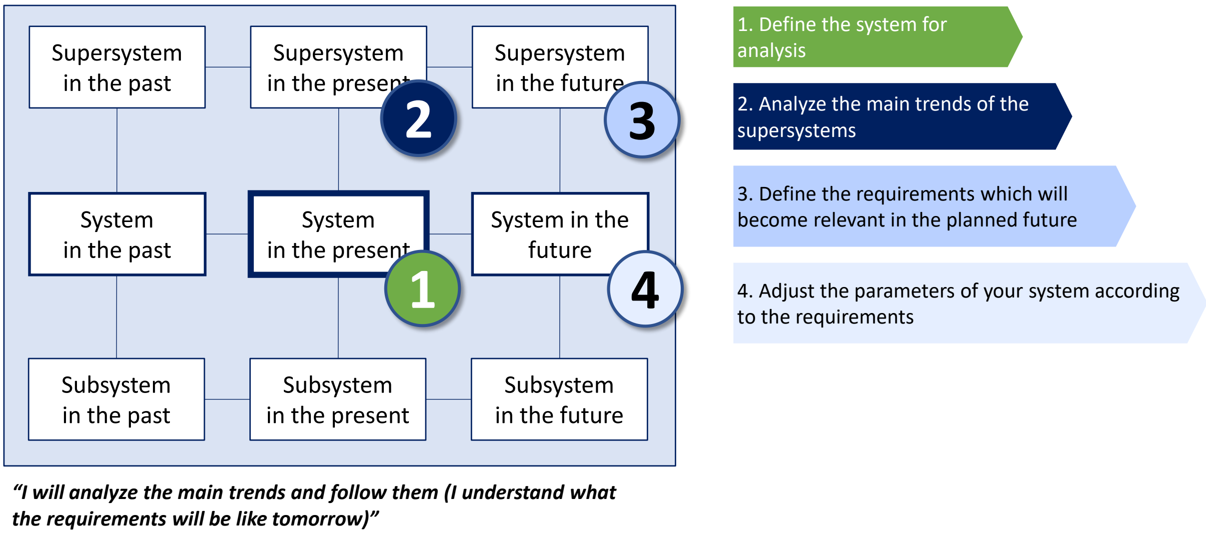

Fig. 1. The "Catch the Flow" Algorithm

Let us illustrate the realization of this approach with the following example.

"Property Management" company (Major federal property management company. The name has been changed) Russian Federation, 2018.

The project team were given a task to suggest the ways of increasing the revenue of the slow-moving properties, which they used to refer to as the "ruins".

The team tried to figure out the ways of profitable use of the "ruins" like shooting disaster movies or organizing paintball or reality quest areas there etc. None of these variants were feasible, however, first and foremost because of the low potential revenue. Even the estimated costs of the reorganization were not likely to pay off. Massive changes were not a viable option because the ownership of the areas was to be transferred for further development in the next few years.

Applying the "Catch the Flow" SO algorithm allowed the team look at the problem from a different angle.

1. Define the system for analysis.

"Ruins" – real estate complex with given features.

2. Analyze the main trends of the supersystem.

Several supersystems and visible change trends within them were analyzed. Among them were the city as a whole, the immediate real estate locations as administrative areas and as residential areas etc. The most interesting idea, however, appeared when the so-call "Operator" supersystem was analyzed.

The team realized basically an obvious fact: currently the operator was a company vainly trying to lend the "ruins" while soon it was going to be a new Developer.

3. Define the requirements which will become relevant in the planned future.

This obvious idea about the Developer led to yet another obvious conclusion that as soon as all the future development issues for the objects (namely the "ruins") had been worked out, the "ruins" would have to be demolished, which would be paid for by the current operator. I.e., the company had already incurred those costs, they have not been written off yet, however.

4. Adjust the parameters of your system according to the requirements.

This having been understood, the idea of demolishing the "ruins" at once became obvious as well. The demolition (which was to be paid for in the future anyway) could allow the company to use the property more efficiently for the rest of the ownership period. Some of the areas were in rather appealing parts of the city and therefore could be used for parking lots or prefabricated warehouses.

Thus, the application of the tool revealed the flaw of a seemingly obvious original idea that spending vast sums of money on the "ruins" was unreasonable.

It must be noticed, however, that the team's coming up with this idea required a lot of work and effort, which are not described in this case. Several supersystems and trends of their development were thoroughly analyzed, the solution was not found on the spot but as a result of a hard thinking process.

2.2. The "realize the potential algorithm

This algorithm is based on the idea that resources existing today may be required in the future in some new shape, quality, or form.

The inner imperative of a problem solver using this approach may be described as follows: "I have a certain resource (deep expertise, unique equipment etc.), so I will be looking for trends which will require it tomorrow and I will start adjusting to these trends today".

The following sequence of actions to realize this approach may be considered:

1. Define the system for analysis.
2. Define the key resources.
3. What is or may become the unique advantage of the system?
4. Define the future SS which will require the resources of the analyzed TS in the planned future.

What changes may be observed today which may lead to the key resource of the TS becoming required tomorrow? What supersystems will appear or change accordingly?

5. Define the current SS which are to be aligned with today to occupy the desired position in the future.

What steps are to be taken today to adhere to the requirements of these SS tomorrow most accurately?

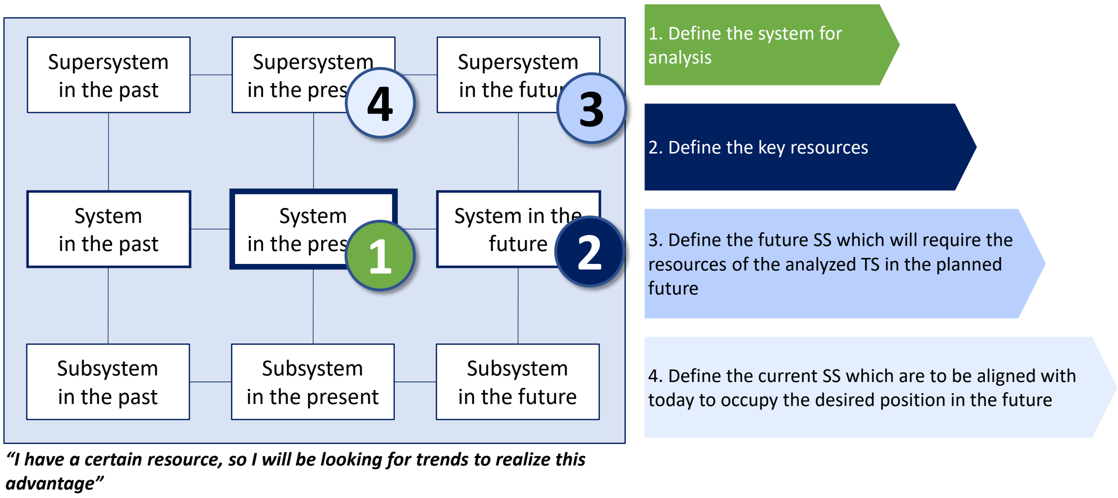

Fig. 2. The "Realize the Potential" Algorithm

Let us illustrate the realization of this approach with the following example.

The "Insurance Company" (One of the major insurance companies in Russia. The name has been changed) Russian Federation. 2018

The problem solver team was given the following task: to propose new products to make up for the inevitable loss of revenue from selling classical insurance products taking into consideration that major players (Sberbank and VTB) are about to enter the insurance market.

1. Define the system for analysis.

The "Insurance Company" company.

2. Define the key resources.

A list of resources was compiled. One of the most interesting solutions was inspired by defining the "accumulated datasets (Big Data) on customers' trustworthiness" resource and the expertise of collecting and processing this data.

3. Define the future SS which will require the resources of the analyzed TS in the planned future.

There is a clear trend of managing sales through Big Data nowadays. This data is becoming a key to high sales figures and is acquiring ever-greater value. Now the "Insurance Company" possesses the biggest amount of data on customers' trustworthiness (recklessness), as well as the expertise of collecting and processing such data. Therefore, the company might become a market leader for selling such data, thus making insurance but a tool to collect the data.

4. Define the current SS which are to be aligned with today to occupy the desired position in the future.

The acquired vision (after the feasibility study) allows the company to formulate a focused development strategy and to already start to work out the legal and the business aspects of such operations, to adopt the mechanisms for collection, processing and storage of the data geared towards potential buyers (multinational commercial companies, banks etc.), thus granting the company an unmatched advantage over competitors when the market race would begin.

2.3. The "uncover the possibilities" algorithm

This approach is based on revealing new ground-breaking possibilities for the development of some components of TS and on figuring out the possibilities of massively increasing the efficiency of TS in future due to this development.

The inner imperative of a problem solver using this approach may be described as follows: "I am analyzing the subsystems. How are they going to develop? I realize what they may be like tomorrow and figure out what opportunities for the development of TS it uncovers. I understand what SS it will be relevant for".

The following sequence of actions to realize this approach may be considered:

1. Define the system for analysis.
2. List the subsystem components.
3. Document the possibilities of their development in the planned future.

For each system's component, one should ask oneself whether any new ways of radical efficiency increase of its function have appeared in the recent years.

4. Document new TS opportunities, which will appear due to the development of its components.
5. Figure out which SS they will be relevant for in future

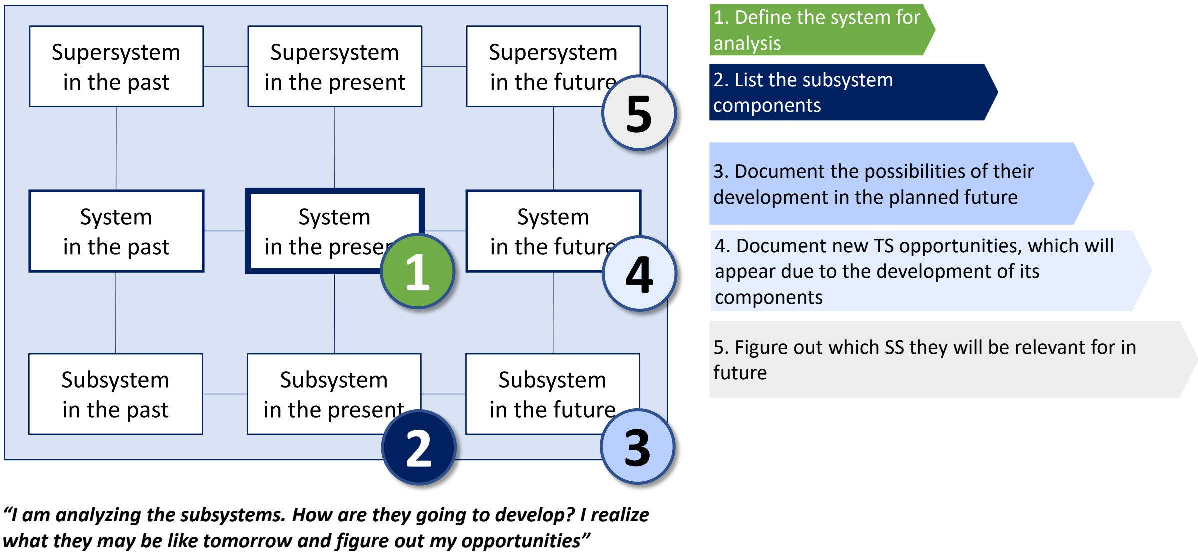

Fig. 3. The "Uncover the Possibilities" Algorithm

Let us illustrate the realization of this approach with the following example.

The "Ofo" company. China, 2014.

"Ofo", a students' start up, was a huge hit on the bicycles rent market in China in 2014. The business model that was implemented turned out to be so successful that in 2017 the authorities of largest Chinese cities had to take steps against bicycles.

1. Define the TS.

A system of bicycles rent (sharing).

2. List the subsystem components.

The classical service of bicycles rent, which was widespread until 2014, may be roughly described as having two components: actual bicycles and a system of customer interaction, namely, "docking stations", where bicycles are parked and paid for.

3. Document new TS opportunities, which will appear due to the development of its components.

The Chinese student founders of "Ofo" discovered the existing but previously unused opportunities to significantly improve the "customer interaction" component and suggested to replace the "docking stations" with a GSM module on each bicycle connected to a user's app.

4. Document new TS opportunities, which will appear due to the development of its components.

Not only did this innovation allow to cut costs by getting rid of the "docking stations" and the need to distribute bicycles among them, but it also saved the users the trouble of returning a bicycle somewhere, thus allowing them to stop using it right where they no longer needed it.

5. Figure out which SS they will be relevant for in future.

The innovation led to an explosive rise in bicycle usage and decreased the average time of lending from 30 to 5(!) minutes. Chinese citizens started renting bicycles literally on every possible occasion.

2.4. The "back to the future" algorithm

This approach is based on the idea that the improvement of some parameters of a given system during the process of the TS development often implies sacrificing others. E.g., an electrical iron is certainly more efficient than its coal predecessor although it was wireless. Uncovering such lost advantages and trying to bring them back by applying new technologies may stimulate strong ideas on improving the analyzed TS.

The inner imperative of a problem solver using this approach may be described as follows: "I am analyzing the systems of the past. What valuable features of theirs are lost today? Is there a possibility to bring such features back using new technology, materials, infrastructure change etc.?"

The following sequence of actions to realize this approach may be considered:

1. Define the system for analysis and describe its Key Parameters of Success (Key Parameters of Success (KPS) are parameters, comparing which a certain stakeholder makes a decision whether to interact with the system or not. E.g., a customer decides whether to buy a product. (KPS)

2. Document the past implementations of the system.

3. Describe the parameters of the past implementations of the system which were lost during development but may become KPS now.

4. Find the ways of applying the lost parameters to the analyzed system using new opportunities.

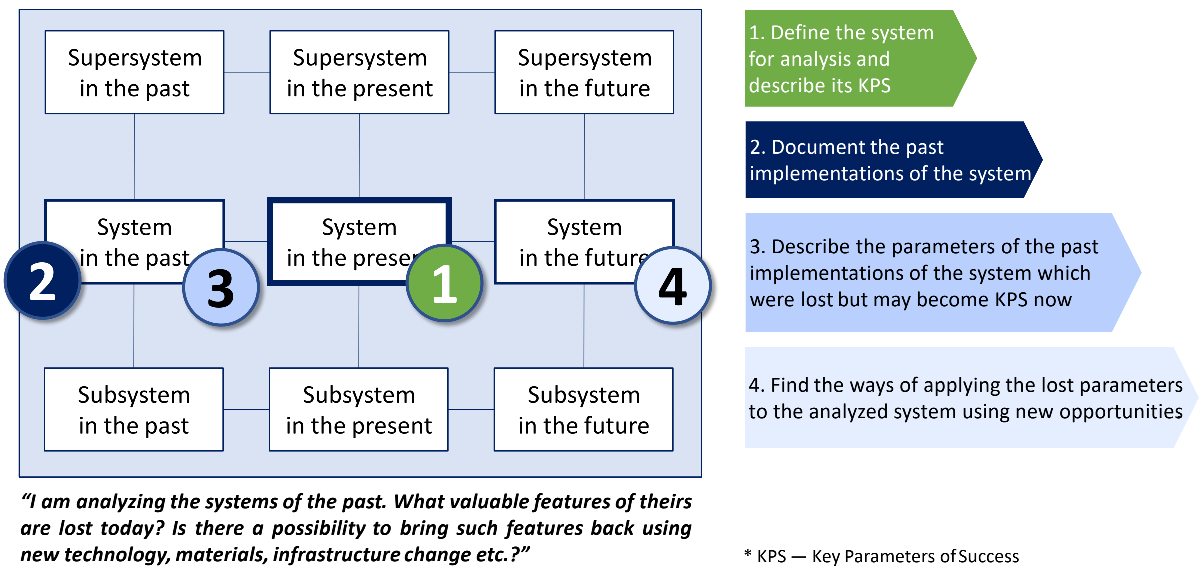

Fig 4. The "Back to the Future" Algorithm

Let us illustrate the realization of this approach with the following example.

"Agricultural holding" (One of the most advanced agricultural holdings in Russia, was visited by two Presidents of Russia as an exemplary agriculture company. The name has been changed) company. Russian Federation, 2017.

In 2000s the owners of "Agricultural holding" decided to massively modernize the agricultural machinery used at the company. World's top companies offered the machinery surpassing the Russian counterparts in their efficiency by far. Yet, there also were some serious disadvantages: they were significantly more expensive and required "special treatment", namely, custom equipment and trained staff. The calculations, however, showed that the high cost was likely to pay off relatively soon, while the problem of "special treatment" could be solved by creating a unified modern maintenance center with all necessary maintenance tools and properly qualified staff. There used to be repair services for tractors and other machinery maintenance in different areas of the vast territories belonging to the "Agricultural Holding". Creating such a center required tenacious effort and a lot of resources, the employees sacrificed a lot to make this plan come true. It was not in vain. The solution proved to be strategically correct, and the "Agricultural holding" became of one of the most advanced agricultural company not only in Russia but in the world.

In 2017, however, a serious efficiency increase opportunity was discovered. It turned out that one third of the mileage of the cutting-edge tractors was a distance to and from this very maintenance center.

1. Define the system for analysis and describe its KPS.

The efficiency of the machinery work (particularly the ratio of the total mileage to the mileage directly connected to useful work).

2. Document the past implementations of the system.

The system of distributed maintenance centers as opposed to the today's centralized system.

3. Describe the parameters of the past implementations of the system which were lost during development but may become KPS now.

A possibility of on-the-spot repair services in the immediate vicinity of machinery operations.

4. Find the ways of applying the lost parameters to the analyzed system using new opportunities.

When the decision to modernize the machinery was made, abandoning distributed maintenance centers was of course justified because the company could not provide all of them with maintenance tools necessary for the repair of expensive imported machinery, to say nothing of the qualified personnel (which is extremely difficult to find in the regions). However, by the time the valuable feature of the system, which was lost in the process of modernization, was defined, the company had accumulated new resources, the maintenance tools had become cheaper, the number of qualified workers in the market had increased.

Thus, a new creative task of returning to the system of distributed maintenance centers was formulated. Solving this task will become another step on the way to the company's ideality.

CONCLUSIONS

The algorithms described above are not intended to be rigorously performed, they are supposed to properly direct the way of problem solver's thinking. To solve a problem, one may combine different algorithms and use them at the same time. E.g., while solving the problem of "finding new business models with regards consumption models change", an automaker company (One of the major automaker companies in Russia, 2019 combined the "Catch the Flow" algorithm with the "Uncover the Possibilities" algorithm. To forecast the development of the industry, they first analyzed all the visible flaws of supersystems and defined the trends of eliminating them (in accordance with supersystem tendency to ideality). Then they analyzed the existing possibilities in the industry to adjust its components to these trends. Compiling the acquired data allowed the company to define an industry development forecast, certain elements of which may be observed even today.

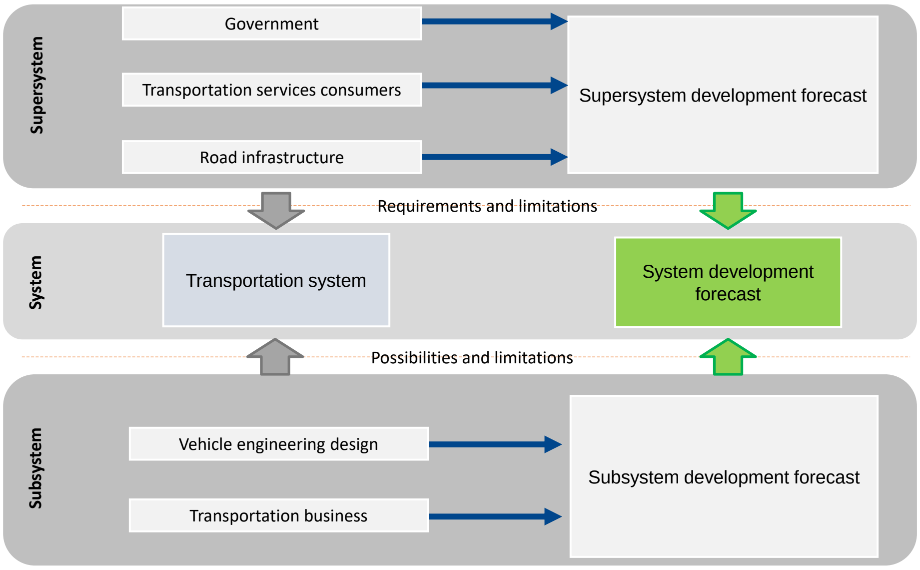

Fig. 5. Transportation System Development, 5 years, Russia

Applying the algorithms described above defined the following advantages of this approach:

- applying an algorithm step by step helps to keep focus of problem solvers on certain aspects of the problem, therefore enhancing its thorough elaboration,
- the algorithms help to direct the searching efforts of the problem solvers in a certain way, thus increasing the manageability of the solving process,

applying algorithms allows for simultaneous usage of the tool (one team performs one algorithm while another team uses another one), which greatly increases the efficiency of the solving process at this stage.

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A. Bushuev

Trends of physical effects

ABSTRACT

A method for finding an invariant, i.e., the same property for effects of different physical and geometric nature, based on the theory of the dimension of physical quantities in the Bartini LT-basis, is proposed. The invariant is determined by the transfer matrix of proportionality between the input and output matrices of the effect. Effects with the same invariant form trends in the development of spatial, temporal and Su-field resources. One example is the well-known trend "point-line-surface-volume". According to the law of folding-unfolding, the trends of effects are collapsed and expanded into trends of invariants. For invariant trends, equivalent electrical analogs are proposed that allow numerical comparison of effects by degree of complexity. The methodology is supposed to be used for the classification of effects by invariant properties, for the synthesis of the operating physical principle, as well as in the process of studying inventive physics in TRIZ.

Keywords: *invariant of the physical effect, trends of effects and invariants, numerical estimation of the complexity of the effect*

FOREWORD

In the theory of inventive problem solving many basic notions are considered as a process, i.e., as a sequence of certain events, objects, which precondition reference points of direction of development. Such sequences are called evolution lines [1]. Historically speaking, the first line of development can be understood as an ARIZ structure, which is at bottom a graph with summits, consisting of known contradictions and with directed edges, pointing out the order of algorithm. In the fullest sense the graphs are presented in the trends of technical systems evolution. [2, 3]. Each peak of these graphs possesses a certain feature, which is common with all peaks. Let us call this common feature an invariant. For example, in the ARIZ line an invariant is the fact that each peak of the graph is a contradiction, in the trend for trimming and deployment of technical systems according to the line 1–2-many each peak has an invariant –certain numerical value. The second important feature of the lines: each peak of the graph, preserving an invariant is a transformer of an input feature into an output one. In the famous abbreviation MATHEM an invariant is the notion of a field as an action of one substance upon another, while a feature of transforming is the transformation of the field of one kind of energy into a field of another kind of energy. Consequently, the peaks in the MATHEM graph are the physical effects, while the entire graph could be called the line of evolution of kinds of physical effects. For particular physical effects the name of the kind becomes an invariant. According to this invariant the effects are classified in indices of physical effects [4, 5] into mechanical, thermal, electrical and magnetic.

It is proposed to conduct further search for invariants already inside the effects listed in [6] with the aid of criteria of similarity. As it is known, «criterion of similarity is a dimensionless value, composed of dimensional physical parameters, which determine the analyzed physical phenomenon». With physical effects the dimensional parameters will be understood as input and output values of effect. If with two effects the criterion of similarity is the same, the effects are also similar, i.e., the invariants in reference to criterion of similarity. Examples of criteria of similarity are the Reynolds number in hydro- and gas dynamic, Prandtl number in heat transfer processes, etc. [7]

However, criteria of similarity are characterized by disadvantages, which are associated with the loss of information regarding the dimensionality of physical values. At the same time inventive problem solving has accumulated certain experience in using theory of dimensionality. In [8] it is proposed to use theory of dimensionality for obtainment of high-quality mathematical model of engineering systems. A couple of contradictory parameters is identified as part of this model and then parametrical method is used for resolving contradictions. In the work [9] a structural model of the system in the form of a graph is created based on expert evaluation of cause/effect connections. System of dimensionality in the basis of MLT (mass, length, time) are used for checking the authenticity of structural model and for finding the peaks of localizing physical contradictions, i.e., the violation of cause/effect connections. The report [10] is focused at the research of known trend «Point-Line-Plane-Volume», which is related to the trend of increasing coordination. The peaks of the graph within the trend form spatial resources, while the invariant is the length L – main unit within the system of dimensions of physical units. In this case the peaks can be set up with the aid of their dimensionalities L^n, where n=0,1,2,3, while the trend can be regarded as a chain of geometrical effects for transforming the space of one dimensionality into a space of another dimensionality.

This work is focused at the methodology for creating trends of physical and physical-and-geometrical effects for the purpose of obtaining the general regularities of evolution of effects and technical devices, which are used for implementing them. The effect is understood here as a transformation of each measurable physical or geometrical value into another similar value.

METHODOLOGY FOR SEARCH OF TRENDS OF EFFECTS IN LT-BASIS

The search is based on the method of analogies in defining the trends of Su-Field resources in LT-basis of the Bartini system of kinematic values [11]. For example, the trend of «Point-Line-Plane-Volume» is located according to its geometric dimensions $L^0T^0 \rightarrow L^1T^0 \rightarrow L^2T^0 \rightarrow L^3T^0$. In Fig. 1 this trend is shown by red arrows.

D.	L^{-1}	L^0	L^1	L^2	L^3	L^4	L^5
T^{-5}	$L^{-1}T^{-5}$	L^0T^{-5}	L^1T^{-5}	L^2T^{-5}	Surface power	L^4T^{-5}	Power
T^{-4}	$L^{-1}T^{-4}$	L^0T^{-4}	Specific gravity, pressure gradient	Pressure	Surface tension	Force	Force momentum, energy
T^{-3}	$L^{-1}T^{-3}$	L^0T^{-3}	Current density	Electro-magnetic field strength	Current, loss mass	Motion quantity, impulse	L^5T^{-3}
T^{-2}	$L^{-1}T^{-2}$	Mass density, angular acceleration	Magnetic displacement acceleration	Potential difference	Mass, quantity of magnetism or electricity	Magnetic momentum	Moment of inertia
T^{-1}	Volume charge density	Frequency	Velocity	Two-dimensional abundance	Loss volume	L^4T^{-1}	L^5T^{-1}
T^0	Curvature	Dimension-less constants	Length, capacity, self-induction	Surface	Volume of space	L^4T^0	L^5T^0
T^1	Conductivity	Period, duration	L^1T^1	L^2T^1	L^3T^1	L^4T^1	L^5T^1

Fig. 1. Examples of dimensional and temporal trends and trends of Su-Field resources within the Bartini system of kinematic values

The trend is dimensional, its invariant L^1T^0 is located with respect to dimensionalities of adjacent cells at the trend: $L^3T^0/L^2T^0=L^2T^0/L^1T^0=L^1T^0/\ L^0T^0=L^1T^0$, while the dimensionality of the output cell is divided into the dimensionality of the input cell. An example of a temporal trend is shown with blue arrows, its invariant is equal to $L^1T^{-2}/L^1T^{-1}=L^1T^{-1}/L^1T^0= L^0T^{-1}$.

The trends of Su-Field resources are located at the diagonals of Bartini table. For example, green arrows on the main diagonal line show the trend of $L^0T^0 \to L^1T^{-1} \to L^2T^{-2} \to L^3T^{-3} \to L^4T^{-4} \to L^5T^{-5}$, reflecting the work of rotating electrical machine (Fig.2) on transforming mechanical energy into electric energy (generator) and back (motor). The invariant of the trend is equal to dimensionality of line speed $[V]= L^1T^{-1}$.

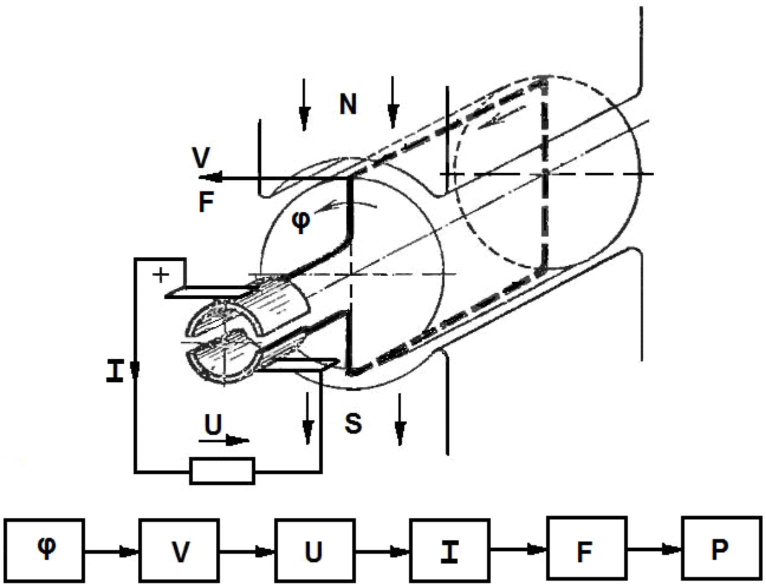

Fig. 2. Electrical machine and the trend of evolution of ideas concerning it

The trend enables to imagine the manifestation of a physical effect of electromagnetic induction, in which the law of Faraday is implemented. In fact the first stage is the angle φ of pivoting (rotation) of a conductor in a magnetic field. The second stage is the idea that the rotation takes place at a linear speed of V. The next idea is the generation of difference of potentials U at the poles of the conductor. Further on, after short-circuiting of the conductor, electric current I is generated in it. The current possesses power action F. Force F, multiplied by linear speed V of rotation of conductor, yields power P, developed by induction machine.

The search for an invariant of trends of effects makes us formulate the task in the following way. Let us know the assigned input (x) and output (y) values of the effect, i.e., their dimensionality in the basis of LT $[x]=L^aT^b$, $[y]=L^cT^d$ is known. Let us introduce matrices X and Y of input and output values respectively

$$X = \begin{bmatrix} L^a & 0 \\ 0 & T^b \end{bmatrix}, Y = \begin{bmatrix} L^c & 0 \\ 0 & T^d \end{bmatrix}.$$

And we shall obtain a transfer matrix of W-effect

$$W = YX^{-1} = \begin{bmatrix} L^c & 0 \\ 0 & T^d \end{bmatrix} \begin{bmatrix} L^a & 0 \\ 0 & T^b \end{bmatrix}^{-1} = \begin{bmatrix} L^{c-a} & 0 \\ 0 & T^{d-b} \end{bmatrix} = \begin{bmatrix} L^m & 0 \\ 0 & T^n \end{bmatrix}. \qquad (1)$$

Transfer matrix shall be treated as an invariant, i.e., all effect, which have one and the same transfer matrix, are included with one trend. The trend of effects will be created in the following way.

- We select in Bartini table any trend of spatial, temporal or Su-field resources.
- We shall treat one of the values within a trend as the input action of the effect.

- Based on reference lists of physical effects and scientific literature we find the name of the effect and, consequently, output value as well.
- Based on the dimensionality of input and output we find an invariant – transfer matrix of W-effect.
- We move along the trend consequently by one cell to this and (or) to that side and find new input action by their dimensionalities in Bartini table.
- We multiply new input action by invariant W and find the yield of effect and thereby we determine its name.

Items 1 and 2 needn't be fulfilled, if some effect is already assigned, and we would like to create a trend, with which this effect is going to be included.

EXAMPLE OF FINDING EFFECTS OF INDUCTIVE TREND

As one of the effects of the trend let us select direct piezoelectrical effect [5], in which the input action is the force F, applied to piezo-crystal, while the output is the electric charge Q, generated on plates (Fig.3c). We find transfer matrix W_1

$$W_1 = QF^{-1} = \begin{bmatrix} L^3 & 0 \\ 0 & T^{-2} \end{bmatrix} \begin{bmatrix} L^4 & 0 \\ 0 & T^{-4} \end{bmatrix}^{-1} = \begin{bmatrix} L^{-1} & 0 \\ 0 & T^2 \end{bmatrix}.$$

Let us move along Bartini table with respect to the cell of force L^4T^{-4} by one cell to the right, i.e., i.e., we move along the trend of spatial resources. We get to the cell L^5T^{-4}, in which the energy and static temperature, measured in SI system in joules are located. However, at the same time this very cell contains the dimensionality of the moment of rotation $M_{rot.}$, measured in SI system in newtons, multiplied by meter (1 joule =1 N·m). Let us consider the moment of rotation $M_{rot.}$ to be the input action of the following element of trend. Physics and geometry of such transition has the following simple explanation. In piezoeffect the force F is applied to the point and acts along the straight line upon the piezo crystal. From the standpoint of fields, used in TRIZ, this action is similar to the mechanical field of pressure. The follwong effect, which is heretofore unknown, the input action is the moment $M_{rot.}$, acting along circularly and being defined according to the known formula $M_{rot.}=F\cdot\ell$, where ℓ is the arm of force. Therefore, this action could be related to the mechanical field of centrifugal forces.

Based on the assigned input and transfer matrix W_1 of the trend we find the output value

$$W_1 M_{rot} = \begin{bmatrix} L^{-1} & 0 \\ 0 & T^2 \end{bmatrix} \begin{bmatrix} L^5 & 0 \\ 0 & T^{-4} \end{bmatrix} = \begin{bmatrix} L^4 & 0 \\ 0 & T^{-2} \end{bmatrix} = M,$$

where M is a magnetic moment. In SI system the magnetic moment M is equal to the product of current I by area S of the circuit and has dimensionality of $A\cdot m^2$, however, in the system of CGS, at which the names of physical entities within the Bartini system are oriented, the magnetic moment has the dimensionality A·m·s ($M=I\cdot S/C$, where C is the light speed in m/s).

In the reference book [5] such input and output is characterized by Barnett effect. The effect shows the association between the atomic magnetic moments and mechanical moments and is contained in magnetizing of the bodies by rotating them under th conditions of absense of external magnetic field. This effect is implemented in ferromagnetics, like Cioffi iron, nickel, cobalt, permalloy (nickel-iron), transformer steel, armco iron, etc. In a specimen, which is rotating at a constant rotation speed ω around the unchangeable axis z (Fig. 3d), elementary small magnets of its material are regarded as sorts of gyroscopes, possessing mechanical moment of amount of movement and magnetic moment. The effect manifests itself on bodies with elongated geometrical shape and also reveals itself throughout the entire volume of a ferromagnetic. The resultant of a magnetic field is directed along the axis of rotation. It was discovered by Samuel Barnett in 1909. The physical effect is applied for research of nature and structure of ferromagnetic substances.

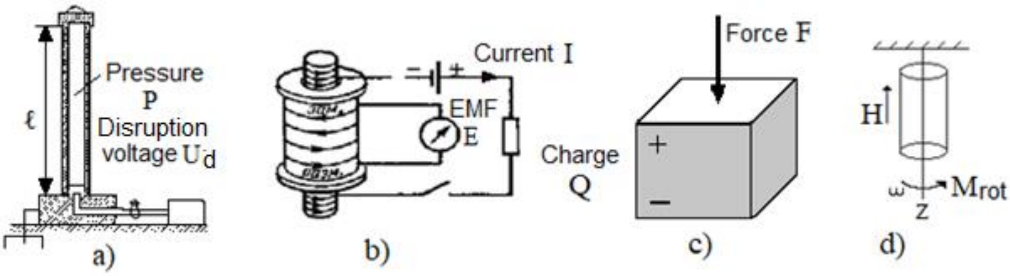

Fig. 3. Inductive trend of evolution of effects

We shall look for other effects of graph of trend, moving from the cell of force of L^4T^{-4} to the left. Let us understand the input as a value with dimensionality L^3T^{-4}. In this case we shall obtain the output by multiplying by transfer matrix of effect.

$$E = \begin{bmatrix} L^{-1} & 0 \\ 0 & T^2 \end{bmatrix} \begin{bmatrix} L^3 & 0 \\ 0 & T^{-4} \end{bmatrix} = \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix}, (2)$$

where E – difference of potentials or electromotive force (EMF), measured in the SI system in volts. The input value is superficial tension or rigidity. Physical effect of transforming these mechanical values into electric voltage or into EMF has not yet been found. Therefore, let us act in the following way: let us find an electric value with the dimensionality of assigned input H L^3T^{-4}. For this purpose, let us go down from the cell L^3T^{-4} lower, to the cell L^3T^{-3}, where we find the electric current, measured in the SI system in amperes. A conclusion can be drawn there from that in the cell L^3T^{-4} there is an electric value – rate of current changing in time dI/dt, where t is time. Consequently, the generation of EMF as a result of changing the current in the conductor is a manifestation of effect of self-induction, discovered by J.Henry in 1831. The value of EMF of self-induction generated in the coil with current (Fig.3c), could be found according to the law of electromagnetic induction of Faraday.

$$E = -L_c \frac{dI}{dt}, (3)$$

where L_c is coil inductivity. The formula (3) written for dimensions of physical values completely coincides with the formula (2). Transfer matrix of the trend of effects in terms of dimensionality coincides with the inductiveness of the coil, therefore the trend is called inductive.

Let us find the next effect of the trend. Using the input of the effect we select pressure P with dimension L^2T^{-4} and multiply it by transfer matrix of the trend

$$W_1 P = \begin{bmatrix} L^{-1} & 0 \\ 0 & T^2 \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-4} \end{bmatrix} = \begin{bmatrix} L^1 & 0 \\ 0 & T^{-2} \end{bmatrix}.$$

In Bartini table the corresponding cell contains a linear acceleration, which has dimensionality m/s^2 in the system SI. Being oriented at the adjacent cell on the right, in which the dimension of the difference of potentials is expressed in volts, while the shift by one cell to the left means subdivision into meters, we obtain at the output of the effect a value of tension of electric field, measured in V/m. The electric strength of dielectrics, for example, disruption voltage U_d is measured in the same units. Effect of variation of electric strength of gasses depending upon pressure is known from physics [12] (Fr.Paschen's law, 1889) and moreover, its use is analyzed by G.S.Altshuller in [1] as part of solving the problem of lightning arrester in (Fig.3a) for the sake of protection of radio-telescope antennae. [13]. Physical-and-geometrical effects of inductive trend are quoted in Fig. 4 (marked with red arrows).

EXAMPLE OF IDENTIFYING THE EFFECTS OF TREND OF CONDUCTIVITY

Let us create a trend of effects based on temporary trend of input actions. Let us select the phenomenon of electroosmosis [5] as a source effect. Electroosmosis is the motion of fluid in a capillary under the action of applied EMF. The effect is assigned by the following mathematic expression

$$V = \frac{\zeta \varepsilon S}{4\pi\eta\ell} E,$$

where V is linear speed of the fluid, ζ – is a zeta-potential, E is a potential of external field, S – cross-section of the capillary, η – viscosity of fluid, and ℓ is the distance between electrodes.

Based on known dimensions of input E and output V we find the transfer matrix of the effect

$$W_2 = VE^{-1} = \begin{bmatrix} L^1 & 0 \\ 0 & T^{-1} \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-2} \end{bmatrix}^{-1} = \begin{bmatrix} L^{-1} & 0 \\ 0 & T^1 \end{bmatrix}.$$

Physical entity in this cell of Bartini table is called conductivity (however, in SI system this value has the dimension Ohm), therefore, the trend of effects will be called by us the trend of conductivity.

We move one step higher and get into the cell of voltage of electromagnetic field H. We find the outcome of effect

$$W_2H = \begin{bmatrix} L^{-1} & 0 \\ 0 & T^1 \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-3} \end{bmatrix} = \begin{bmatrix} L^1 & 0 \\ 0 & T^{-2} \end{bmatrix} = a.$$

where *a* is a linear acceleration.

Such effect could be related to electromagnetic acceleration of charged particles, at which the Lorenz force F, depending upon the voltage of electromagnetic field H acts upon a charged particle, for example, in a solenoid. With the mass m under the action of force F the particle acquires linear acceleration *a* = F/m. This effect is also used in electromagnetic weapons, in which a charged body, flying from the field, performs the killing action [14].

For the next effect of the trend the input action is the pressure P. We find the output value

$$W_2P = \begin{bmatrix} L^{-1} & 0 \\ 0 & T^1 \end{bmatrix} \begin{bmatrix} L^2 & 0 \\ 0 & T^{-4} \end{bmatrix} = \begin{bmatrix} L^1 & 0 \\ 0 & T^{-3} \end{bmatrix} = j,$$

where j – density of flow or, as applied to the flow of charged particles, density of current, measured in SI system in A/m^2. The variation of density of current depending upon gas pressure is characteristic of gas discharge in electric vacuum devices [15]. At atmospheric pressure inside the glass bulb with electrodes there is no discharge, because even at high voltage the discharge cannot break through a gap between electrodes. When the gas is pumped out the pressure drops down and a breakdown in the form of an arc discharge – thin crimson rope (for air). At the further reduction of pressure, the arc discharge is transformed into a glow discharge, the current density grows and the discharge occupies the entire glass bulb. The effects of conductivity trend are presented in Fig. 4 with blue lines.

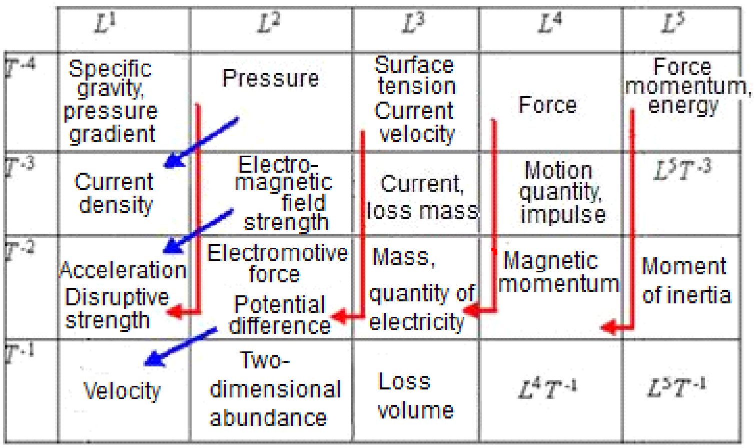

Fig. 4. Physical-and-geometrical effects of inductive trend (red arrows) And conductivity trend (blue arrows)

Trends for other effects could be created in a similar way.

BASIC RESULTS

Introduction of transfer matrix of the effect, which formally coincides (visually) with the matrices of physical values, enables to place the effects in the cells of the Bartini table. Several effects, which have got into one and the same cell, form a trend. Thus, all effects of the trend possess the same specific feature or an invariant. Bartini table of dimensions can be used as a means of classification, coding and storage of effects, which makes it easier to search for them for the purpose of solving inventive problems. Fig. 5 quotes a fragment of LT-table, in which the effects are placed under the serial numbers.

	L^{-2}	L^{-1}	L^{0}
T^{0}	14	8,9,10 w_3	
T^{1}	13	5,6,7 w_2	15
T^{2}	11,12	1,2,3,4 w_1	

Fig.5. Fragment of LT-table of trends of effects

The following effects are included with the inductive trend with invariant W_1:

5. 1.Barnett effect
3. Direct piezoelectric effect
4. Effect of self-induction,
5. Effect of variation of electrical strength of gasses depending upon pressure
6. The following effects are included with the trend of conductivity with invariant W_1 :
7. 5.Effect of electroosmosis
6. Effect of electromagnetic acceleration
7. Effect of variation of current density in a gas discharge
8. Besides, the following effects are shown as an example of filling-in the table:
9. Radio metrical effect of manifestation of repulsion force between two surfaces in a rarefied gas, which have different temperature, input – temperature difference L^5 T^{-4}, output – force L^4 T^{-4}

10. Doppler effect, input – linear speed L^1T^{-1}, output – frequency L^0 T^{-1}

11. Mechanical-and-geometrical effect of slab rolling into a sheet, input – volume L^3T^0, output – surface L^2T^0

12. Dorne effect (sedimentation), input – force of gravity (or centrifugal force) L^4 T^{-4}, output difference of potentials L^2 T^{-2}

13. Faraday's law (electromagnetic induction), input – force L^4T^{-4}, output – EMF L^2T^{-2} 13. Piezoresistive effect, input – linear deformation L^1T^0, output – electric resistance $L^{-1}T^1$

14. Hooke's law, input – force L^4 T^{-4}, output – mechanical tension, pressure L^2 T^{-4}

15. Doppler effect, input – linear velocity L^1T^{-1}, output – length of the wave L^1T^0.

The main difference of this table indicator consists in the fact that certain structural specific features of technical implementation of the effect are taken into account in it. Many physical effects are characterized by several different input and output actions. For example, tens resistive effect (No.13) can have a linear deformation at the input, i.e., tens resistor is elongated or compressed along its length, but it may also be a film effect. With a film effect pressure will be an input, and the tens effect with a film tens resistor will get into a different cell – $L^{-3}T^5$. Similarly for the outcomes – the Doppler effect (No.9 and No.13) is placed in different cells depending upon what is obtained at the output of Doppler's meter of speed, wavelength or frequency.

The analyzed trends are related to the trend of trimming and deployment of technical systems, not only to the trend of increasing coordination. [10]. In fact, the trend «Point-Line-Plane-Volume» is trimmed into the cell L^1T^0 of Bartini table, in which the invariant L^1T^0 мcan be included with the trends of invariants with neighboring cells. Fig. 5 presents the temporal trend of such kinds of invariants $L^{-1}T^{0} \rightarrow L^{-1}T^{1} \rightarrow L^{-1}T^{2}$ in brown, blue and red cells respectively. For the trend of effects located in the brown cell the transfer matrix W_3 is equal to

$$W_3 = \begin{bmatrix} L^{-1} & 0 \\ 0 & T^{0} \end{bmatrix},$$

While in Bartini system the dimensionality $L^{-1}T^{0}$ is presented by the values of curvature (Fig. 1). The trend of invariants $L^{-1}T^{0} \rightarrow L^{-1}T^{1} \rightarrow L^{-1}T^{2}$ can be presented by its electric equivalent. If instead of dimensions in the basis of LT we include the conventional notation of elements of electric circuit, we shall obtain the following circuit:

$$1/C \rightarrow R \rightarrow L,$$

In which C is capacitance, Ф, R – electric resistance, Ohm, L is inductivity, henry. With effects No. 1,2,3,4 in an inductive trend with invariant W_1 the inductivity L is an ideal model reflecting the main feature of transforming of input into output. This feature consists in the fact that if we feed to the input the effect of the flow (or the current – for charged particles), certain force is generated in the effect, which hinders the variation of this flow (current). The energy of interaction is not dissipated, it remains in the effect. From the informational viewpoint it could be said that the memory is generated, which remembers this state.

In a similar way with effects No. 5,6,7 an ideal model in the trend of conductivity with invariant W_2 is the active Ohm resistance R. The resistance also hinders the input flow (or current), however, the result is not remembered, since the energy of interaction is dissipated in the form of heat.

A characteristic example is the phenomenon of electromagnetic induction, it is used in effects No.3 (self-induction) and No. 6 (electromagnetic acceleration). While the current changes, in terms of value or direction, the feature of inductivity L is retained. When the current becomes constant, the feature of inductivity disappears and the feature of Ohm resistance R appears, the energy gets dissipated as a result of heating of the conductor. The effect is transferred to the trend of conductivity. Of course, this example relates to the ideal conductor, which possesses either only inductivity or only active resistance. In case with electromagnetic acceleration the shell flying out of the gun, carries the energy of the field, which is dissipated as a result of friction during the flight.

Effects could be numerically compared in terms of complexity degree of their models in the form of transfer matrices. If the effect is assigned by the transfer matrix W (1), them the number of complexity N_C is found from the formula $N_C=|m|+|n|$. With all effects in inductive trend $N_C=3$, with effects in conductivity trend $N_C=2$. The complexity number of the Число сложности effect reflects the expenditures of spatial and temporal resources on transforming the input action into an output one.

CONCLUSION

In analysis of physical effects in LT-basis of kinematic values, the methodology of hidden regularities, trends of evolution of effects. This methodology can be used

- In search and classification of technological effects
- For synthesis of a physical principle of operation of technical systems [16] and comparative evaluation of information-and-energy schemes for the purpose of patenting
- For teaching inventive physics as part of TRIZ

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CONFERENCE 15 OCTOBER 2022

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M. S. Rubin

On the concept of TRIZ-civilization

The disorder is not in WC, but in the brains.
Mikhail Bulgakov, «Head of a Dog», 1925

SUMMARY

The message of TRIZ (theory of inventive problem solving) consists not only in solving problems and developing inventive thinking of people, but also in the creation of a system of values, which corresponds to the goals of uniting civilizations on Earth based on domination in the society of creative and loving interrelations, not the exploitive, money-grubbing and authoritative relations. The civil-sphere formed on such principles (uniting earthly civilizations into a single system) is a geosphere of a new type together with lithosphere, hydrosphere, atmosphere and biosphere.

The present work reviews regularities of forming and development of geospheres. The comparison is drawn between the scale of civilization processes and the processes of development of other geospheres, which enables to conclude that the civil-sphere is at the starting stage of formation. It is shown that on the one hand culture is a key factor in evolution of civil-sphere, since it includes not only art and sciences, but also technologies and systems of values, while on the other hand this is culture, which appears to be a source of cognitive distortions, which are able to bring civilization to catastrophic events. The formation of TRIZ civilization is one of the tools used for compensating such cognitive distortions.

In this work the author for the first time offers a definition of civil-sphere, TRIZ civilization as well as introduces other terms, associated with the corresponding notions. Different aspects of forming the concept of TRIZ-civilization are analyzed, as well as the goals, tasks and structure of TRIZ –civilization, key tasks of development of TRIZ and TECP (theory of creative personality evolution). The structure of TRIZ-civilization proposed in this work, implies that by the middle of the 20th century the need for scientists, specialists, consultants and trainers, related to TRIZ as well as TRIZ students and trainees will amount to more than 20 million.

Key words: *theory of inventive problem solving (TRIZ), theory of creative personality evolution (TECP), Dignified goal of the personality, inventive thinking, TRIZ-civilization, civil-sphere, forecast of civilization evolution, TRIZ-education, function-and-targeted systems (FTS), culture, system of values, cognitive.*

1. BASIC TERMS

In order to describe models of civilizations and the key regularities of their evolution, special terms are used in this article. In order to avoid any ambiguity in their treatment and understanding, we shall quote short definitions of them in this section.

1.1. Types of systems and their evolution

We shall consider evolutionary succession consisting of three types of systems:

Resource systems are systems, of which other systems may be created (formed), while at the same time they don’t possess any features of self-organized or functional systems.

Self-organized systems. The term was introduced by W.R. Ashby, 1947. It is possible to single out the following features of self-organized systems:

- Cooperative processes play a decisive role in the formation of the system; they are based on coherent or coordinated interaction of system elements, type of molecular behavior changes;

- system is dynamic, its motion is of non-linear, badly predictable character;

- system is open, non-balanced, which provides for material-and-energy as well as informational exchange with the environment.

Self-organizing systems don't meet the requirements of supersystems. Self-organizing system is a resource system, in which spontaneously (not in keeping with the requirements with the supersystem) the energy flows lead to formation of processes and flows, which are associated with the changes in elements and system taken as a whole in time and space, for example, whirlwinds, swirls, volcanic eruptions, formation of stars and planets, etc.

Function-and-targeted system is a system, formed for fulfillment of complex of useful functions attainment of goals in keeping with the requirements of supersystems and operation principle of the given system. Function-and-targeted system is formed based on self-organization, natural or artificial selection or as a result of targeted actions of one of supersystems. To function-and-targeted systems we can relate biological systems, technical systems, social, financial-and-economic as well as scientific and other similar systems. [1].

System ontogenesis is an individual development of any system (material or non-material) is a generalization of the notion of biological ontogenesis.

System phylogenesis is a historical development (evolution) of any systems (material and non-material). System phylogenesis is described through information models of regularities of evolution and is impossible without a succession of system ontogenesis, the evolution of which forms a phylogenesis. System phylogenesis is a generalization of biological phylogenesis, its origination became possible only owing to appearance of information systems, which are able to transfer the accumulated experience of variation of subjects.

TRIZ – theory of inventive problem solving is a field of knowledge of objective regularities and laws of technical system evolution, methods and tools of forecasting, identification, analysis and resolving contradictions of system evolution. TRIZ is based on the laws of dialectic and presupposes the use of evolutionary, system-based, functional, model-based and other fundamental scientific approaches. TRIZ reveals regularities and methods for forming and development of inventive thinking as well as methods for developing creative imagination. Methods and tools of TRIZ are applicable to solving inventive problems not only in engineering, but also in non-technical systems. TRIZ is used in practice for developing creative personality, for solving inventive problems in various fields, in innovative enterprising, in solving problems at industrial plants. [2, 3]

Invention is a significant improvement of the existing system or creation of a new system enabling to resolve the requirements contradiction, which existed before or creating fundamentally new potentiality of the system. In contrast to patenting, TRIZ does not consider insignificant changes in the system, which don't lead to resolving requirements contradictions to be an invention.

Inventive problem is an inventive situation, which contains a contradiction of requirements made to the system.

Evolutionary system studies (evolution studies). The main object of exploration in evolutionary system studies are not the systems themselves, but the mechanisms of system evolution in the processes of phylogenesis and ontogenesis. It means that the object under discussion is not every change within the system, but only such ones which lead to stable evolutionary transformations, which are positive for the present system. In evolutionary system studies the object of exploration is a set of mechanisms of evolutionary development of any system: material and non-material, live and non-live. [4]

TECP – theory of creative personality evolution. It was developed by G.S.Altshuller and I.M.Vertkin in 1980-ies. It includes the analysis of the main concepts of creative personality evolution, of life strategy development (LSCP) and ideal creative strategy («maximum upward motion»), as well as a complex of practical materials (business games, problem books, collections of cards) intended for developing features, which are necessary for a creative personality. As part of TECP an ideal model of creative personality was developed – a set of features of a creative personality (FCP).

Thinking (psychology). Thinking is involved in the process of solving any problem, which a human being might encounter, if the problem is vital, has no ready solution and a powerful motive induces a human being to search for an outcome. The thought appears as a kind of induction of a force field between the need and the opportunity. In the opinion of L.S.Vygotsky, it appears not from the word, not from another thought. A decisive role in its generation is played by motivation. Thinking presupposes the ability of the human mind to split the phenomenon under discussion into parts and extract from them what can lead them to a correct conclusion. One of specific features of thinking is the capacity for orientation under new conditions through generalization and analysis. [5]

Inventive thinking is a type of thinking of the human being, which includes procedures of analysis, synthesis of systems and evaluation of results of introduced changes, which is distinguished by the presence of components of sensitivity to contradiction and to solving it, evolutionary nature, system character and critical character. [6]

System of values is a set of traditional ideas (social settings) of people, concerning the meaning of corresponding objects as well as natural and social phenomena in their lives, which serves as a criterion in evaluation and selection of solution. [7]

Value –is a universal generic category, which embraces the nest of axiological notions pertaining to the same row: the good (and the evil), the beautiful (and the ugly), the true (and the untrue), the just (and the unjust), the right (and the wrong), the pleasant (and the unpleasant), the useful (and the useless, the harmful), the reasonable (and the unreasonable), i.e., the basic (but specific!) categories of ethics, aesthetics, logic, legal awareness, political, economic and other kind of consciousness, economic and other kinds of awareness and corresponding sciences. Axiology harmonizes these rows of notions, classifies them, coordinates, subordinates them and gives them definitions. [8, p. 13]

TRIZ-civilization –is a model of civilization, in which civilization, in which TRIZ, as a social tool of evolution is an important constituent of state and science, widely spread field of human activity. The term TRIZ-civilization can be related both to local civilizations and to civil-sphere as a whole.

1.2. Geospheres of the Earth: lithosphere, hydrosphere, atmosphere, biosphere, noosphere, civil-sphere.

Geospheres successively alternate, diverging from the center of Earth, intersect (interpenetrate) in space and time (transition from one geosphere to another), however, preserve their independence in their formation and development. Geospheres are interconnected and form a stable dynamic system. Geospheres are self-organized (not function-and-targeted) systems.

Abiogenic sphere is a unification of lithosphere, hydrosphere and atmosphere. Abiogenic matter is a matter, which is formed without participation of live organisms. The formation started 4–3,5 billion years ago. About 2 billion years were needed for formation of supercontinent Pangea. [9]

Biosphere – is a shell of the Earth populated by live organisms, staying under the action of these organisms and occupied with products of their activity as well as a set of its features as a planet, where the conditions are created for the development of biological systems; global ecosystem of the Earth. The term «biosphere» was introduced by Austrian geologist E.Suess in 1875. V.I.Vernadsky discovered powerful transforming geological and geochemical features of the biosphere. The foundation of biosphere are biogeocoenoses.

Noosphere. The term «noosphere» was first proposed in the 1930-ies by French historians and natural philosophers (Teillard de Chardin, Le-Roix). In the literal sense the term means «sphere of mind» (noos is mind).

Noosphere is the highest stage of evolution of biosphere, associated with the origination of a civilized society inside it, with the period, when the conscious activity of the human being becomes the main, definitive factor of development. Scientific thought concerning the activities of a human being changed the structure of biosphere and preconditioned physical and chemical changes of all its shells (atmosphere, lithosphere, hydrosphere). [10]

The formation of noosphere started approximately 3 million years ago, with the appearance of the human being. It is believed that noosphere is a part of biosphere. There is no clear model and mechanisms of noosphere development. V.I.Vernadsky wrote that «Noosphere is the last of many states of biosphere evolution in geological history – the state of our days. The development of this process only recently became the object of studies based on exploration of its geological past in its certain aspects». [11]

Civil-sphere (sphere of global planetary civilization of the Earth) is a new geosphere, which is formed through system-based unification of earthly civilizations. At present it is in the state of formation and dramatic changes. Civil-sphere is different from Noosphere. The minimum constituent of noosphere is the human being, the formation of noosphere started with the origination of Neanderthal men 40 000 years ago; mechanism of origination and the model of evolution of noosphere haven't been described. Civil-sphere appears since the moment of formation of the first civilizations 6000 years ago (for example, Schumer civilization), and its minimum system is a socio-cultural system (ethnos). According to V.I. Vernadsky noosphere is a new state of biosphere. [12] The concept of civil-sphere is based on the fact that this is a new type of geosphere, which is different from noosphere, since the culture as a geological force is generated only after the formation of civilizations.

Proto-civil-sphere is a set of earthly civilizations, which are not united by system bonds into a civil-sphere; unfinished civil-sphere, which possesses all features of geosphere.

Civilization is a self-organized social-and-technical system, in which humanity, united by culture, transforms surrounding natural environment into an artificial ambience in order to create more beneficial conditions for existence and development of the society. This process inevitably leads to the growth of civilized substance, controllable energy and information. [13]

1.3. Models of system capture:

Capture of resources is a fundamental feature of any system, which defines the entire course of its formation and evolution. Five types (models) of the capture of resources of one system by another system are proposed in the theory of system capture. They can be divided into two groups.

Negative capture (one of the systems loses resources or acquires nothing):

1. Reaction of capture with acquisition or adjoining of the capture object (exploratory, possessive type of capture).

2. Reaction of capture by displacement (substitution) based on struggle for limiting factor of evolution (acquisitive, saving type of capture).

3. Reaction of decomposition (internal capture, division of the system into separate parts).

Positive capture (both systems get something useful for development):

4. Reaction of capture with exchange (market type).

5. Fruitful capture, synthesis of a new system from the elements (active, mindful and loving type of personality).

Each type of capture in the society finds its equivalent in a definite type of character in this society, which prevails over the others. In case with the negative capture this is the taking, possessing, devoted, authoritative, money-grabbing, saving type of human character. Characteristic for a positive capture in the society is a fruitful character of a human being: active, loving and reasonable. [14]

1.4. Culture. Socio-cultural systems

Culture. Culture will be understood by us as a system of all non-material (information) complexes of human activity, aimed directly or indirectly at changing the material world or at forming the system of human values: technologies, science, religions, art, economics, politics, etc. We shall distinguish culture from material vehicles (transmitters) of elements of culture.

Socio-cultural system (SCS) is a union of many live systems or sets of them based on cultural ties, possessing qualitatively new characteristics and not reduced to a simple sum of these characteristics, of which these systems are composed. Each socio-cultural system can itself become a foundation (element or resource) for another socio-cultural system. Thus, the elevation of a hierarchical level of SCS can take place (people, family, tribe, ethnos, nation, state, civilization, unions of states, civil-sphere). [15]

2. GLOBAL CIVILIZATION AS A STAGE IN THE EVOLUTION OF GEOSPHERES OF THE EARTH

2.1. Civil-sphere as a development of geospheres

We shall consider civilizations (both the local ones and a planetary civil-sphere) as a continuation of one process of formation and development of global geospheres. All geospheres of the Earth have common features in terms of their properties and stages of their evolution.

Table 1. Main stages of evolution of any geosphere on an example of biosphere and civil-sphere

Stages of geosphere evolution	On example of biosphere	For civil-sphere
1.Formation of individual elements of future geosphere	Approximately 3800 million years ago first signs of life on Earth appeared (micro-organisms). [16]	0.006 million years ago first civilizations appeared in Egypt, Mesopotamia, India, Far East and Peru.
2. Uniting these local elements into a global sphere of planetary level	Approximately 3200 million years ago the influence upon the composition of atmosphere (biological registration of nitrogen) [17,18], hydrosphere and lithosphere	0.0007-0.0009 million years ago (15-17th centuries of our era). Great geographical discoveries
3. Stage of dramatic revolutionary changes in the process of geosphere evolution	2400 million years ago oxygen catastrophe (entrance of oxygen into the atmosphere). [16] 555 million years ago – Cambrian explosion. [19]. Quick evolution of multicellular organisms	0.00002 million years ago (1800-1900) exponential growth of the world population number, industrial revolution
4. Stage of stabilization, homeostasis and evolutionary development of geosphere (can include separate revolutionary changes, smaller in scale than at the 3rd stage)	Approximately 500–400 million years ago – stabilization of growth. Plants conquer the firm ground. Oscillations in evolution. Formation of combustible minerals [20]	Has not come. Number of population of the Earth will be approximately 18.8 billion people in 2100 [15] and approximately 30 billion in 2300
5. Stage of forming elements of new geosphere based on newly formed geosphere	3–0.04 million years ago. Origination of humanoids, humans and tribes as elements of would-be civilizations	Has not come.

The Table 1 enables to draw a number of conclusions. Time of civil-sphere formation is immeasurably lower (hundreds of thousand times) than the time of formation of lithosphere, hydrosphere, atmosphere and biosphere. Civil-sphere stays at the beginning of its formation and will go through millenniums (or even millions of years) of dramatic changes, then stabilization and origination (on its basis) of global (planetary or cosmic) formations.

In order to understand what form the image of civil-sphere might take by the moment of stabilization of its evolution, it is possible to evaluate the rates of growth of its key parameters as compared to other geospheres, which have already attained a certain level of balance. One can form the opinion on dramatic growth of civil-sphere by high (exponential) growth of the population number, growth of weight of all civilized substance, generated energy, volume of information in civilizations. It is most logical to compare the future image of civil-sphere and its geological influence with biosphere. Will civil-sphere become a part of biosphere? Or if biosphere become a part of civil-sphere? Are civil-sphere and biosphere interacting entities or are they at the same time different geospheres?

Table 2. Evaluation of weight and energy in biosphere and in civil-sphere. Information from different sources might be significantly different. The table contains approximate data from the sources, which explicitly inspire confidence

	2021	2100	2300
Weight of civilized substance (tons) [21]	~$1{,}5 \cdot 10^{12}$ (rate of growth equal to $1 \cdot 10^{12}$ each 15-20 years)	~$5 \cdot 10^{12}$	~$10 \cdot 10^{12}$
Dry weight of live substance of biomass (tons) [22, 23, 24]	~$2{,}4\text{-}3{,}6 \cdot 10^{12}$		
Weight of entire biosphere (tons) [23]	~$3\text{-}10 * 10^{18}$ (including live, biogenies, bio-abiogenic and biogenic substance)		
Generation and use of energy in civil-sphere (Joule) [25, 26, 27,]	~$6\text{-}7 \cdot 10^{20}$	~$11 \cdot 10^{20}$	~$16 \cdot 10^{20}$
Annual energy input in biosphere Joule [28]	~$1{,}8 \cdot 10^{20}$		
Overall store of mineral energy in biosphere (Joule) [24, pp. 59, 29]	~$2{,}5 \cdot 10^{22} – 4 \cdot 10^{25}$ (earth crust, soil, etc.)		

Table 2 quotes the evaluation of energy and weight of the substance in biosphere and civil-sphere.

Comparison of quoted data shows that in the forthcoming years the weight of civilized substance will be higher than the biomass of living organisms on the Earth. In 2300 the weight of civilized substance will be 3 times greater than the weight of biomass. The rate of growth of energy in civil-sphere is still higher. Mineral substance and energy accumulated in the biosphere, can also be quickly converted into a civilized substance. The processes of formation of biomass and energy flows in civil-sphere will thereby develop 500 thousand times quicker than in biosphere. Due to what reasons and based on what resources does such dramatic growth of civil sphere take place?

2.2. Models for forming and evolution of the Earth civil-sphere

Fig 1. Reflects generalized (and simplified) model for forming geospheres of the Earth. Every preceding stage in the evolution of this process prepares resources for the next stage of geospheres formation. In this case each new geosphere starts to influence the evolution of all other geospheres. Civil-sphere is not a part of biosphere, since it is based on a new kind of interaction – socio-cultural fields of interaction.

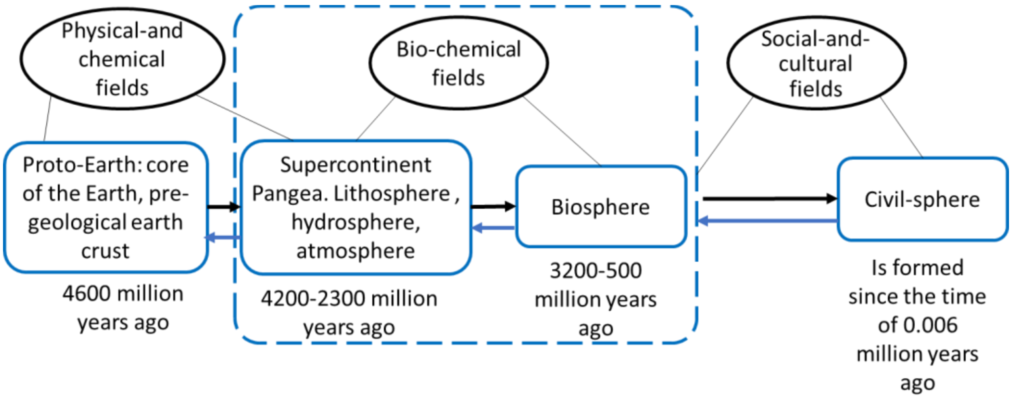

Fig. 1. Generalized model of processes for forming geospheres of the Earth. The formation of each new geosphere is associated with new fields of interaction

Fig. 2 shows in greater detail the model of the process of forming biosphere and civil-sphere. Without claiming exhaustiveness, we shall single out some fundamental features distinguishing bio-sphere from abiogenic sphere.

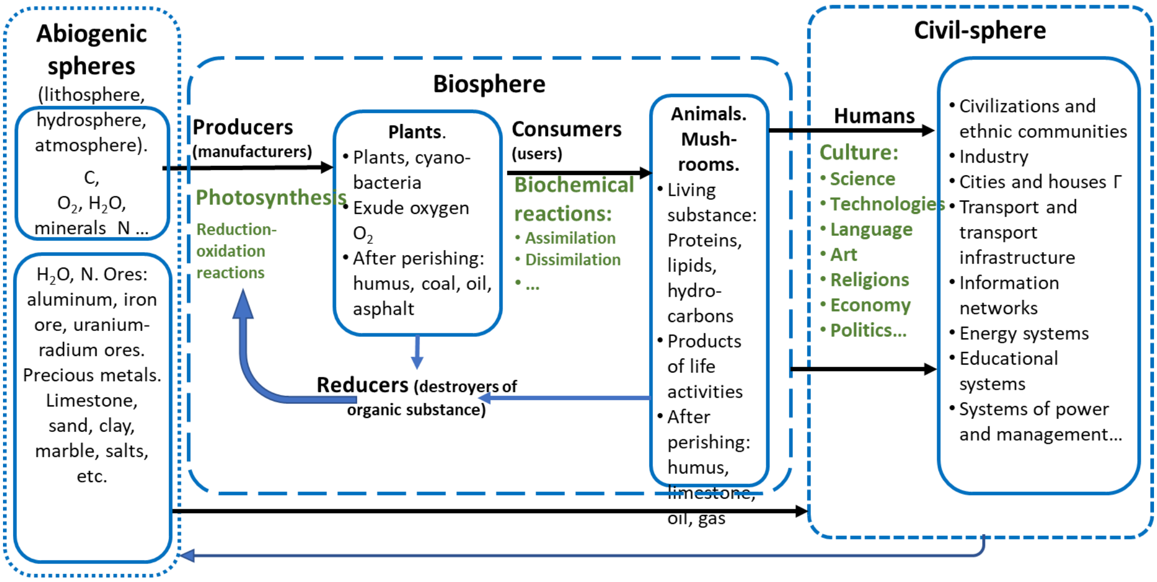

Fig. 2. Model of processes for forming civil-sphere from abiogenic sphere and bio-sphere

1. In contrast to abiogenic sphere, biosphere consists of function-and-targeted systems (plants, animals, bacteria, mushrooms), but it remains a self-organized system. In abiogenic sphere there are no function-and-targeted systems;

2. With the appearance of live organisms the mechanism of feedback is originated as well as the information proper, i.e., an opportunity to store and to deliver information from one agent to an-other with the aid of genes and with the origin of animals – through social mechanisms;

3. With the appearance of information systems phylogenesis as such comes into being. At first, with unicellular, it had few features distinguishing it from ontogenesis, however, with the origin and evolution of multicellular organisms the difference between onto- and phylogenesis grows;

4. In contrast to abiogenic substance of abiogenic spheres, live substance of biosphere (organisms on the whole and each of its cells separately) requires a ceaseless flow and store of energy in order to support vital activity based on metabolism;

5. An important feature of live substance is the presence of ageing and death as a completion of ontogenesis of live organisms. This important evolutionary invention enables to free resources for new organisms, thereby retaining the main information accumulated during life process; [58]

6. Biosphere is based on biogeocenose – set of living organisms (plants, animals, bacteria, mushrooms) on a certain territory, which provides for circulation of substances and energy pyramids. Thus, the organic matter of three types is formed: living organisms, results of their vital activity and organic substances, which are formed after the death of the organisms. In abiogenic spheres there are no such mechanisms for substance and energy conversion.

Civil-sphere is formed based on abiogenic spheres and biosphere, but is not reduced to them, since it has its own specific features and distinctions.

1. The main difference of civil-sphere from biosphere is the presence of culture and socio-cultural systems, which are formed due to thinking and system of values of the humans;

2. The key factor of forming and development of civilizations is information systems: from the anatomy of larynx and origin of speech to modern computer-assisted information systems. We already noted dramatic tempo of growth of the Earth population and of the weight of civilized substance. However, the tempo of growth of information is 480 million times higher than the tempo of growth of the civilized substance weight. Mechanisms for variation and spreading of information in civil-sphere are much more dynamic than in biosphere;

3. System phylogenesis has much in common with biological phylogenesis, however, it is built on other, more flexible information mechanisms, which also include imagination, thinking, systems of design, manufacturing and verification of new systems. In this case the information from one technical or other artificial «species», for example, horse wagon, may be transferred through the system of design to the system of quite a different «species», for example, to mechanical clock. Besides, it may take place at any distance, at different continents, which is essentially impossible in case with biological systems;

4. In contrast to living matter the greatest part of the civilized substance doesn't require any energy replenishment supply, as it is the case with living cells. For example, buildings and edifices, frames of machines and shells of engines don't require constant supply of energy supporting these systems;

5. The death of ethnos in civilizations is the decomposition of system-based and cultural unity, but not the entire extermination of people, of which this ethnos consists. [30]. It can be the loss by the system of ethnic values, as well as the values of the language, traditions and history, technology and any other significant components of the culture pertaining to this socio-cultural system. Like in the living systems, a socio-cultural system, which has perished, transfers part of its information and material systems to new ethnic formations;

6. During 1–2 billion years biosphere stored energy in biomass which is 100 times greater than the energy, which it annually receives from outwards from the Sun. The portion of stored ener-

gy in civil-sphere is, on the contrary, approximately 100 times less than the energy produced during one year;

There are mechanisms in civil-sphere, which are intended for using sources of substance and energy, which are hardly accessible for application in biosphere: oil, gas, ore materials, metals, sand, clay, limestone, etc. It accounts for a quick growth of the civil-sphere weight.

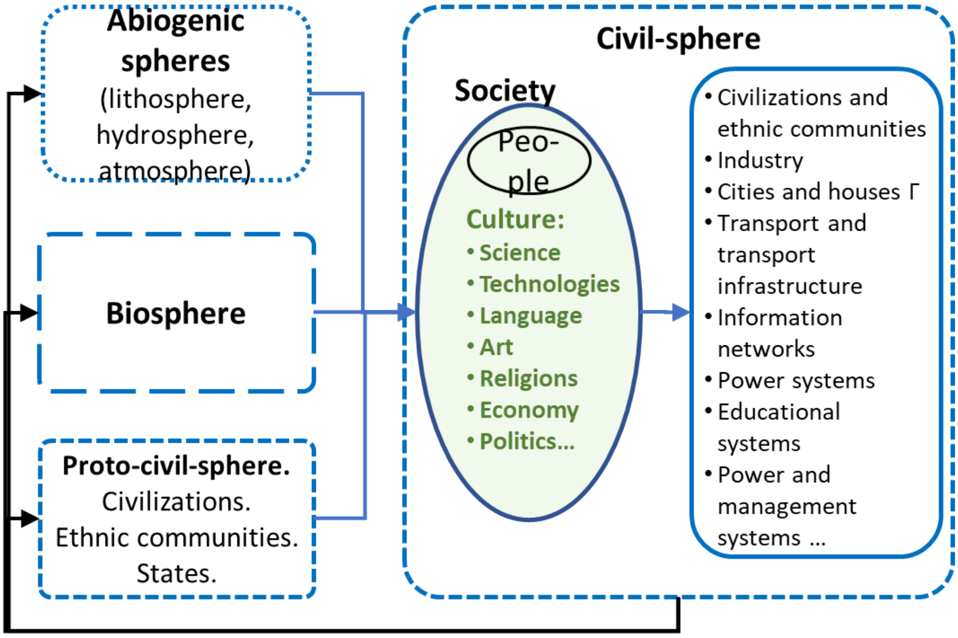

Fig. 3. Process of transformation of abiogenic sphere, biosphere and protocivil-sphere into civil-sphere or into a new state of civil-sphere

Fig. 3 shows a simplified pattern of the process for transformation of abiogenic spheres, biosphere and protocivil-sphere into a civil-sphere or into a new state of civil-sphere. It means that civilizations themselves could play the role of a resource for formation or development of a new or simply of another civilization.

It can be concluded form the performed analysis that the main factors of a powerful growth of civil-sphere are culture and the information processes, which are associated with it and providing for both growth of substance weight and growth of energy. The reasons for global processes in civil-sphere are in the imagination and thinking of the human, systems of values, religion, art, science, technologies, economy, politics and other socio-cultural and social-technical constituents of civil-sphere and society, which constitute its core. The same factors also form the basis for the majority of problems, which are encountered by humanity.

2.3. Tendencies of formation and key problems of development of civil-sphere

2.3.1. Ecological problems

Many ecological problems of planetary scale can in reality appear to be myths and mystifications, set up in the interests of business and politics. For example, the myth of ozone «holes» in atmosphere (judging by many publications) has been so popularized in the interests of particular manufacturers of aircrafts and refrigerators. In the same way the myth concerning global warming is exploited for the sake of additional taxes in favor of state budgets or in favor of dishonest competition at the global level in order to restrict the development of industry of other states. Kyoto protocol and carbon tax are non-market tools used by some countries in order to influence industry and economy of other countries. [31, 32, 33]

In 1991 600 oil wells were ignited in Iraq in order to initiate ecological catastrophe and decrease the temperature of the world by 5-10°C. The wells continued to burn for many months, but it never led to any influence upon the climate. [33]

Global radiation contamination could be an actual ecological catastrophe. And this danger only emphasizes the fact that the foundation of modern problems of civilizations and also of biosphere is the culture of these civilizations proper. [34, 35, 36, 37]

2.3.2. Aggressions of civilizations

One of the problems for forming civil-sphere is the fact that some civilizations could be looked upon by other civilizations as a resource for development or absorption. If such an interaction is built on the principles of aggressive capture implying the extermination or absorption of one of the civilizations, it could lead to global civilization and to military conflicts. In biosphere the competition takes place between living organisms of different species, while in civilizations living organisms pertaining to one and the same species take part in the competition. Positive kinds of system capture prevail in biosphere (symbiosis, fruitful capture), which is characteristic of the stage of stability and homeostasis in system evolution. At the same time civil-sphere is at the stage of dramatic growth, which is rather characterized by negative types of capture (absorption, displacement, decomposition). Culture of civilizations is a source of menace for these civilizations themselves. In the history of origin and evolution of people there were 9 sub-species of the human and it is known that some subspecies could displace or absorb the others. For example, archanthropus (Homo erectus) is displaced by Neanderthals, while Neanderthals, in their turn were in this or that way displaced by Cro-Magnons. [38, 39]

Similar processes of displacement and absorption are found in the evolution of civilizations, for example, the extermination of Maya civilization by Spanish conquistadors.

Social aggression of the people and constant evolution of criminality based on growing and developing civilization resources and technologies is an existential menace for the mankind. Growth and globalization of criminality are directly preconditioned by inequality of people and uneven distribution of resources on the earth. [40]

2.3.3. Growth of the population number

According to the forecast, in 2100 the number of populations of the Earth will reach 18.8 billion people. [27] By 2300 the number of populations of the Earth could attain 30 billion people and the density of population will be equal to this parameter value as of 2022 in Germany. Even if by that time the population number will constitute 50 billion people, it will correspond to the density population in modern India. Currently 70% of existing population live on 7% of the firm ground. The growth of the Earth population should not be looked upon as the motion to certain ecological catastrophes. If the earth population decreased every 12 years by 1 billion persons, it would be a real problem.

Increase of the population number should contribute to economic growth and might lead to stabilization of the population number in a natural way, without any cruel measures consisting in the decrease of birth rate. And we needn’t wait for any biosphere cataclysms. Available and developing resources will be enough for all. The task of civilizations is to provide the growth of population with resources: technologically, energetically, ecologically, politically and in terms of other social aspects. Humanity will conquer not only firm land, nut also seas, oceans, and non-distant space.

The average age of the population in 100 years will approach 100-110 years and the population number will start to stabilize out of natural reasons. The growth of civilization will continue due to capture of non-live matter, development of information systems, art, science, systems of values, but not the living mass of the mankind.

2.3.4. Culture and systems of values as sources of catastrophes.

The main vehicle of evolution inside the civilizations is culture: system of values, level of thinking of the people, science, technology, economy, politics, art. This is culture, which distinguishes humans from animals, biosphere – from civil-sphere. This is culture which is the reason for catastrophic rates of changes in civilizations, source of main conflicts and potential catastrophes. It has to be noted that in the broad sense mass culture (or it would be better to say counter-culture) could also include cult of force, atrocity, self-annihilation, drug addiction, which are often translated through feature films, music and other sub-culture products. [41]

During the process of their evolution civilizations created a whole complex of social institutions, which are directed against equal rights of different strata of society. For example, in Ancient Athens there was nobility, demos (people) meteks and slaves. Women, slaves, meteks and slaves were not allowed to take part in Public Gathering. It is surprising, but any ideas, directed at social equality and love, are artfully converted by civilizations into maintaining a hard dependence of one part of society upon the other. For example, inquisition, crusades, religious wars. This line of aggression and fanatic passions finds logical counterparts in colonialism, racism and fascism as forms of separation of global society into commanders and subjects. This obviously contradicts the idea of preserving the human as a species and the fundamental values of the world religions. This is the basis for global problems for civil-sphere formation.

2.3.5. Dissonances between the personality and its potentiality in civil-sphere

The culture of civilizations forms and develops mechanisms, which enable one person to directly influence the lives of billions of people. [42] Natural psycho-physiological mechanisms don't presuppose the presence of such potential. Let us quote several examples. At present 4 billion people, which accounts for a half of the population of the Globe have the daily budget of 2 to 10 dollars per day. The richest man on Earth possesses the capital of more than $219 billion. This gap is constantly increasing and leads to formation of a small group within the society, which has huge, non-comparable with anything opportunities of influencing the greater part of the Earth population in future perspective.

Another example is private social networks. For example, such social networks are known, which have about 3 billion active users every month. Not a single state in the world has the population of such scale, which could be influenced through information sources and rules for organizing them. Moreover, there is an opportunity of targeted, individual influence upon every person from the network. Interests and system of values of one rich man, psycho-physiological opportunities of one person are incompatible with that great influence, which civilization enables to concentrate in the hands of one person. This is also a source of great risks for forming civil-sphere. There are no necessary tools of social braking, which might prevent catastrophic changes of civilizations.

As we have already noticed, all geospheres of the earth are self-organizing systems, i.e., they have no supersystems, which might form and regulate the functions of these geospheres. At the same time in forming civil-sphere attempts are constantly made consisting in converting all civil-spheres into a function-and-targeted system, which develops in the interests of particular persons or narrow clans of people. It means that the person himself, as an individual, staying in the foundation of a multi-layer social hierarchy of civil-sphere simultaneously tends to become the top of this very hierarchy, but already as an owner of a certain social mechanism.

2.3.6. Information and distortion of it as a foundation of social degradation

It was already noticed above that the revolutionary distinction of civil-sphere from biosphere can be understood as the new technology of information processing and storage, which includes imagination, language and thinking and also modern information technologies. It gives essential advantages in forming and development of civilizations. At the same time these are information processes, which are the most tangible component of civilizations.

The evolution of animals and plants it is impossible, for example, to distort the information about the past, if it is recorded on a gene level. At the same time history of mankind is constantly rewritten and distorted in the interests of certain social groups. There is a large number of technologies for distorting the notions and opinions within the society. A well-known example is «Windows of Overton». The essence of this conception consists in a simple thought, worded by Joe Carter in 2011 based on the developments of Joseph Overton: with the aid of money and mass media propaganda it is possible to incorporate absolutely any idea into any society (in terms of level of development) so that this idea will be perceived as a norm. This is a technology of substitution of notions and changing opinions consisting of six stages: 1. From the unthinkable to radical; 2. Radical; 3. Applicable; 4. Rational; 5. Popular; 6. Applicable norm. [43]

According to another theory, which is called “spiral of silence” people are apt to hide their opinion, if it does not coincide with the opinion of those social groups, to which they belong. [44]

The law of self-synchronization is also thereby experimentally proved (the law of 5%): in a certain group 5% active persons are able to lead all other members of this group, even if this is a wrong selection. [45]

One more global problem concerning information, models and evaluations used for decision-taking is associated with cognitive distortions. More than one hundred cognitive distortions, violation of logic and distortions of received information are known. Cognitive distortions or irrational convictions are characterized by dogmatism and «absolute truthfulness», are expressed in certain obligations, appear automatically and are usually accompanied by negative emotions and generate changes in human behavior (phobias, depression, problems with self-evaluation, etc.). [46]

Let us remind the reader that information is also that part of civil-sphere the development of which is the quickest. The rate of increase of information volume is more than 500 million times greater than the rate of increase of the weight of civilized substance. And this very foundation became the most tangible for distortions and manipulation. In particular, it creates the grounds for self-annihilation of civilization, origination and development of fascism.

«Social basis of fascism is illiteracy or psychic inferiority, i.e., controllability through subconscious and mysticism, so called collective subconscious, which also relates to religion. Devotees lose the spark of Reason in their eyes and are converted into a blind and irrational tool of someone else’s Will. Therefore, the loss of reason always leads to fascism through intermediate ties coming from neofascism and capitalism. To create an opportunity to control society in such a way, one had to create an intermediate layer of psychic activity, which stays in contrast not only to the Human, but also to biological, i.e., animal nature». [47, 48]

One of the methods of eliminating cognitive distortions is a set of tools of TRIZ and TECP [49], enabling to develop a more independent and effective behavior due to developing system-based and critical thinking, habits of building correct cause/effect chains, psychological resistance to contradictions, ability to reject the blows of society in attainment of set goals and other qualities of creative personality.

3. TRIZ AND EVOLUTIONARY SYSTEM STUDIES AS A DEVELOPMENT OF SCIENTIFIC METHOD

Science can be looked upon as a system, which is destined to eliminate cognitive errors, to which people are prone because of their nature. The very phenomenon of cognitive distortions is a scientific discovery. The term was proposed in 1972 by the scientists D. Kahneman and A. Tverski and is extensively used in humanitarian disciplines. [46]

It is possible to single out three main assertions, which characterize science both as a part of culture of civilization and as a tool for compensation of cognitive distortions:

- the world surrounding us and the processes occurring in it have certain regularities and laws, which can be studied and used in practical activity as well as for forecasting (4th millennium B.C.);

- the laws have an objective foundation, i.e., they are not dependent upon subjective factors, associated with personality or some image, but have a rational, abstract foundation with a system of proofs of scientific knowledge and theories. (6th century B.C.);

- the proofs of scientific knowledge are based on scientific method: obtainment of scientific knowledge through experience, experiments and transition to induction as a method of cognition (XII–XIV centuries).

Thus, science, was gradually formed as an alternative to myths and superstitions, belief in a miracle and mysticism. It is assumed that scientific method and science as a state social institution date back to the works of Francis Bacon on the development of sciences, written in 1597–1627. [50] However, in the 20th century there were failures in the application of scientific method. The fact is that with the development of science a gradual transition took place from studying rather stable objects of natural history (physics, chemistry) to exploration of quickly changing social objects. While objects of natural history offer a possibility to collect data, stage experiments, form and verify the models of certain processes and regularities practically on the same objects, in case with social objects science encounters with quite different rates of the objects' changes. Science assumes that the experiments performed, for example, with gravity, mechanical objects and molecules, staged many centuries ago, are the same in our days, since the features of these objects did not change. The situation is quite different with such objects of scientific exploration as technical systems, tribes, ethnic communities, economy and politics. The features of such objects change so quickly, that since the beginning of scientific studies till their end they can be significantly changed. One more problem associated with the scientific exploration of such objects is a large number of factors, which are not always known, but which influence the object of study. Thus, a scientific method based on a set of observations and verification experiments, appears to fail in such fields of studies, which are currently most demanded as an object of studies – social-and-technical, economic, political, ethical. Based on this, arguments are formed, which enable to doubt the fundamental workability of a scientific method. Moreover, it offers the reason to doubt other basic theses of science: an opportunity to study surrounding world and the objectivity of identified laws and regularities of phenomena surrounding us. Science as a tool of compensation of cognitive distortions starts to surrender its positions in two directions simultaneously:

- people gradually start to abandon the ideas of scientific approach as an important tool for perception of the surrounding world, while mythology, superstitions and mysticism return their past influence upon the society;

- science itself begins to lose its strictness and its compliance with the source theses, based on which it was created.

Moreover, reference to research, which purports to be scientific, themselves become a tool of cognitive distortions. Simple belief in certain «facts» and interconnections of these facts without any critical analysis is able to implement into the conscience of society the most absurd ideas concerning the surrounding world. Science itself is more and more susceptible to cognitive distortions. For example, such an experiment was staged in Austria, in Karl-Franzens-Universität (Graz). One and the same article was presented for reviewing to 3300 of scientists – specialists in the corresponding field. In one case it was indicated that the author is a Nobel prize winner (it was approved by 77%), in the second case the author was not indicated (and 52% expressed their approval), and in the third case an author, which was little known was indicated (35% of reviewers approved of it). [51] It means that scientific system is subjective and does not cause any special trust, is unable to perform the function of correcting cognitive distortions. In this situation the influence of emotional, non-scientific evaluation grows. Utterances of actors, sportsmen or simply mentalists could have a much higher social weight than numerous researches of the scientists. People are prone to perception of simple models, though they might not have been verified, not the objective and proved truths, which are difficult to understand.

Fig. 4 shows the visualization of general logic of appearance of distortions in culture in forming civil-sphere. From abiogenic sphere and biosphere civilizations are formed, the main specific feature and foundation of which is the presence of society (people and culture) and essentially new mechanisms for information processing and storage.

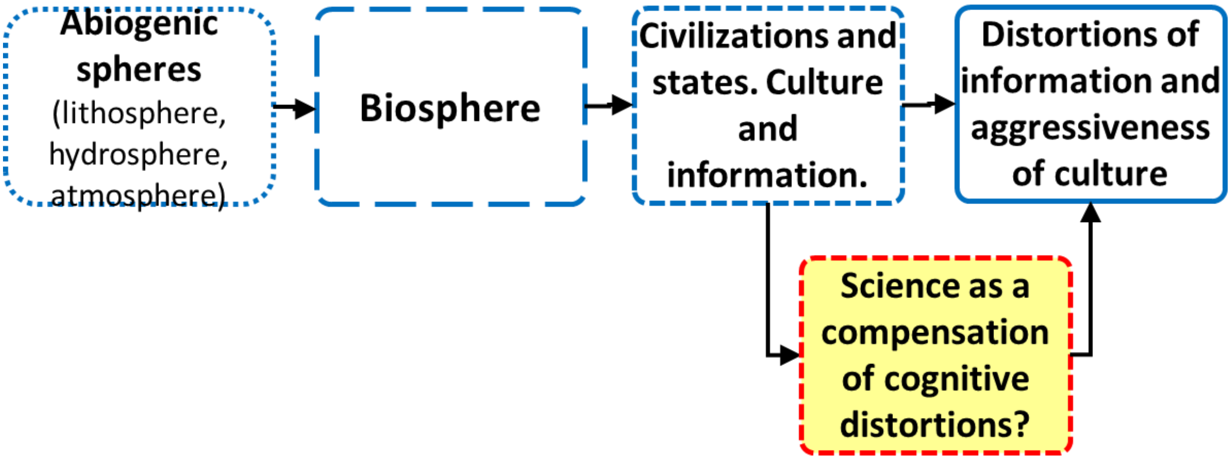

Fig. 4. Visualization of general logic for occurrence of distortions in culture in forming civil-sphere

These specific features in particular become simultaneously sources of dramatic development and a method of cognitive distortions, aggression and concentration of huge resources without any opportunity of controlling them adequately. The problem could be reduced to two main constituents:

- ineffective thinking of the humans, which allows for significant cognitive distortions;

- ineffective system of values in the society, which allows for catastrophic consequences and leads to aggression, inequality of people, states and civilizations.

It is necessary to create and develop social mechanisms, which are able to correct two constituents of the key problem of civilizations. An important role in this process could be played by TRIZ and TECP. The former (TRIZ) is directed at forming effective, evolutionary, dialectic and critical thinking (inventive thinking). The latter (TECP) could offer the basis for developing a system of values of the society directed at the elimination of intra-species aggression of the people, at the formation of creative personalities, the activity of which is concentrated on the attainment of Dignified goals: socially useful goals directed at the development of life and society as a whole. Civilizations, in which TRIZ and TECP have an important social-and-cultural meaning, will be called by us TRIZ-civilization.

TRIZ has been developing since 1956 as a discipline, which is directed predominantly at solving inventive problems in technology and identification of trends of inventive problem solving. As the sphere of TRIZ application developed, it absorbed a number of other theories and methods, directed at forming inventive thinking with people and at the identification of trends of evolution of any, not only technical and material, but also non-material systems (evolutionary system studies).

The main object of analysis for TRIZ and evolutionary system studies is not a set of objects and processes themselves, but their development and the process of ontogenesis and/or phylogenesis. The systems, which have different functions and operation principles, are thereby subjected to the same general laws and regularities of evolutionary development. For example, a common feature of all function-and-targeted systems is the transition from the system to supersystems, tendency to increase of degree of ideality of these systems (there is no system, but the functions are performed and the goals are attained), the development through forming and elimination of requirements contradictions given to the system and attributes contradictions of system elements. In technology, in business, in biology, in socio-economic systems these laws and regularities of evolution explicitly manifest themselves as well as many other laws and regularities. TRIZ is based on a number of fundamental sciences and scientific approaches: dialectic and dialectic approach, system-based approach, functional approach, evolutionary approach, parametrical approach and model approach. In this case effective TRIZ methodologies for solving inventive problems from various fields of knowledge, for forecasting the evolution of social-and-technical systems, evolution of creative imagination and inventive thinking are developed and successfully used in practice.

Formation of inventive thinking implies the formation of mental components aimed at analysis of systems, synthesis of systems and components for evaluation of the found or proposed solution of the problem: sensitivity to resolving contradictions, critical approach and novelty. Practice of inventive activity implying TRIZ methods creates conditions for formation and development of both individual components of effective thinking and inventive thinking on the whole. Such evolutionary approach to mentality forming enables to broaden the opportunities of scientific method in order to apply it not only to systems with stable features (physics, chemistry), but also to quickly changing systems: social-and-technical, social-and-cultural, etc. Development and wide spreading of TRIZ will enable to reduce the influence of cognitive distortions, reduce the probability of global catastrophes in forming civil sphere and to find effective solutions of emerging problems of its development.

To develop the potential of TRIZ in terms of reducing cognitive distortions and development of civilizations, it is necessary to solve sets of problems in two directions:

- further evolution of TRIZ tools as an effective method for correcting cognitive distortions, development of inventive, system-based and critical thinking;

- broad dissemination of TRIZ in the society, in social structures as a development of a scientific method.

TRIZ-civilization should presuppose social institutions for developing TRIZ, practical use of TRIZ in various fields of industry, business, social and scientific activity. TRIZ-civilization should also imply the formation of more stable, substantiated and objective social mechanisms for development of society and decision-taking. TRIZ is destined to reduce cognitive distortions in the society and in state management, form evolutionary thinking with people.

4. SYSTEMS OF VALUES IN TRIZ-CIVILIZATION

It is possible to single out two types of cognitive distortions:

- distortions of perception and thinking;
- distortions of evaluation, values and priorities.

We shall distinguish thinking (inventive thinking) from evaluations and system of values. Thinking is associated with formation and conversion of abstract models, while systems of values and evaluations are associated with defining the importance of certain objects and factors of their influence, with identification of priorities and processes, which are dominating at a given moment.

In section 3 we considered the potential of TRIZ in terms of reducing cognitive distortions due to formation of inventive thinking. In this section we shall discuss the systems of values, their influence upon cognitive distortions and on the role of the system of values in TRIZ-civilization.

4.1. Systems of values and evaluations

Systems of values and evaluations consist of a large number of socio-cultural and psycho-physiological complexes. Axiology – theory of values and at the same time theory of evaluations studies different approaches to forming systems of values and evaluations in their interaction with psychology, ethics, esthetics, hygiene, religious philosophy, cultural theory, ethnography, anthropology, etc. The main notions of axiology are: meaning, significance, value-based relation, value, evaluation.[8] In practical aspect, 10 commandments from the Bible can be looked upon as the foundation of all basic values. Since there are many systems of values and they are fairly different, it is necessary to work out some basic criterion: what values are useful for the civilization and what of them are useless. Useful values will be understood as systems of values and evaluations, which lead to the development of civilizations and formation of civil-sphere without conflicts, wars and sub-division of people into better and worse, commanders and subjects.

Such feature (criterion) will be understood by us as types of system capture, which dominates in the society: Negative or positive. If a set of values systems in the society leads to domination of negative types of system capture or influential complex of evaluation-related contradictions and contradictions and conflicts, this is a situation around the system of values, which is undesirable. But if the system of values leads to the domination of positive types of system capture, these are systems of values, which are useful for the society and for civilizations.

Let us quote the words from the fundamental work by S.M. Shirokogorov concerning the evolution of ethnic communities: «Finally ethnic environment places one more problem before the ethnos: creation of relations with other ethnic communities, taking into account that these relations may take fairly different forms: the form of cooperation, the form of mutual profits, the form of parasitism and the form of absorption or amalgamation, if the complete extermination or displacement of one ethnos by another, which depends, of course, first of all upon the capacity of ethnos.». [52]

It proves that ethnic communities (like civilizations and states) are characterized by fairly different forms of system capture. These forms of capture also correlate with forms of system capture in human behavior and in the character of a human being. Peculiarities of human psychology and socio-cultural portrait of civilizations have a tendency to balance and mutually pre-condition one another. Erich Fromm, for example, singles out two types of relation of the human to the surrounding world: assimilation (of everyday life objects) and socialization (incorporation into society). Thereby E. Fromm singles out two types of orientation in human behavior: non-fruitful orientation and fruitful orientation.

«There is no human being, whose orientation is completely fruitful and there is no human being, who is completely devoid of fruitfulness. However, specific weight of fruitful and non-fruitful orientation is different in the character of each particular person». [12]

Similar forms of capture of resources described in Table 3, are characteristic of social systems and of individual persons, in particular.

In the Stone Age, probably, there were also inventors and a kind of creative personalities, but they obviously did not dominate in that society. The general tendency of development of socio-cultural systems consists gradual transfer of emphasis (in the society) from negative types of capture to positive (market-based and creative). In keeping with this tendency, the system of values and evaluations should also develop. Values consisting in loving, creative interrelations should dominate in the society over the values, which are associated with exploitation, money-grabbing and authoritarian.

Table 3. Types of capture and their characteristics for socio-cultural systems and for types of character of persons

Groups of types of capture	Socio-cultural systems	Personal characteristics (type of character)
Negative capture (one of the systems loses something or acquires nothing)	1. Capture with absorption or adjoining the object of capture. 2. Capture through displacement (substitution) based on struggle for limiting development factor. 3. Capture through decomposition (internal capture, subdivision of system into separate parts)	1. Exploiting, possessive, taking 2 and 3. Money-grabbing, preserving. Authoritative, faithful.
Positive capture (both systems get something useful for their development)	4. Reaction of capture with exchange. 5. Fruitful capture, synthesis of a new system from its elements.	4. Market-based, indifferent type of personality. 5. Active, reasonable, loving, creative

In the society (ethnic community, state, civilization), in which domination of negative types of capture, conflicts with creative personalities will inevitably take place because of the difference in their systems of values.

4.2. Management of values and evaluations system as an inventive problem. On features of the fields of socio-psychological forming of values

Any systems of values and evaluations, like any other system, consist of separate elements and bonds between them. It is possible to single out channels of perception of information for a system of values as the key elements of values system values. With different objects these channels may be different, however, principles of their organization and functioning are the same.

For example, the following channels of perception and factors of external influence: preliminary information and evaluation of analyzed object, visual image (environment, gestures), acoustic image (intonations, timbre), smells, tactility, information flow, internal goals of the human, evaluation of consequences (forecasting).

For a social and industrial object these factors and channels could be different. For example, history of supply of goods and services in the past (including the references of other companies), financial flows, logistics, legal bonds, personal contacts of the employees, branch forecasts, general information flows and marketing.

Socio-cultural systems and, in particular, personality, possess a universal feature to evaluate the channels proper, through which the information comes, the degree of importance and trustworthiness of the channels, the very information received. [53] Let us enumerate some of these features of system values and evaluations:

- The subject of socio-cultural interaction possesses the feature of evaluation of information, which is received from each of the available channels. Conventionally it could be positive, negative or neutral evaluation (+, 0, –).
- Several kinds of interaction could be consciously or unconsciously integrateed into one channel, which also can have its evaluation concerning the quality of interaction (+, 0, –).
- All channels of communication have different value for the subject: some of them are more important, others are of secondary importance. Some of them are more trustworthy, others are less trustworthy. Thus, it is possible to single out important (leading) and secondary channels of communication.
- The evaluations can be formed either based on creating logical cause-and-effect chains, or based on emotions and evaluation of authoritative, influential subjects (people, mass media, etc.). It means that there is an induction of evaluations, which varies from one subject to another.
- The evaluations are characterized by the feature of induction.
- If the information comes through different channels both with positive and negative evaluation, it could lead to conflicts.
- Information with positive evaluation, which comes from the channel with negative evaluation (and vice versa) could be a reason for conflicts.
- Inertia of evaluations could also be a source of conflicts.

It is possible to single out two classes of conflicts:

- External, when the internal wishes (evaluations) are in conflict with the external situation – social-socio-technical and interpersonal contradictions;
- Internal, when the conflict occurs between the wishes and evaluations of one person (intrapersonal conflicts).

There are three variants of reaction to such conflicts:

- \- Change of external situation, which causes contradictory groups of evaluation (thinking over a problem – solution – action);
- \- change of internal system of evaluation (emotions – change of internal evaluations – resolution of the conflict);
- \- creating a barrier in the chain of contradictory evaluations (escaping from the conflict instead of resolving it – drinking, drugs, psychic disorders).

- Internal conflicts could create external ones and vice versa.
- Groups of people create socio-cultural fields of interaction based on interaction of their systems of values and evaluations.

In the evolution of system of values and evaluations it is necessary to set the following goals:

- try to attain high level of moveability, changeability and controllability of available evaluations;

- trying to think over and to analyze the components of integral evaluations;

- trying not to avoid the occurring conflicts within the system evaluation, but to remain calm in evaluating them as objects of analysis, identifying contradictions and resolving them due to changing priorities in local channels of perception, precision and revaluation of information coming through these channels and general integral evaluation.

Formation and evolution of general socio-cultural fields of interaction takes place through comparison of evaluations, occurrence and elimination of contradictions contained in these evaluations at different levels: from local to integral level and from individual to group level.

TRIZ and evolutionary systemology operates with general laws and regularities of system evolution, as well as tools for analysis and resolving of the contradictions. All these tools can be used for forecasting the development of systems of values and evaluations (dynamization of systems, transitions to supersystems, trimming, increase of controllability, formation of programs for development of systems of values, etc.), as well as for solving contradictions inside these systems (in time, space, transition from one system to another, in interpersonal relations, etc.)

4.3. The concept of TRIZ-civilization as supersystem of TECP

Above we came to the following preliminary conclusion: in the society, where the negative types of capture will dominate, conflicts with creative personalities will inevitably occur due to difference in their systems of values. The object of research of TECP is a creative personality and its interaction with the environment.

6 basic features of a creative personality are singled out in TECP:

1. Presence of Dignified goal and a strong intention to attain it;
2. Presence of a set of realistic working plans for attainment of a Dignified goal;
3. High workability;
4. Good problem-solving skills;
5. «Ability to bite the bullet»;
6. Good results.

This set of qualities to a certain extent corresponds to a certain system of values, characterizing a creative personality. In TRIZ-civilization the system of values of a creative personality should also dominate in the society as a whole. First of all, it concerns the presence of a Dignified goal, which in many respects defines the social character of the personality and his or her system of values. In TECP one can single out a complex of criteria of a dignified goal: novelty, social usefulness, specificity, significance, heretical character, independence, ambitiousness. Criteria of a dignified goal, proposed by G.S. Altshuller, in the fullest sense reflect what every mature creative personality desire – a tendency to improve the quality of their life and the lives of the people, who live on the planet Earth. Let us single out such criteria, which first of all form system-based connections between a personality and the society as a whole.

Dignified goal of creative personality should necessarily be socially useful, positive and directed at the development of life. Or: positive results of the attainment of the goal should be global, while negative – if they are still inescapable – local. All structure of the society and its system of of values should correspond to this criterion. Complexes of cognitive distortions in our time make most popular such ideas and values, which are directed against personality, against the evolution of life on Earth.

Selected Dignified goal of Creative personality could be called an equivalent of proper human life and its values. Therefore, the scale and significance of tentative results characterizes the "price", which is the evaluation of the human of himself: it has to be noted that the time of the human life is wasted on it. Hence the importance of this quality – scale of the goal – for the human: the duration of our life is restricted, it means that the number of goals, which we shall be able to attain, is also restricted. We have to choose and we need a reliable criterion for that, so that the life should not be squandered on attaining some smaller goals. Let it be necessary smaller goals, but still, they are small. For the society these are the goals and values, which are planned for hundreds of years.

A new dignified goal is, as a rule, to such an extent ahead of its time that it is often perceived by other people as heretic. At a glance this criterion seems strange and not enough substantiated. However, the degree of «heresy», (if we may use this word) determines the distance from the universally accepted level of opinions, culture of knowledge to attained goal, to the level of obtained results. If the goal or obtained results are not perceived as today's «heresy», this is an indicator that something is wrong with the selection of a Dignified goal, that a small or insufficiently new goal has been selected and that the attained results will not be revolutionary. «Heresy quality», however, though constituting a feature of dignified goal, characterizes not the goal itself, but a typical attitude of the contemporaries to the revolutionary idea. Time will pass and the perception will change. But until the goal becomes popular and the results are universally accepted, both the goal and the results shall be considered to be a heresy. In TRIZ-civilization the problem might take the form of masking obvious lie or an anti-human goal as a purported heretical goal. One needs special mechanisms enabling to distinguish and to protect one from another.

A dignified goal is a personal goal of the human or of a small team, a group of fellow-fighters. Large teams appear later, when the main directions of search are already identified, when the very promotion is no longer connected with the former mortal risk. TRIZ-civilization should presuppose the existence of professional creative teams, for which formation, design and development of Dignified goals from different fields of knowledge is a work obligation, while the time of attaining this goal is not restricted by the frames of life of one man.

While choosing a dignified creative goal it is necessary to strive that the goal should be unattainable, that it should surpass the potentiality of one human or of a team, which sets this goal. It does not mean that the goal remains unattainable: the humans can everything. The attainment of such "unattainable" goals is a contribution to the collection of orienting points: it is difficult to say, what is more valuable – the results, which are received directly or the very fact that the person or the team were not afraid and did not make a single step back. TRIZ-civilization should presuppose the formation of such socio-economic mechanisms, which support such reality.

Professional formation, design and development of dignified goals could be backed up by a concept of maximum upward movement, which was developed as part of TECP. The essence of the concept consists in the fact that Dignified goals are set and developed until they are transformed into conceptual and verified concepts first at the level of a narrow field (technical, scientific, artistic),and then a transition to the branch level without any implementation expenditures takes place, and after that (also without any implementation expenditures) a transition to a still higher level takes place –socio-technical or socio-scientific or social-artistic level takes place starting from this, higher social level. Complexes of new problems, which are socially and economically important are formed thereby as well as their solutions, which were invisible at lower levels of development. An example of such an approach is the developments of Konstantin E. Tsiolkowsky, who, as it is known, did not manufacture rockets themselves, but on the whole developed the field of space travelling in a system-based way.

The concept of maximum upward movement in the Strategy of Creative Personality is an opportunity to attain the pan-social level of civilization development as quickly as possible. Civilization and state should support strategies and developments, which are directed at solving the key problems of civilization development.

There is a tool, which is developed as part of TECP, which describes the regularities of interaction of Creative personality and society – life strategy of creative personality (LSCP). LSCP, presented in the form of a chess game between a creative personality and external circumstances, describes complexes of contradictions between a Creative Personality and external circumstances (state, society, teams, other persons). All this life game is subdivided into 4 parts: opening phase, midgame, end game and post-end-game (continuation of the Activity after the death of a creative personality). Each of these parts of LSCP is characterized by its level of goals and it's set of contradictions between a creative personality and external circumstances. One of the paradoxes of LSCP consists in the fact that the activity of a creative personality, which is directed at the development of humanity and society, meets with a powerful resistance directly from this very society.

Ideal TRIZ-civilization should make the steps, which are useful for a CP stronger and should weaken (till complete extermination) such steps, which are harmful for. Thus, it is possible to formulate the requirements to TRIZ-civilization, in which creative activity and system values of a creative personality are an important dominating trend in the development of society.

5. TASKS AND STRUCTURE OF TRIZ-CUVILIZATION

The main goal for forming TRIZ-civilization is the creation of conditions for socially stable existence and evolution of human society due to TRIZ tools of strong thinking and formation of the system of values of a creative personality, which are worded in TECP.

It is possible to formulate three basic complexes of problems in forming TRIZ-civilization:

- creation of system for increase of efficiency of solving complexes of global socio-technical and socio-cultural problems aimed at increase of stability and attainment of homeostasis of civil-sphere due to wide dissemination in the society of strong, system-based and efficient thinking devoid of cognitive distortions of mentality and based on TRIZ;
- creation and support of a system of values (characterizing the system of values of the civil-sphere society) as internally non-contradictory and directed at fruitful (creative, mutually profitable for participants) interrelations based on values of creative personality, formulated in TECP;
- development of TRIZ and TECP as theories, practical methodologies and system of educating personalities for the sake of efficient solving of problems, which are quoted above.

These three interconnected complexes of problems contain a large number of dignified goals for a creative personality, for example [54]:

● It is necessary to plan such a TRIZ civilization, which will be sustainable in socio-technical sense and which will stay in relative balance with environment;

● It is necessary to plan such power industry, which minimally depends upon natural conditions and minimally influences it;

● It is necessary to solve a complex of problems on design of sustainable TRIZ-civilization with a high degree of excessiveness, excluding or minimizing possible cataclysms;

● TRIZ-civilization should necessarily be characterized by beauty, aesthetics and inexhaustibility of cognition, which should not be surpassed by the beauty and inexhaustibility of natural world;

● It is necessary to provide for TRIZ-based high level of thinking in TRIZ-civilization, enabling to solve a large number of complicated super-problems without significant errors, to which the method of trials and errors often leads;

● In TRIZ-civilization it is necessary to form a system of values, which would eliminate aggression and consumerism as the main life value. Creative philosophy of life should become a main value in the system of upbringing;

● TRIZ, as a tool for correcting cognitive distortions should itself resist the tendency to convert TRIZ into a method for generation of cognitive distortions.

It is necessary for humanity thereby to reject the ideas, which constrain the development of civil-sphere:

- ideas of depopulation and decrease of the Earth population number should be considered as crimes against mankind;
- there should be no global constraint of the most important needs of the people, which provide for sufficient comfort and reliability, but not a minimum, necessary for survival;
- inefficient are ideas for creating constraints in the development of economy, production sector and power industry, which exactly serve as tools for adaptation to complicated or even catastrophic changes of the environment;
- wealth of some people should not be provided for on the account of disasters and poverty of other people, which are proclaimed to be «less successful».

The experience of development of science as a social institution could be an example of an analog in forming the concept of TRIZ-civilization. This process lasted for several centuries: from the ideas of Francis Bacon (end of the 16th century) till the formation of classical science in the 18–19th centuries (it was about this time when the term «science» was introduced, in contrast to the term «philosophia»). It is possible to propose that the temporal scale of inclusion of TRIZ into state scientific structures, into industry and system of education with regard to acceleration of society evolution processes could occupy 100–150 years. The population number of the Earth by that time (2100–2150) could attain 18 billion people, the number of scientists in the world by this time could be 27–30 million people. In this case it could be that production sector, research institutes and the sphere of services will need 1.5–2 million TRIZ specialists (in the whole world) for performance of TRIZ projects, directed at the enhancement of effectiveness of the companies' activities and their quick adaptation to the changing external conditions. Such evaluation could be made based on modern experience for creating TRIZ structure at big industrial companies.

The level of dissemination of TRIZ in the society should be similar to spreading scientific knowledge in modern society. In order to train TRIZ specialists and simply in order to disseminate TRIZ knowledge one needs trainers and pedagogues. With primary school it could be approximately 0.5 million pedagogues, approximately the same number of teachers are needed for secondary and high school. The number of scientists dealing with the development of TRIZ as a science might be needed in the number of 5 thousand. And they should be high-quality TRIZ specialists.

On the analogy with the historical experience of development of scientific and educational infrastructure and of the experience for implementing TRIZ at the industrial enterprises it is possible to form the concept of TRIZ-civilization structure: what roles should be played, what competences are needed for that and how to prepare employees for the process of formation (based on their competences) of necessary knowledge, skills and values.

Fig. 5 shows a possible infrastructure of TRIZ in TRIZ-civilization in the middle of 22nd century (after a lapse of 100–150 years). By this time the population number of the planet Earth could constitute 15–18 billion persons.

TRIZ infrastructure might include:
- educational unit (primary, secondary, higher and special education);
- TRIZ specialists at the enterprises, in organizations and in consulting structures;
- TRIZ researchers in scientific institutions.

Main tasks of TRIZ-civilization were already listed above:
- solving socio-technical and socio-cultural problems of civilization;
- creation and support of system of values of society.

These tasks are fulfilled exclusively by TRIZ infrastructure and only by it. Many social structures take part in solving them, while TRIZ plays the role of a catalyst of the process for forming necessary tools for this creative work.

The presence of the described structure of TRIZ is in itself insufficient for solving all key problems of TRIZ-civilization. About 1 billion people should possess the knowledge of inventive thinking and share the values of fruitful, creative, loving type of mutual relations. It is clear that it should be the citizens of different countries, which represent the majority of states of the world. The background for that already exists in our time. Now TRIZ is popular approximately in 60 countries of the world, which totally account for more than 70% of the entire population of the Earth and about 70% of the area of all countries of the world.

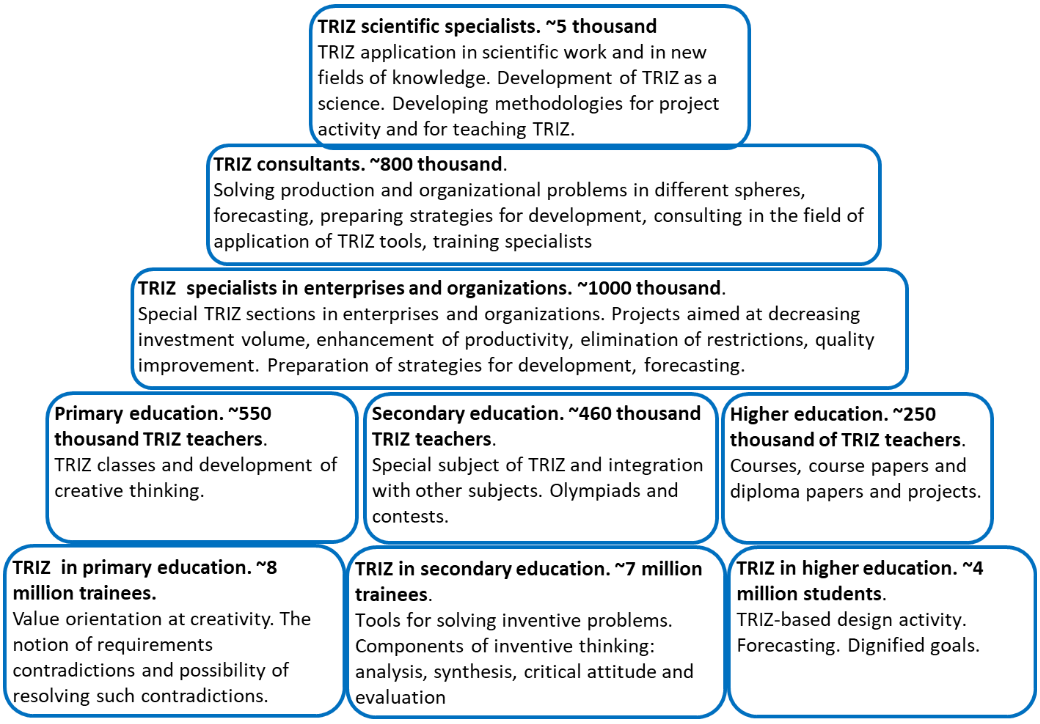

Fig. 5. Pssible infrastructure of TRIZ in TRIZ-civilization in the middle of 21st century and in the middle of 22nd century, based on which it is possible to develop strategy of evolution of different parts of TRIZ

It is possible to draw an analogy with science. Now there are totally 9 million scientists out of 8 billion people living on Earth. However, the basic of science are known to billions of people. Engineers, doctors, artists, poets and even politicians cannot be surprised by key ideas connected with scientific knowledge. The same situation is going to occur in the 22nd century with the main knowledge and values of TRIZ. The main TRIZ tools and components of inventive thinking should be accessible to the majority of population of the world countries.

Without claiming to offer a global forecast of the evolution of civilization and formation of civil-sphere we shall try to offer a list of certain possible tasks the humans of the 22nd century is going to set.

Since the primary source of global problems in the evolution of civilization are first of all the problems of socio-cultural character, key inventions should relate to the sphere of politics and social systems on the whole, to the field of science methodology, to education, art, religion, law, in information technologies and communications. Let us quote only one example of such a complex of inventive problems of 22nd century: global information system of automatic indexation of information units, as well as subjects of socio-cultural interrelations from the standpoint of correctness of information and correspondence to the values of fruitful, loving relations. Let us offer a short explanation of this idea.

Global information systems are currently able to trace the chains of information units: from their appearance to the stage of numerous changes, specifications and copying. These opportunities will be only broadened. If the source of information and the subjects of its copying have a low level of trust, the rating of information authenticity will be automatically lowered. If there are contradictory data on the information unit itself, the authenticity rating becomes lower. The violation of system bonds, resistance to laws of nature, signs of typical cognitive distortions – these and many other signs could offer the basis for calculating the authenticity rating. Of course, one cannot expect an opportunity to create an ideal, absolutely precise system for forming the information authenticity rating. Moreover, in terms of laws of society evolution these systems of compiling rating tables could have a tendency to perform a capture in the interests of the narrow groups of people. Most probably several different global ratings of authenticity will be created. The people will be able to select such tables, which seem to be more trustworthy or even use them for creating their own indices of authenticity based on the existing ones depending on their own ideas and with regard to their own system-based and critical mentality. It is possible to create landscapes of authenticity correctness as applied to this or that information, for example, on the map of the world. Libraries and scientific institutions could become centers of dissemination of authentic information. Systems of authenticity rating should have a law support, the information should not be copied without its rating, the very rating tables should correspond to generally accepted structural principles. It is important that ratings should be calculated instantaneously, so that any possibility of inclusion of distortions into information fields of socio-cultural systems should be avoided.

Another axis of evaluation of information and subjects is their correspondence to this or that type of relations (type of system capture, human character). They single out different types of personality: exploiting, possessive, money-grabbing, taking, saving, authoritative, devoted, indifferent, market-oriented, active, loving, reasonable, creative. Each of these types can be distinguished by words, gestures, voice intonation, deeds and actions. Based on certain specific features it is possible to draw a conclusion as to what type of interrelations (type of personality) relates this or that text, publication, web-site, journal, information channel, person, information agency, institution, city and country. Of course, each of these objects should correspond to a certain type of interrelations, but some of them will dominate over the others. As a rule, such subjects come through something like a specialization in terms of types of relations. Global information system, collecting information on a multitude of subjects, including separate publications, could give a characteristic to the dominating type of their direction: negative or positive type of capture. From simple measurement and information, it will be necessary to pass over to management and restriction of negative type of information materials, formation of the system of values, corresponding to fruitful, creative and loving relations. The process should be supported by all socio-cultural systems (art, education, religion, law), creating systems of value management. Having a common vector and principles, these systems can and even must be different one from another, interact one with another, excluding fundamental contradictions between different systems of values. Thus, portraits and landscapes of systems of values can be formed for different subjects of different scale: from an individual person or publication to a state or a union of states.

It is obvious that creation of such a global system for evaluation of authenticity and value coloring of information units and different subjects is important. It is also important to know that a huge number of non-trivial inventive problems will be encountered on the way to forming this global system. The vital character of these ratings will only grow with the development and dissemination of technologies of artificial intellect, which have a huge potential for unnoticed manipulation of huge social groups.

There are many socio-cultural and socio-economic problems and contradictions on the way to sustainable civil-sphere. For example, «clip-like», fragmentary, simplified thinking should be combined with long-time strategies of society evolution. Rather a short period of action of power structures (president, government, local power, etc.) should be combined with long-time (hundreds of years) strategies for development of states and civilizations. In future not the system of values will follow economy, but the economy should correspond to the system of values of the society. Money should not be the definitive factor of development of civil-sphere. System of upbringing of children should be based on the family, ethnic community and state and thereby avoid coming into conflict with the culture of other ethnic communities and civilizations. A system of upbringing and training in civil-sphere on the whole, not only in separate states.

No doubt, beside socio-cultural problems, it is also necessary to solve complexes of socio-technical problems, which support stability of existence and development of civilizations. For example, civilizations should be less and less dependent upon particular earth conditions. [55] This will not only contribute to resistance to possible changes in the conditions of the life on Earth, but also will create e a potential for life in the near space, in the seas and oceans. Development of power industry should also develop in the direction of independence from natural conditions of the Earth, application of energy sources with the highest possible density of energy and providing for the highest level of safety. The 3-fold growth of power industry implies the setting of a huge number of non-trivial problems connected both with energy sources, with the method for energy transportation and energy storage. One can speak, for example, about the use of helium-3 on the Moon as an energy source [56, 57], about the placement of automated production lines in space and in the oceans. There are many problems. How will the life of 30 billion people on Earth be arranged in 2300? What will the world look like, when the amount of civilized substance in it will be 3 times greater than now? Will this material and energy suffice for the life of 30 billion people? Due to what technologies would it be possible to attain the homeostasis of substance and energy of civil-sphere?

It is necessary to provide for reduction of transport services due to information technologies, automation of production lines and optimization of manufacturing, electricity-generating and social infrastructures. The volume of inside-the-city transportation should be reduced due to organization of remote work, pneumatic post instead of couriers, merging of individual and social city transport.

To state and to solve a huge number of socio-cultural and socio-technical problems one cannot be based on the trials-and-errors method, waiting, that we shall be lucky and necessary solutions will be found before the irrevocable catastrophes take place. TRIZ tools are destined to make the process of problem statement and problem solving effective and controllable (we are talking about the problems of planetary scale). This is a huge challenge also for the very system of evolution, dissemination and application of TRIZ. Strategy of TRIZ evolution as of a part of science and society as a whole should be worded and realized with regard to key problems of forming the civil-sphere. The ideas of forming strong thinking and system of creative values are able to magically transform the view of our planet. Disorder should not concern either WC, or our heads, or our hearts.

SUMMARY AND CONCLUDING REMARKS

The following conclusions can be drawn based on the above analysis:

1. Civil-sphere as a system merger of civilizations is at the stage of dramatic changes and is transformed into a new geosphere of the Earth together with abiogenic spheres and biosphere. Civil-sphere is a geosphere of the new type and shall not be treated as a stage in the evolution of biosphere.

2. The beginning of formation of civil-sphere should be related to the origination of the first civilizations 6 thousand years ago. This time is immeasurably short as compared with the periods of formation of other geospheres, which account for more than one billion years.

3. Rates of growth of weight and energy of civil-sphere are so high, that it makes its development dangerous from the standpoint of its resistance to catastrophic changes.

4. System-based phylogenesis as a method for system evolution appears as a result of emergence of information objects in biosphere, while in civil-sphere it attains a fundamentally new level of evolution, which provides for unbelievably high growth rates of information.

5. The main factor of powerful growth of civil-sphere are culture and information processes associated with it. The reasons of global processes in civil-sphere are hidden in the imagination and mentality of the human, systems of values, religion, art, science, technologies, economy, politics and other socio-cultural and socio-technical constituents of the society. Ecological problems and catastrophes occurring on Earth should be corrected and prevented due to global adaptation potentiality of technologies, developed by civilizations.

6. Culture, being the main source of development of civil-sphere, at the same time takes the form of the main source of conflicts and problems of this evolution because of the growth of cognitive distortions, aggression, disadvantages of scientific method, imperfect system of values, targeted at the negative forms of capture (absorption, displacement and decomposition).

7. Civil-sphere should be formed as a self-organized system similar to other geospheres, in particular, biosphere. Civil-sphere as a function-and-targeted system would be submitted to the possibility of monopoly management by a restricted group of persons and irrevocable catastrophic consequences of such management.

8. One of the methods for compensation and elimination of problems characterizing the development of civil-sphere are transition to domination of fruitful (creative) type of capture, in par-

ticular, based on methods on which TRIZ and evolutionary systemology is based and in formation thereby of TRIZ-civilization.

9. System of values of TRIZ-civilization should be formed in keeping with the values of a creative personality, in particular, in TECP and directed to domination of fruitful creative capture. Domination of fruitful capture in civil-sphere, in particular, should lead to formation of fruitful economy: economic profits should not be private and local, but global and just in time and in space and embrace a broad number of subjects of economic activity.

10. In the middle of 22nd century the infrastructure of TRIZ in civil-sphere can include more than 20 million person and excise influence upon 2 billion people working in different fields: education, industry, business, in management of organizations, in scientific sphere.

11. Mission of TRIZ should be directed at solving key problems of civil-sphere in the field of politics and social systems on the whole, in the field of methodology of science, in education, art, religion, law, in information technologies and communication systems, in global socio-technical processes. Problem statement and solving these problems should be directed not only at getting profits, but also at solving global problems of sustainable development of the society and civil-sphere on the whole for dozens of years henceforth.

12. Strategy of development of different spheres of TRIZ should be developed based on formulated problems and the image of infrastructure of TRIZ in TRIZ-civilization. TRIZ should become an active tool for forming strong thinking, compensation of cognitive distortions and domination of creative interrelations within the society.

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Innovation Education in Practice at Tsinghua University

ABSTRACT

China has become the world's second largest economy after decades of development and is undergoing a fundamental transformation from a resource-driven country to an innovation-driven country. Tsinghua University (THU) is one of China's top comprehensive research universities, with a mission to train world-class scientists and outstanding engineers. Since 2017, the founding team of IMA-Innocloud has been invited to offer the first systematic innovation course at Tsinghua, and has so far offered several innovation-related courses for postgraduate and doctoral students from various faculties, which are open to postgraduate students across the university and have been widely praised by students and faculty members.

This article describes the differentiated educational needs of individual faculties as well as big challenges we have to face in digitalization era, esp. during the hard time of pandemic. The architecture of innovation education courses is introduced, including the Innovation Technology course and the Innovation Psychology course; it describes the basic framework and content of the courses and the modular combinations adapted to different teaching purposes. SolvingMill and TRIZTrainer SaaS software and the fusion of on-line and off-line teaching method are introduced. The article concludes by showing examples of students' innovation training and looking at the way forward for innovation education in China.

Key Words: *innovation education, TRIZ-based systematic innovation, innovation technology, innovation psychology, innovation digitalization.*

NATIONAL INNOVATION POLICY OF CHINA AND STATUS OF INNOVATION EDUCATION

On Sep 20, 2021, WIPO released the Global Innovation Index 2021[1]. China broke into the top 20, ranking the 12th among 126 economies around the world, and China is the only middle-income economy among the top 20 on the ranking list. Furthermore, improvements over the previous year can be seen in terms of innovation environment, innovation input & output and innovation efficiency. China even stands on the top 1 position in the world in areas such as R&D expenditures and the number of researchers, patents, and publications. However, these innovations are mostly improvement-based or incremental innovations, relatively few invention-based innovations. In order to further enhance global competence China launched many national policies these years aiming to transform its economic growth mode from resource and energy driven to innovation driven mode.

GII 2021 rankings overall and by pillar

Country/Economy	Overall GII	Institutions	Human capital and research	Infrastructure	Market sophistication	Business sophistication	Knowledge and technology outputs	Creative outputs
Switzerland	1	13	6	2	6	4	1	2
Sweden	2	9	2	3	11	1	2	5
United States of America	3	12	11	23	2	2	3	12
United Kingdom	4	15	10	10	4	21	10	4
Republic of Korea	5	28	1	12	18	7	8	8
Netherlands	6	6	14	16	31	5	7	7
Finland	7	2	4	11	19	6	5	16
Singapore	8	1	9	15	5	3	13	17
Denmark	9	8	5	5	7	11	14	13
Germany	10	17	3	21	20	12	9	11
France	11	19	15	17	17	19	16	6
China	12	61	21	24	16	13	4	14
Japan	13	7	20	9	15	10	11	18
Hong Kong, China	14	11	25	6	3	24	62	1
Israel	15	34	19	40	8	8	6	30
Canada	16	5	18	30	1	20	23	19
Iceland	17	14	23	25	25	18	25	10
Austria	18	16	7	7	40	15	19	27
Ireland	19	18	27	4	48	17	15	29
Norway	20	3	13	1	21	23	28	25

Feature 1: Global Innovation Index 2021

Tsinghua University (THU), founded in 1911, is the top 1 university in China, esp. in engineering and technology areas. THU is the most demanding university in China, attracting the most brilliant students around the country each year, offering the most excellent teachers and first-class courses. THU also offers best innovation and entrepreneurship education and becomes the best demonstration effect.

Tsinghua has dozens of courses related to innovation. They can be divided into three categories: business and innovation management, professional development methods and design thinking. After a brief study we can find some deficiencies of the existing course: too many theories with little applications; too many tools with few processes, too much popular science with little specialized expertise, and too many teachers with few experts. Hence we proposed a new innovation course framework with some recommendations. At least three combinations were presented: innovation tools + entrepreneurial skills, technical method + business planning, and technological competitiveness + market development.

SYSTEM FRAMEWORK AND CONTENTS OF INNOVATION EDUCATION COURSES

Since 2017, the founding team of IMA-innocloud company has been invited to develop innovation education courses based on above ideas. The target was postgraduate students of several selected departments at beginning, and then opened to all master students from all faculties of THU. Hereafter are several examples:

- An Introduction to Basic Innovation Concepts and World-wide Innovation Theories and Methods, general studies literacy program for all postgraduate students of whole faculties.
- Creative Psychology and Creative Thinking, general studies literacy program for all postgraduate students of whole faculties.
- Innovation and Entrepreneurship in Energy Internet, Electrical Engineering Department, also open to the whole faculties.
- System Innovation Technology and Entrepreneurial Practice, Electronics Department, also open to the whole faculties.
- Theory and Practice of Inter-disciplinary Engineering Technology Innovation, innovative leading engineering doctoral program, open to all engineering doctorial students of whole faculties.

These courses are designed to acquaint students with innovative thinking and innovation technology before they select interdisciplinary R&D works. Meanwhile, by taking the courses, students will have a deeper understanding and preliminary experience of entrepreneurship before they actually start their own businesses. All these courses can be supported by three fundamental sections: innovation technology, innovative thinking and business thinking.

1. Teaching style of innovation technology section

This includes some aspects: theory explanation, case study, problem discussion, group work, and demo presentation. In cooperation with our strategic partner, famous Triz master Nikolay Shpakovsky, we introduce AIPS process of OTSM theory and revolution tree methodology in classes with different depth according to the purpose of education and level of students.

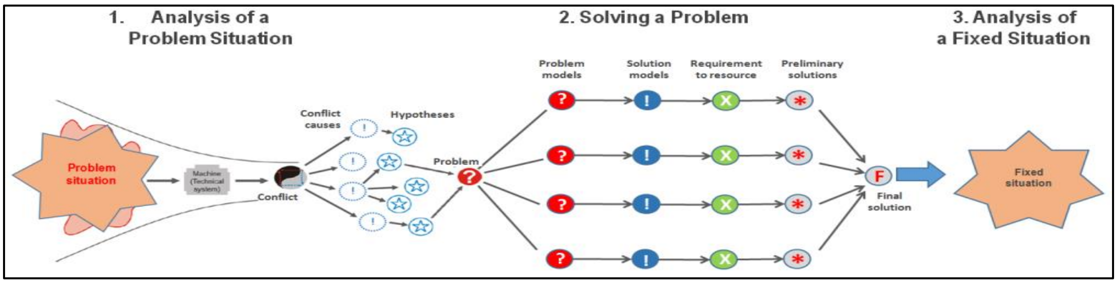

Figure 2: AIPS Process of OTSM Theory [2]

To better understand the overall framework of business and the relationship between technology innovation and commercial value creation, a small part of technical transfer and entrepreneurship is arranged at the end of the course. Two core concepts are enlightened: core competence and business plan. Figure3 shows a basic framework for business excellence.

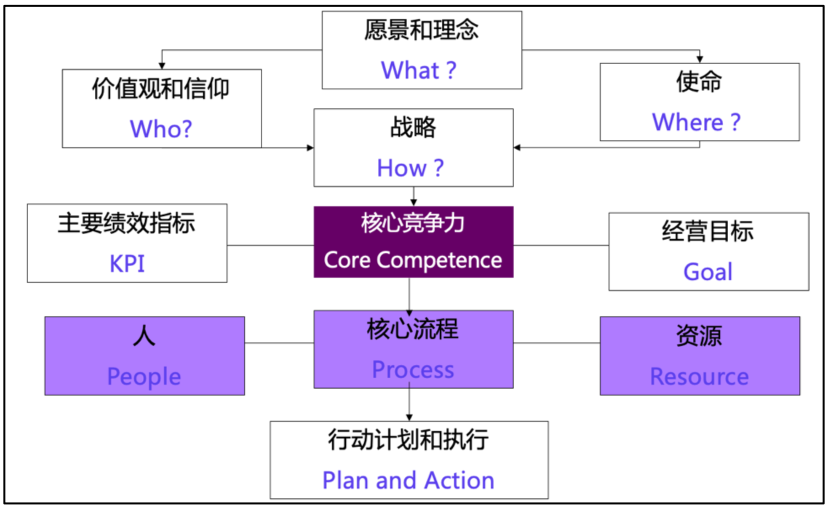

Figure 3: Building a Framework for Business Excellence [3]

The overall structure of the innovation technology course contains the following four modules with several sessions in each:

- Systems analysis and its development forecast

Session 1: Technical systems and functional analysis
Session 2: Functional models and tailoring of technical system
Session 3: Finding solution
Session 4: Evolutionary routes and applications of technical systems

- From problem situations to hypothesis formulation

Session 5: Problem situation analysis
Session 6: Causes of conflict and hypotheses
Session 7: Methods of hypothesis formulation

- Identifying and solving conflicting problems

Session 8: Ideal solutions and the AIPS algorithm

Session 9: From hypothesis to problem model

Session 10: Technical contradictions and the invention principle

Session 11: Physical contradictions and the separation principle

- Entrepreneurial practice and core competencies

Session 12: Entrepreneurial practice_5W1H

Session 13: Business models and core competencies

2. Creative psychology and innovative thinking section

This section contains three basic modules: theoretical knowledge of creativity, developing the ability to think creatively and theories of personal creative development. We developed the so-called psychodynamic model of innovation (Figure 4) to illustrate the multi-level relationships between innovative activities, innovation methodologies and all kinds of emotion status and mind conditions. Through this course, students will learn that in different stage of entire innovation activity, different mind condition as well as emotion status are needed. A leader of innovation team shall have the ability to identify and adjust the overall status of the team to ensure higher innovation efficiency.

Figure 4: Psychodynamic model of innovation [4]

This course also has four modules with several sessions listed as below:

- Introduction: The innovation capability and creativity model

Session 1: Innovation and the ability to innovate

Session 2: Becoming a pioneering talent

- Thinking and methods in the innovation process

Session 3: The science and technology innovation Process

Session 4: Thinking and methods for defining problem

Session 5: Thinking and methods for generating idea

Session 6: Dialectical thinking and imagination

Session 7: Exploring innovative thinking pattern

- Mental processes in the innovation process

Session 8: Emotion and will in the creative process
Session 9: Motivation and values
Session 10: Personality traits of creative people

- The path to becoming a creative person

Session 11/12: The path to becoming a creative person

3. Innovation Life-cycle Management (ILM)

A very impressive innovation training camp are periodically implemented at X-lab platform of THU. X-lab is the leading platform in China university ecosystem for spurring student innovation and entrepreneurships. Till now, thousands of student teams have ever been involved, they come from quite different departments and faculties, starting their journey here from ideation to innovation and to commercialization. Many startups have been spin-off from the platform. We developed a model called innovation life-cycle management trying to cover the full process from customer needs to product concept, then technical innovation, technical prototyping, commercialization, and technical transfer. Such a life-cycle model features the setting of standalone stage of innovation between ideation and R&D stages, and the close loop process of value creation which starts from market and comes back to market. Technical innovation will only be verified through fulfillment of market needs.

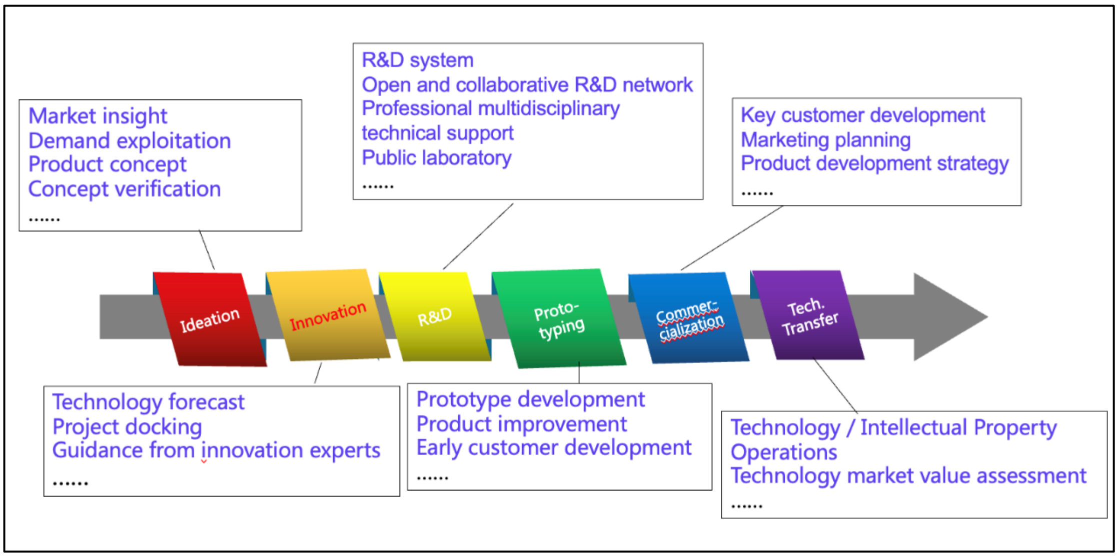

Figure 5: Innovation Life-cycle Management (ILM) Model [5]

Innovation life-cycle management training camp targets innovation teams from all fields. Students will be asked to select independent topic through field trip and demand exploration. Collective discussions are organized to determine tasks. No formal classroom teaching session, teacher or mentor only make proper guidance: explaining, guiding, and summarizing.

4. Course effects

Different from other professional courses, the innovation and entrepreneurship courses we offer teaches “transversal knowledge”, i.e., the knowledge of how to apply professional knowledge from all domains. By taking these courses, students will have a broad vision and an open mind, thus getting mentally and methodologically prepared for future innovation. Students will also master the methods and techniques of applying the knowledge they have learned, which is essential to entrepreneurship.

Figure 6 is just an example collected from a master student of electronic engineering dept. He tried to use innovation method to build a flexible electronic circuit for wearable electronic device, instead of hard PCB board.

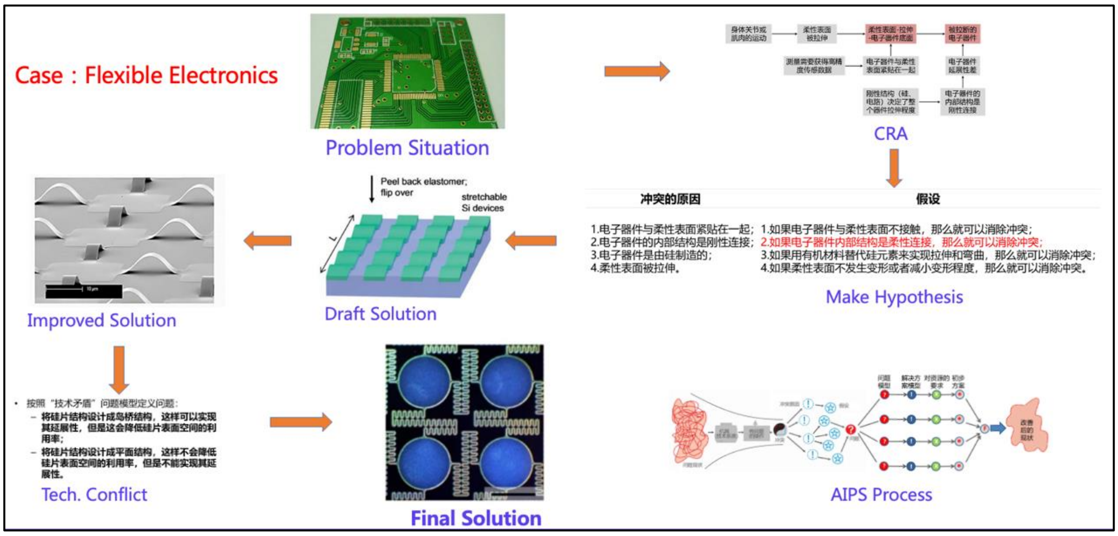

Figure 6: Case study: Flexible Circuit for Wearable Electronic Device

ONLINE DIGITAL INNOVATION EDUCATION TOOLS

Nowadays almost every aspect of the society is fully digitalized. Online tools are widely accepted in our life, including shopping, communication, collaboration and much more. Online education tool and SaaS version innovation software for training purpose or real-world problem solving were developed years ago, which are quite helpful to innovation education esp. during the serious pandemic times in the passing three years.

Figure7 shows a kind of online education tool “Raining Classroom” widely used in THU campus. It is well integrated with Powerpoint software, launched by online meeting system, and has powerful functions for online interaction, quiz and polls.

Figure 7: Online Education Tool “Raining Classroom”

Figure8 and 9 are two SaaS software: SolvingMill for real-world problem solving, and TRIZ-Trainer for innovation training purpose. These two products were initially developed by the expert team in Minsk led by Nikolay Shpakovsky, and fine-tuned by joint work with IMA-Innocloud recently.

SolvingMill perfectly implements the whole process of AIPS and supports team working. Innovator or user starts the journey with scenario description and then step forward along a structured and systematic route towards final solutions. It is a little complex and stricter than some other light weight innovation tools, but is very helpful for new innovators to taste and then solid a set of highly efficient process.

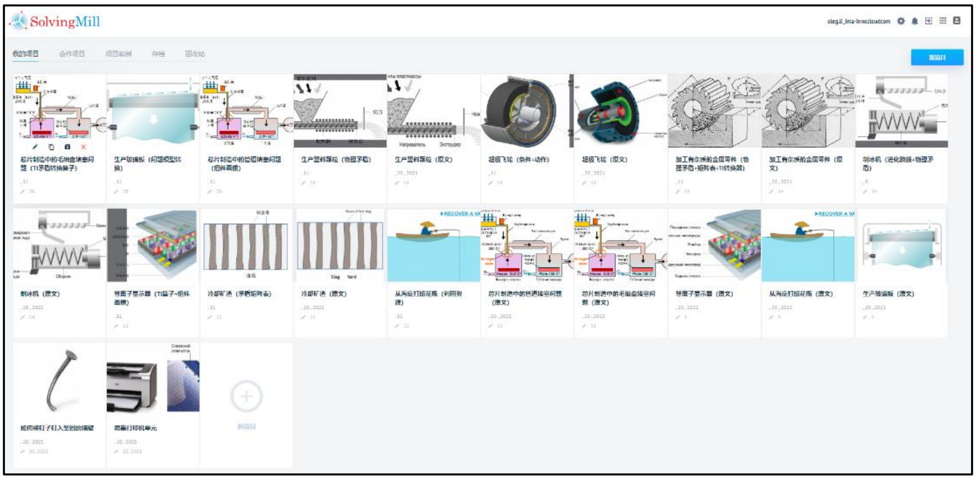

Figure 8: SolvingMill innovation software

TRIZTrainer SaaS software is dedicated to education and training purpose only. The internal process is the same as SolvingMill, with rich guidelines and helps at each step. It contains dozens of pre-designed innovation problems with different difficulty levels. A registered student will see several problems and try to solve it step by step in software. Each interaction with software will be recorded automatically, so that it is possible to draw the digital profile of innovation behavior of a specific student. Throughout the past years, we have accumulated innovation behavior data of hundreds of students. Considering these students are the most brilliant geniuses of China, we believe the data collected are of great value to understand the mindset mode of Chinese young generation when they do innovation.

Figure 9: TRIZTrainer Innovation training software

HOW TO USE TRIZ TO IMPROVE THE QUALITY OF INNOVATION TEACHING

1. Challenge

The diagram in Figure2 shows the innovative algorithm we taught at Tsinghua University. There are many algorithm steps and many tools involved. It takes a lot of class time to explain and train. But class time is limited, so how can we ensure effective teaching?

2. Existing measures and the conflicts arising

Currently, it is standard practice to enhance students' understanding of innovative concepts and tools through homework. For example, we use TRIZTrainer to effectively train students' innovative skills. This approach solves some of the problems, but there are still some shortcomings. Two technical conflicts are arising:

Technical conflict 1:

Students use after-class time to do practice problems, and the teacher makes a short summary in class, which can save class time, but cannot give targeted guidance to each student.

Technical conflict 2:

In order to ensure that students truly master innovative methods, it is necessary to evaluate the results of each student's practice individually and point out their problems, but this will seriously affect the progress of classroom teaching.

In conclusion, we get a pair of technical conflict: quality of teaching vs. classroom time.

3. Final ideal result with physical contradictions

Final ideal result 1:

Ensuring quality teaching and learning within limited classroom time and using available system resources.

Physical conflicts：

The need to take class time to tutor students in order to enhance the quality of teaching and learning, but to compromise the progress.

Cannot take class time to tutor students in order to ensure course progression, but would reduce the quality.

Final ideal result 2:

The need to find the X-element, which ensures that the teacher provides personalized tutoring for each student without taking time away from the class and delaying progress.

4. Resource analysis

Physical resources: teachers, students, course materials, TRIZTrainer software

Field resources: Internet

Time resources: time in class, time after class

Spatial resources: classroom, space for students and teacher after class activities

5. Initial solution

Use spatial separation to resolve temporal contradictions. That is, targeted tutoring in the space where students and teachers are active after school. But how do they communicate when they are not in the same space? This could be solved by using existing communication tools. But this adds a new system that is not ideal.

6. Final solution

Based on the results of the resource analysis, teacher-student communication can be implemented using the existing TRIZTrainer software. It is decided to add instructor-student communication features to TRIZTrainer. Specifically:

1) Adding an evaluation function for each step of the answer.
2) Adding a non-realtime teacher-student communication function.

Figure 10: An example problem in TRIZTrainer with communication features

7. Implementation results

After five semesters of use since 2020, It can be said that the conflict between teaching time and teaching quality has been completely eliminated. Figure11 shows status of innovation behavior performance for students of different categories, we can see that , after instruction and classroom practice, for top class A students (15%), correct thinking patterns can be quickly established without additional tutoring; For class B students(50%) they have the ability to adapt quickly to new modes of thinking through teaching, classroom practice and some tutorials; while for class C students(35%), there are some change in thinking after teaching, classroom practice and coaching, but more training is needed afterwards.

	有用产品与冲突描述	假设与条件	问题模型转换	资源分析	解决方案模型与解决方案
自卸车	0	1	1	1	0
图书馆	1	1	1	1	1
火车启动	1	1	1	1	1
车轮螺母	1	1	1	1	1
护目镜	1	1	1	1	0
防止盗窃	1	1	0	1	0
喷砂工艺	1	1	0	1	0
安瓿瓶	1	1	1	1	1

Class A students, 15%
After instruction and classroom practice, correct thinking patterns can be quickly established without tutoring.

	有用产品与冲突描述	假设与条件	问题模型转换	资源分析	解决方案模型与解决方案
自卸车	1	0	0	0	0
图书馆	1	1	1	1	1
火车启动	0	1	0	0	1
车轮螺母	1	1	1	1	0
护目镜	1	1	1	1	1
防止盗窃	1	1	1	1	1
喷砂工艺	1	0	1	1	1
安瓿瓶	1	1	0	1	1

Class B students, 50%
The ability to adapt quickly to new modes of thinking through teaching, classroom practice and some tutorials.

	有用产品与冲突描述	假设与条件	问题模型转换	资源分析	解决方案模型与解决方案
自卸车	1	1	0	0	0
图书馆	1	1	0	1	1
火车启动	0	1	0	0	1
车轮螺母	0	0	0	0	1
护目镜	1	1	0	1	0
防止盗窃	1	1	1	0	1
喷砂工艺	0	0	0	0	1
安瓿瓶	1	1	0	1	1

Class C students, 35%
Some change in thinking after teaching, classroom practice and coaching, but more training is needed afterwards.

Figure 11: Innovation behavior performance for students [6]

CONCLUSIONS

In this paper, best practices in innovation education in Tsinghua University are introduced. The architecture of innovation education courses is introduced, including the Innovation Technology course and the Innovation Psychology course; it describes the basic framework and content of the courses and the modular combinations adapted to different teaching purposes. SolvingMill and TRIZTrainer SaaS software and the fusion of on-line and off-line teaching method are introduced. Digitalization of innovation behavior and data driven analysis are firstly mentioned, which show great potential in future research of innovation education and training. Finally, TRIZ tool is used to improve the quality of innovation education.

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I.L. Misiuchenko, D. Gurkov, T. Kamlenok

Life cycle and specific features of innovation TRIZ project

SUMMARY

The object of analysis is the life cycle of innovation TRIZ project, which is a «vortex», consisting of four consequent types of projects: exploratory, verificatory, innovative proper and the implementation project. In exploratory projects the search for ideas is performed as well as the evaluation of their potential economic efficiency, influence upon business, technical implement ability (contradictions are identified and resolved), presence of market and potential applicability for creating innovations. Conceptual trends are developed. Further on, the concepts are developed and the benchmarking of these concepts is carried out. In verificatory projects the actual check of implement ability of technical solutions is carried out within the frames, proposed at the preceding stage of leading concepts, secondary problems are identified and the solutions for solving them are developed, specification of their economic evaluations is carried out, market perspectives are evaluated and potential Customers are identified. As a result, leading verified concepts are identified, which are most applicable for creating innovations. In an innovative verified concepts are optimized until a new product and technology is created and based on them the model of new business is developed (or already existing business is substantially modified). And finally, the implementation project presupposes the implementation of developed innovations in the actual business. Milestones and stages of project types is described, typical benchmarks for milestones and stages are established. A two-level verification pattern is proposed. Also, the basic principles for controlling the portfolio of innovation TRIZ-projects.

Key words: *TRIZ, resolving of contradictions, benchmarking, secondary problems, innovation, project, milestone, stage, benchmarks, economic efficiency, project portfolio.*

WHAT IS AN «INNOVATION TRIZ PROJECT» (ITP)?

TRIZ community has accumulated large experience for performance of different projects, which contain TRIZ-related constituents, and on the whole the notion of TRIZ-project. Everybody understands that this is such a project, in which the role and significance of TRIZ tools and TRIZ approaches is rather great. It means that TRIZ project is a project, directed at creation/transformation of a system implying the use of TRIZ tools. Exactly in the same way the innovation community has already developed a crystallized notion of innovation project. Innovation project is a project, which is directed at creation and implementation of innovations. What is an innovation? There are many definitions, but we prefer to use the one, which is probably the most laconic: innovation is an invention, which has become a business. Then what is an «Innovation TRIZ-project» (ITP)? At a glance it might seem that this is simply a TRIZ-project, the result of which is an innovation. But in reality, this approach is too mechanistic, resembling the integration of two systems in one «box». It appears in reality that TRIZ and innovation activity are integrated at a much deeper level, at the level of project goals. We propose the following formulation: ITP is the creation/transformation of the system for the purpose of creation/transformation of business. If with the «ordinary» TRIZ-project the project goal is the creation or improvement of the system, the goal of ITP is first of all the creation/transformation of business, while the creation/transformation of the system using TRIZ methods is a means for solving business problems.

GOALS AND PROBLEMS OF ITP

Let us formulate more precisely the goal of ITP: creation of a more efficient business based on transformation within the system (not necessarily a technical system). Innovation TRIZ-project implies broad use of TRIZ tools both at the stage of creating the inventing basis of the project, and at the stage of creation (transformation) of business-part of the project, including its investment-related constituent.

ITP begins not with the analysis of the system proper, but with the search for and formation of an image of the future business. For example, we are planning to rather significantly transform some existing business. For example, to considerably reduce its part associated with expenditures. Then we assume that we manage it (via a method, which is as yet unknown) and analyze such changes, which will take place in its structure, its economic parameter values and other values characterizing it, what is going to take place in connection with the positioning of this product at the market, with the consumers, how the turnover will increase, etc. It is probable that the planned reduction of expenditure part will cause a whole cascade of changes in business, and not each of the changes is going to be desirable. It is probable that unexpected and non-trivial changes in the entire business structure will be required. And only after the pattern of the future modified business is created and starts to predict positive desirable transformations, it will be possible to start well-targeted modification of the system (systems). Which form the foundation of the business being modified?

LIFE CYCLE OF ITP

Four types of the projects, which consequently drift one into another, are considered within the frames of life cycle of innovation TRIZ projects:

1. Exploratory.
2. Verificatory.
3. Development of ITP.
4. Performance of the project (implementation).

In practice even an exploratory project does not appear «from nowhere», it is based either on such business problems, which are already known or preliminary, non-refined statements of such problems, which are contained in the Register of ideas, which is constantly renovated and augmented. Such ideas, which pass through preliminary selection, become a starting point for performing an exploratory project, as a result of which the Concepts appear after the application of TRIZ tools. These concepts pass through minimum business-modeling for the purpose of understanding their suitability for business. Concept benchmarking is also carried out with regard from the positions of business. At the next stage the concepts, which passed through the procedure of benchmarking, get both technical and business detailing. The concepts, which passed verification successfully, are converted into projects for innovation development. If the customer takes the decision concerning the implementation of these innovations, an implementation project appears, which ends with the creation/transformation of a real business. LC proper of ITP is presented in Fig. 1.

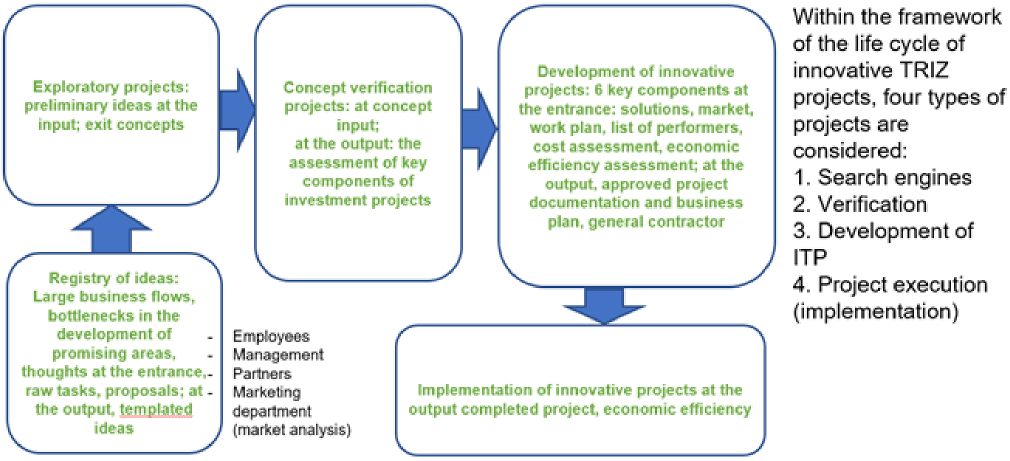


Fig. 1. Life cycle of innovation TRIZ project

STAGES OF ITP LIFE CYCLE (LC)

Stages of life of innovation TRIZ-project are reflected in Fig.2

Stage	1. Search project	2. Verification project	3. Development of an innovative projec
1	Formation of the product image	Verification of developed technologies and products	Approval of technical and product solutions
2	Estimation of market volumes	Clarification and expert confirmation of the volume and structure of the market	Confirmation of the planned sales system and business model
3	Search for technologies (methods + objects)	Solving identified and predicted contradictions	Approval of the work schedule for the implementation of the project
4	Assessment of the availability/accessibility of personnel, their qualifications	Clarification of the required personnel and their availabilit	Approval of the business plan (FEM and economic indicators are part of it)
5	Estimation of financial flows	Determination of the structure and volume of financial flows	Making a decision on financing and project implementation
6	Efficiency assessment, draft business mode	Preparation of FEM for concepts	Preparation of project documentation for project implementation
7	Preliminary concepts benchmarking	Benchmarking of verified concepts. Clarification of the list of persons for decision-making.	Transfer of documents to the Customer and the Contractor and closing of the project

4. Support for the innovative project implementation
Project Consulting
Solving secondary problems that arise during implementation
Making changes to project documentation

Fig. 2. Stages of life cycle of innovation TRIZ-projects

SPECIFIC FEATURES OF ITP

Specific features of ITP are:

1. Enhanced level of indefiniteness and, as a consequence, enhanced risks of failures, especially at the initial stage of projects. For the purpose of diminishing the risks, the innovation projects are united in the Portfolio of projects in such a way, so that the risks are balanced and planned economic effect is ensured during the specified period of time.
2. Higher level of required investments (averagely) if compared to industrial TRIZ-projects.
3. Longer terms of development and implementation (averagely).
4. Complex nature of concepts and developed solutions (successful innovations seldom relate only to one certain aspect, more often it is necessary to introduce changes at once into several constituents both of the technical system and of business).
5. Dynamic nature of innovation projects (during the process of project performance economics, logistics, attained technical level could substantially change, which would require prompt revision of project solutions).

6. There is a broader range of opportunities for creating a successful business due to a broader envelopment of a field of ideas.

PORTFOLIO OF ITP

To attain successful functioning of the company and to provide for its successful development it is necessary to have in store several trends, variants and ideas concerning innovations, i.e., so called «portfolio» of innovation projects, which is constantly renovated and augmented.

Portfolio of innovation projects should be balanced and should consist both of significant innovations with a high anticipated profitability and of less radical innovations, characterized by lower risk and expected profitability. The figure shows an example of a forecast for evolution of a project's portfolio.

Example of actually used metrics for controlling the Portfolio is given in Fig. 3.

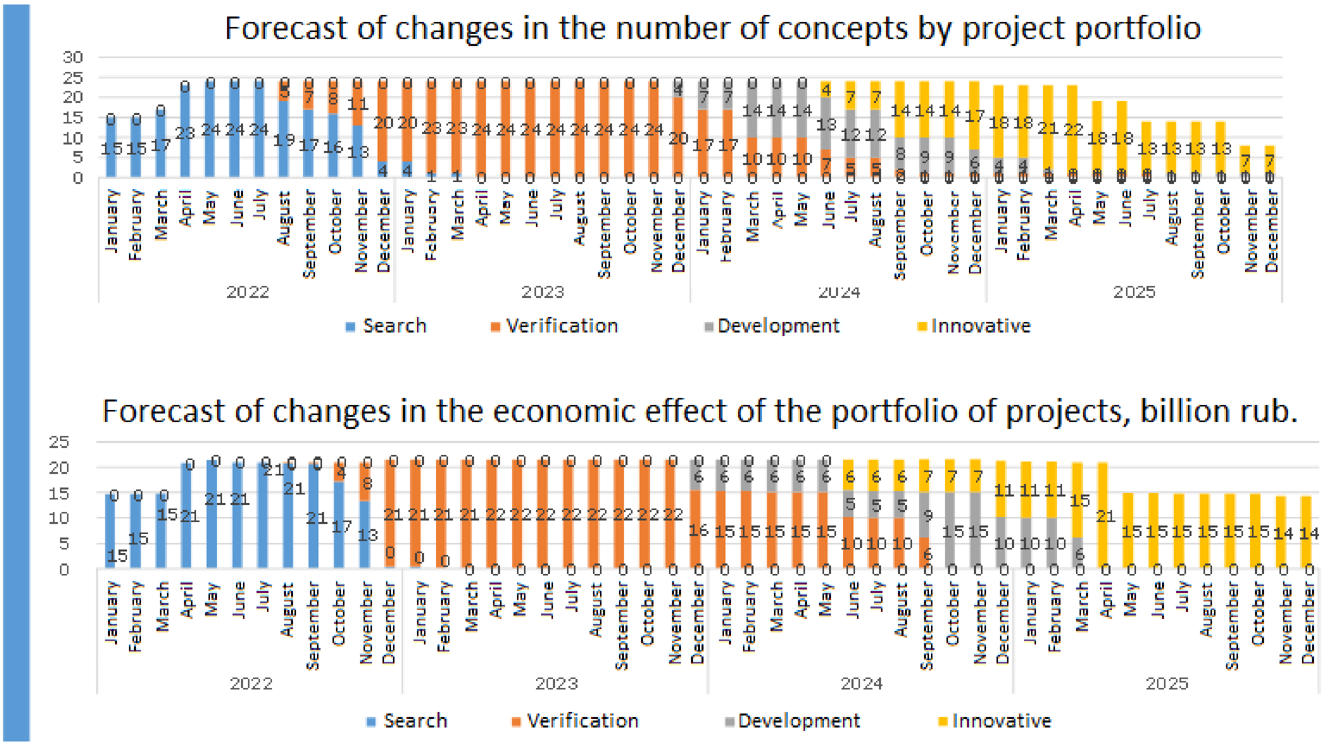


Fig. 3. Example of controlling ITP Portfolio. Forecast made with the use of metrics

The following metrics are proposed as basic metrics of innovation projects and portfolio of projects:

<u> with individual projects</u>

Present discounted value NPV

Internal profitability rate IRR

Profitability index PI

Payback period PBP (DPP)

<u>- for the entire project's portfolio</u>

Present discounted value NPV

Internal profitability rate IRR

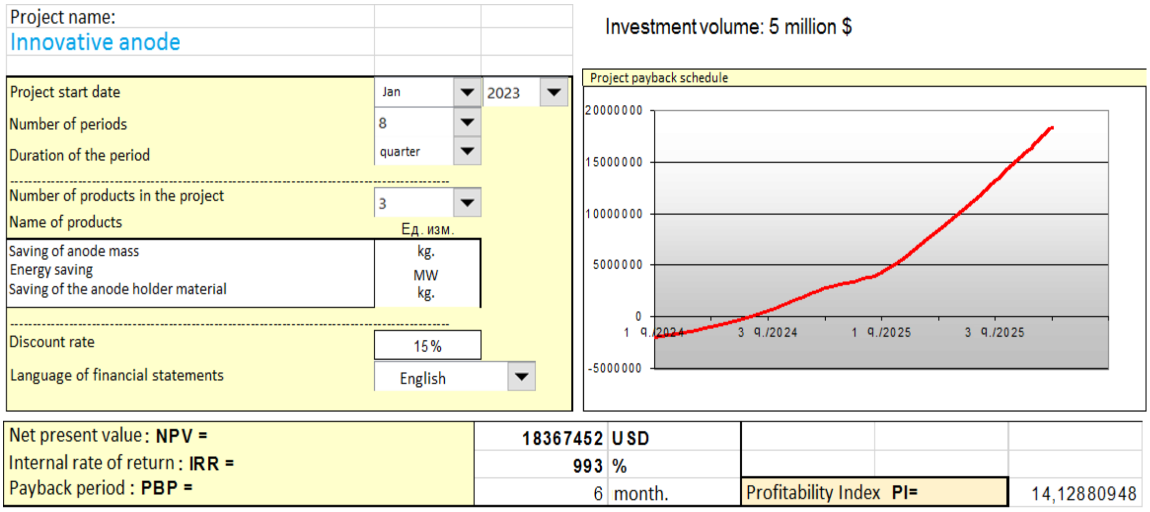
Profitability index PI

SPECIFIC TOOLS OF ITP

Early detailed business design.

Already at the stage of search the developed concepts get not only the evaluation of economic efficiency, but also the minimum business model, according to which the main investment parameter values of the would-be investment project are evaluated. To achieve this, a simplified business inventory is used, which is traditionally used for creation and express analysis of business plans. In this case the technical improvements, which are obtained as part of concepts are also formulated as «products». For example, such a product as «millivolts» or «kilograms» can exist, because such «products» have output and «market price», expenditures, raw material/supplies for their manufacturing, i.e., all attributes of such ordinary products as, for example, «footwear» or «car».

In fact, business plan for manufacturing and distribution of products (or «products») is developed, the number of necessary investments is identified, basic economic and investment-related parameters of the project are evaluated. This tool enables to evaluate the economic feasibility of a project or of an individual concept. Example of such detailed business-design is quoted in Fig. 4.



- The Project creates 3 products: savings due to weight reduction, savings due to reduced maintenance costs and savings due to reduced voltage losses.
- All products create EE (generate income) and require initial and operational costs for reproduction (create an expense)

Fig. 4. Example of detailed business design

Express verification of concepts

Due to high expenditures and large number of concepts, developed in ITP, their full-scale verification requires long time and significant expenditures, while «survival rate» of concepts is decreased at early stages.

For the purpose of reducing expenditures the verification is performed in two stages: at an early stage, while the concepts are being developed, express verification is carried out implying the maximum use of such techniques as substitution of the object with the model of it, decrease of system scale, checking of the most significant hypotheses without the optimization of less important technical specific features, etc.

For such concepts, which were preliminarily verified and can be characterized as «survived concepts» their full-scale verification is carried out as part of Verification project.

SPECIFIC FEATURES OF LARGE ITP

Some projects (as a rule, large-scale ones, with high anticipated economic effect and high scientific-and-technical level) containing a large number of concepts, themselves constitute a mini-portfolio of sub-projects.

Among the concepts of such projects, it is possible to single out the main concepts, which are destined to yield the highest effect (and these concepts can be both competing and mutually supportive), auxiliary concepts (as a rule, they are subject to main concepts and serve for solving emerging secondary problems) and additional concepts, which can be implemented as self-contained solutions or in combination with two preceding types of concepts. In fact, each of the concepts in such a set is an innovation project (sub-project).

Respectively the control over such a portfolio is carried out based on the same fundamental principles as the control over the portfolio of projects.

CONCLUSIONS

- Life cycle (LC) of innovation TRIZ-project is different from LC of the so called «industrial TRIZ project»
- In innovation project it is required to consider a large number of concepts in order to compensate for its decreased «survival rate»
- Business-analysis of the concepts should be carried out as part of a Search project, in order to leave out such concepts, which initially have low business parameter values and which are unsuitable for investment project performance.
- In order to carry out business modeling, it is necessary to reformulate technical effects (Watts, kilograms, minutes, etc.) as manufactured «products», then an opportunity appears to analyze them using typical business tools.
- It is necessary to carry out the verification of concepts in two stages: the first (simplified) stage is carried out during the performance of Search project, so that it might be possible to ensure the fundamental working efficiency of proposed concepts, effects and technical solutions. During the stage of verification project full-scale verification is carried out, but only of such concepts, which are preliminarily verified and went through the benchmarking procedure.
- It is necessary to take specific features of big ITP into account, in particular, by decomposing them into «sub-projects».

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M.S. Rubin

Original problem situation in TRIZ

SUMMARY

The problem, which the inventor encounters while improving the system, is a key source point for the entire process for inventive problem formulation and solving. From the outset TRIZ developed around the problem solving. Tools were developed in TRIZ for identification and solving of problems within the systems. At the same time in TRIZ there is no unity not only in terminology used for describing problem situations, but also in understanding the ontological meaning of this theme.

The present work quotes the analytical analysis of TRIZ tools used for describing the inventive situation. As a result, the author proposed a strict system of terms and models for describing the original problem situation, requirements field and requirement contradiction. Formalizing procedure has been developed for describing the inventive situation with regard to evaluation of level of completeness of describing components, which form the model of inventive situation. Examples are quoted for formal evaluation of completeness of inventive situations description, which demonstrate the mechanisms for transition from inventive situation description to formulation contradiction of requirement and to analyzing them.

INTRODUCTION

G.S. Altshuller singled out three types of contradictions: administrative, technical and physical contradiction. Each subsequent one is the specification and aggravation of the preceding one. Here is a quotation from the book by G.S.Altshuller: «The very fact of appearance of an inventive problem already contains a contradiction: it is necessary to do something, and it is not known how to do it. Such contradictions are conventionally called administrative ones (AC). There is no necessity to identify administrative contradictions, they are on the surface of the problem. However, the eristic, «prompting» force of such contradictions is equal to zero: they don't prompt us, in what direction it is necessary to look for a solution. In the depths of administrative contradictions there are technical contradictions (TC)… and a technical contradiction, which is correctly formulated, is characterized by a certain eristic value. » [1].

At the initial stage of TRIZ evolution in 1970-ies such a methodological basis of TRIZ consisting of three key notions – administrative, technical and physical contradictions – was quite workable. With time two reasons appeared, due to which the necessity originated to specify these two notions:

- TRIZ application in non-technical spheres, in business and management of enterprises;
- broad spreading of TRIZ requires more exact definitions of the notions used.

In this work we will analyze the existing TRIZ terms for describing original problem situation and will offer an ontological description of them, which is more exact and definite.

The author is thankful to the colleagues, with whom he during the last years discussed the topic of problem statement in TRIZ: A.Kurian, A.Kulakov and A.Trantin.

THE NOTIONS OF PROBLEM AND ADMINISTRATIVE CONTRADICTION IN TRIZ

G.S. Altshuller used several terms, the meaning of which is similar: problem, inventive situation, inventive problem, administrative contradiction. There are other analogous terms in TRIZ literature: problem situation [2], non-desirable effect, non-desirable situation, original problem. There are other word combinations for the same notion: surface contradiction [3], solver's contradiction [4], original situation.

Table 1 quotes eleven variants of terms, which are close one to another in meaning and which are used in TRIZ and comparative analysis of them is made based on advantages and disadvantages of these terms from the viewpoint of the opportunity to use them not only in technical systems and their correctness from that point of view that at the beginning of analysis it can be unclear, if there is a contradiction in this situation or not.

Term	**Advantages**	**Disadvantages**	**Rating**
Problem situation	TRIZ term. Not necessarily contains a contradiction. Is applicable to non-technical systems.	Not widely used in TRIZ	**9**
Inventive situation (GSA, 1975)	TRIZ term. There is no accent upon the presence of the problem.	The word «inventive» presupposes that there is a contradiction.	7
Non-desirable situation	It points at the presence of difficulties, but not necessarily due to contradictions	Subjective character of evaluation of non-desirability.	7
Administrative contradiction	Conventional and widely known TRIZ term.	Is unsuitable for non-technical systems. May not contain a contradiction.	6
Original problem	The word «original» presupposes the necessity of analysis	The meaning of the term «problem» is too broad and polysemantic.	6
Original situation	The word «original» presupposes the necessity of analysis	Does not point at the presence of certain difficulties	6
Source problem	The word «Source» presupposes the necessity of source searching	The meaning of the term «problem» is too broad and polysemantic.	5
Non-desirable effect	There is no indication of necessary presence of contradictions	Subjective nature of evaluation of non-desirability. Describes a narrow phenomenon.	4
Inventive problem	Conventional and widely spread TRIZ term.	This term rather relates to a technical contradiction.	3
Surface contradiction	Can be used for non-technical systems	Points at the presence of contradictions.	2
Problem	Is understandable intuitively. Widely spread.	Not a TRIZ term, is applied in many meanings.	2
Solver's contradiction	-	Not a TRIZ term. Points at the presence of contradictions and subjectivity	1

Table 1. Comparative analysis of TRIZ terms, which describe the Original problem. The term «Problem situation» has the highest rating.

In order to select the most appropriate term it is possible to use one more approach. It is possible to analyze the frequency of used words with regard to all eleven terms, which are quoted in Table 1. The results of this frequency analysis are quoted in Table 2.

Words contained in terms	**Frequency**	**Rating**	**Comment**
Situation	4	9	High frequency, no indication of necessary presence of contradictions
Problem (adj.)	3	8	High frequency, but the characteristic is not substantial
Original	3	8	High frequency and the characteristic is substantial
Contradiction	3	4	There is an indication of necessary presence of contradictions
Inventive	2	4	Low frequency. The term need not necessarily point at the invention
Problem	2	4	Low frequency. The problem need not necessarily exist. Broad meaning of the term.
Non-desirable	2	5	Contains subjective evaluation
Administrative	1	2	Is unsuitable for non-technical systems
Effect	1	1	Term with broad meaning. Low frequency.
Surface	1	1	Low frequency. Does not reflect the meaning.
Of the solver	1	1	Low frequency. Does not reflect the meaning.

Table 2. Frequency analysis of words in 11 terms from Table 1. The word «situation» has the highest frequency of use (4 times). The words «problem», «original» and «contradiction» are encountered 3 times each. Such analysis also leads us to the term «Original problem situation».

Based on the quoted analyses, it is proposed to use the word combination «Problem situation» or «Original problem situation» as the desired term. The definitions of these terms will be quoted below.

ORIGINAL PROBLEM SITUATION AS THE BASIS FOR STATEMENT AND SOLVING OF INVENTIVE PROBLEMS

Analysis of original problem situation can be reduced to three scenarios:

- it is necessary to meet certain problem requirements to the system, however, during the analysis it becomes clear that these requirements can be specified or corrected in such a way that the problem should not appear at all;
- it is necessary to meet certain problem requirements to the system and while performing the analysis it is possible to find the information about known methods for meeting these requirements in the given system;
- it is necessary to meet certain requirements to the system and while performing the analysis it is possible to single out at least one pair of requirements, in which meeting one requirement using known methods does not allow to meet another requirement and vice versa.

Of greatest interest in TRIZ is the third variant, in which the contradiction of requirements is contained in the Original problem situation.

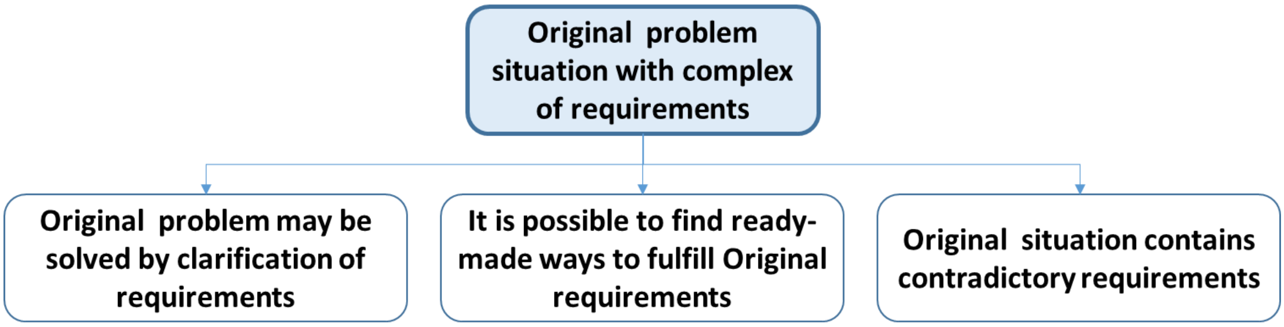

Fig. 1 Scenarios for transforming a problem situation

Problem, problem situation is a certain objective obstacle, a difficulty on the way from the system AS IT IS to the System AS TO BE, which requires a solution and can be formulated as a question or a set of questions. In contrast to a problem or contradictions of requirements, the problem situation may not contain all possible methods for resolving it. For example, the problem may be analyzed as a set of difficulties associated with improvement of this or that parameter: increase of profits, efficiency and reliability of the equipment functioning, quality of products, etc. In this or that way the problem or the requirements contradiction can also contain the method for solving the given problem, which turns to be inefficient due to this or that reason. For example, based on the quoted problem situations it is possible to formulate the following problem: how to enhance reliability equipment due to increase in stores and doubling without increasing warehouse stock and unused assets of the enterprise.

This or that complex of requirements to the system "AS IS" is described in the original problem situation for the sake of obtainment of a System AS TO BE. Analysis of a problem situation can lead to correction of original complex of requirements, to finding a known method for meeting a whole complex of requirements or to identification of contradictions in a complex of requirements, when the known methods for meeting each requirement separately are used. In the latter case the problem situation transcends to the requirements contradiction.

It is clear from the quoted problem situation analysis and from the proposed definition that with the original problem situation the key notions are «requirement», «contradiction of requirements», «system AS IS», «system AS TO BE». For further structuring and formalizing of the notion «problem situation», it is necessary to structure these notions more precisely. This is done in subsequent sections of the present article.

SYSTEM OF INTERACTING REQUIREMENTS IN TRIZ

In TRIZ, which is predominantly aimed at the search of requirements contradiction, it is possible to single out two types of contradictions:

- function-and-targeted requirements (motivation requirements, generating energy for further actions) directed at attainment of a certain goal due to performance of certain functions;

- restrictive requirements (certain conditions, which it is necessary to take into account and which should be adhered to in attainment of function-and-targeted requirements).

These two groups of requirements are shown in Fig.2. Restrictive requirements, requirements to interrelations and goals can be related to the general group of non-functional requirements.

These two groups of requirements can form the basis for requirement contradictions within the system: known methods for attainment of certain goal-and-function methods lead to non-fulfillment of other function-and-targeted methods or to violation of restrictions.

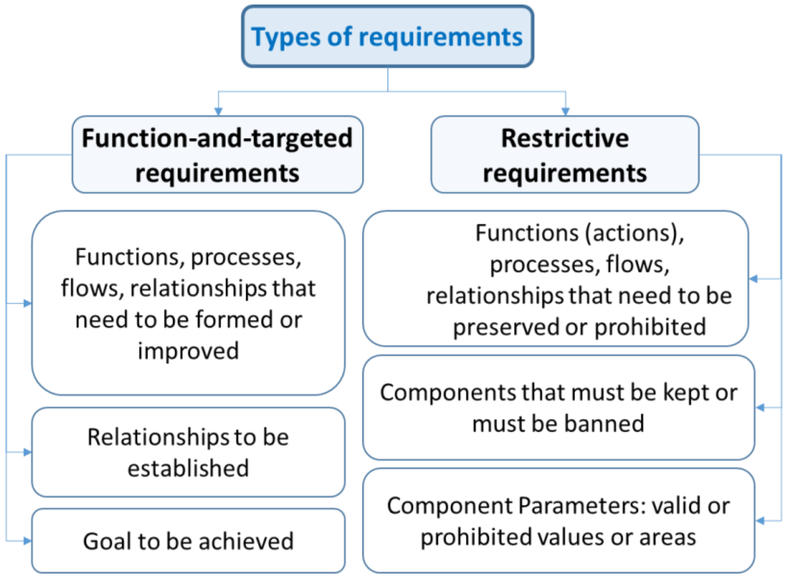

Fig. 2. Types of requirements: function-and-targeted and restrictive

It is possible to single out three originals within the system of requirements in TRIZ: requirement of supersystems to the system (for example, requirements of a family to the child: it is necessary to clean the teeth every morning); requirements of the system to a supersystem (for example, requirements of the child to the family: to feed him or her, to provide for a lodging and clothes and to take care of the child); the requirement of "adjacent" systems to the system (for example, requirements of neighbors to the family and to the child: not to make noise, not to break windows).

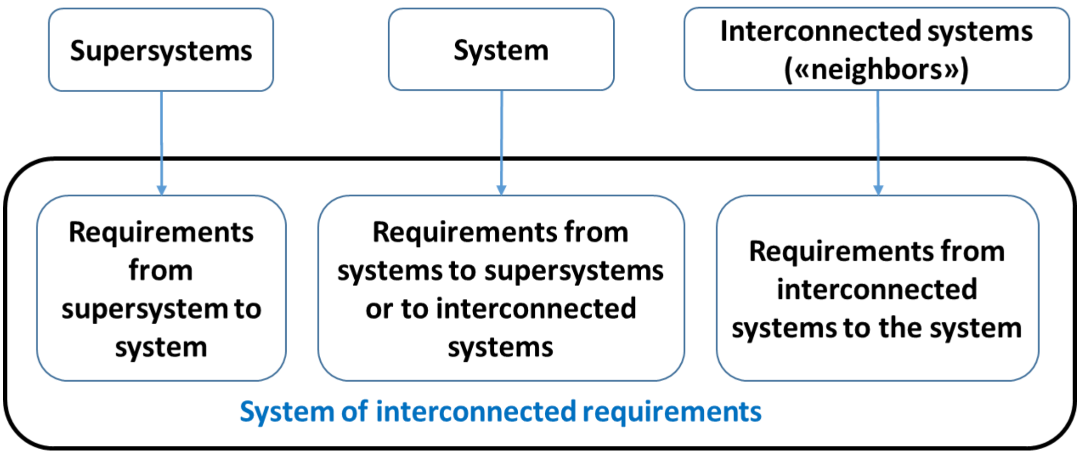

Fig. 3. Originals of requirements in a single field of interacting requirements. Requirements can be given to different, but interconnected objects

By way of example let us analyze the system of interacting requirements in design and construction of a certain manufacturing plant. The Customer (supersystem) gives to the manufacturing plant requirements concerning the palette of manufactured products, production efficiency, terms of starting the manufacturing process, conditions of labor of would-be employees, etc. The equipment, which is planned to be used has its own requirements to energy resources and their quality, requirements to temperature and humidity, to shape of the foundation and necessary loads upon it, etc. Also there are requirements coming from the interacting (adjacent) systems: requirements from the adjacent residential estates, entertainment parks, other enterprises. With innovation projects evolutionary requirements can be formulated, which presuppose the improvement of already known parameters of the system analyzed. All these requirements appear to be interconnected and form a single system through objects and processes, which are included concurrently with several requirements. For example, requirements to emissions of chemically active substances into the atmosphere could influence the requirements to chemical durability of the material, of which the roofs of the plant buildings are made.

It is also necessary to take into account dynamic change of requirements system in time and its irregularity in terms of level of significance and mutual influence. The requirements system changes depending upon the phase of life cycle of the systems, which are included with this complex of requirements. For example, requirements to industrial building changed in time from one century to another. Requirements to the system during the manufacturing process, transportation, operation and utilizing change in the course of transition from one phase of life cycle to another. At the same time one system of mutually interacting requirements may include systems, which stay at different phases of life cycle. For example, the edifice is only being built, while the equipment intended for it is already at a given site or being transported, or vice versa, the building is created, while the equipment is only being manufactured. Some requirements may dominate over other; they can also have a higher level of importance than the other requirements. For example, requirements to wind load influence the requirements given practically to all other construction elements of the building. Requirements to higher elements of the building (the roof, the beams, etc.) influence the requirements to lower elements of the building (columns, foundation, etc.), since the parameters of the lower elements of structure depend upon the weight of higher elements.

The system of mutually interacting requirements can be looked upon as an ordinary system using a system operator. It means that the system of requirements has a supersystem, for example, legislation, the laws of nature, etc. Also, there should be subsystems, for example, depending requirements, constituent requirements (components, parameters). The system of requirements has its past and future, it is also characterized by the evolution in time. Correspondingly it can evolve in ontogenesis (evolution of the system of requirements to design of a particular building) and in phylogenesis (system of requirements to constructing buildings in the past centuries is different from the modern system of requirements).

CONTRADICTION OF REQUIREMENTS TO SYSTEM IN TRIZ

In 1860 F.Engels published a known work «The history of a Rifle» [5]. It is said there in particular in the description of contradictions in rifle evolution: «It was always a great difficulty to connect the shutter with the barrel in such a way so that it might be easy to disconnect it and to install once again, while the connection thereby should be strong enough so that it might endure the pressure of powder gases. There is nothing surprising that under the conditions of imperfection of technology of this time both these requirements cannot be combined: either the parts, which connect the shutter with the barrel, were insufficiently strong and durable or the very process of dismantling and fastening was performed fairly slowly».

In 1959 G. Altshuller and R. Shapiro in their article «Expulsion of a six-wing seraph» formulated and analyzed a collection of cards containing the descriptions of contradictions of system evolution in fairly different spheres: aviation, ship-building, mining equipment, heat generation equipment, etc. It appears that in contrast to a designer, who balances between mutually contradictory characteristics of a machine, selecting them in such a way that the requirements of a particular problem should be fully met, the inventor should break this compromise, should improve (or enhance the quality) of one part of the machine in such a way that the qualities of other parts should not deteriorate. [6]

S.N. Semionov remarked at the TRIZ conference in Novosibirsk in 1984, that the technical contradictions emerge due to the formation of technical requirements, which the society gives to the technical system and the features of the object, which is used in the given device. [7]

In 1994 the author proposed to use the following terms, which are applicable to all systems (not only technical ones): contradiction of requirements as a generalization of a technical contradiction and contradiction of attribute as an analog of a physical contradictions. [8]

It is important to pay attention to the basic difference between a contradiction of requirements (CR) to the system and contradiction of attribute (CA) of an element of this system. In the formulation of CA the element should be different from the system in CR, while the attribute of an element in CA should be different from the change (action), which is introduced into the system, and which is used in CR. Otherwise, the CA will not be different from CR whatever, and the formulation of CA will not yield new ideas. The figure shows a pattern of the model («Sandwich») of association between CR and CA.

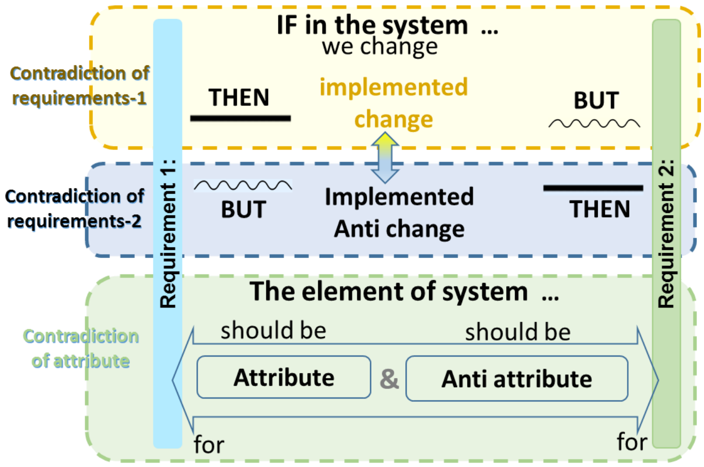

Fig. 4. Pattern of interconnection of contradiction of requirements and contradiction of attribute as a single cause/effect connection and mutually preconditioned connections (model «Sandwich»)

Using the formulation of contradiction of requirements in the analysis of the problems enables to integrate TRIZ with such developed technologies of requirements management used in different spheres of human activity. In future this pattern of contradictions and methods of work with them can be integrated into systems enabling to perform requirements management (RMS – requirements management systems) [9]. Requirements management is one of the methods for resolving requirements contradictions.

Contradiction of requirements (CR) is a situation, in which this or that change in the system enables to meet one Requirement (Requirement 1) of a supersystem to the system, however, does not enable to meet another Requirement (Requirement 2) to the same system, and vice versa – the opposite change in the system enables to meet Requirement 2, however, does not enable to achieve meeting Requirement 1.

Contradiction of requirements, in which Requirement 1 is met, is called Contradiction of requirements 1 (CR-1). Contradiction of requirements, in which Requirement 2 is met, is called Contradiction of requirements 2 (CR-2).

The following pattern is used for describing contradiction of requirements (technical contradictions):

Contradiction of requirements 1: IF... (Implemented change is indicated), THEN (+ indicate Requirement 1 being improved), BUT (- indicate Requirement 2 being deteriorated).

Contradiction of requirements 2: IF... (opposite change is indicated), THEN (+ indicate Requirement 2 being improved), BUT (- indicate Requirement 1 being deteriorated).

Contradiction of attribute (CA) is a formulation of the opposite state of this or that attribute of one element of the system, which is necessary for meeting contradictory requirements to the system. It is possible to formulate several contradictions of attribute for one contradiction of requirements.

Physical, chemical and biological attributes are used for material systems. The wording of contradiction of attribute intended for physical attributes has the following wording: physical contradiction.

Here is the pattern for formulating the contradiction of attribute:

The element of a conflicting pair should possess attribute A, in order to provide for Requirement 1, and should possess attribute "NON-A", in order to meet Requirement 2.

The description of the original problem situation should be fairly complete and informative, so that one might single out and correctly formulate contradictions of requirements and contradictions of attribute.

GLOSSARY OF TERMS FOR DESCRIBING ORIGINAL PROBLEM SITUATION

Let us quote the definitions of several important notions, which are necessary for describing original problem situation and passing over from these notions to statement of inventive problems and formulation of requirements contradictions.

Original problem situation is a situation, which implies that the System AS IS gets this or that complex of requirements for obtainment of a system AS TO BE. Analysis of the problem situation could lead to correcting the original complex of requirements, to finding a known method for meeting a complex of requirements or to identification of contradictions in using known methods for meeting each of requirements separately. In the latter case the problem situation passes over to contradiction of requirements.

Multitude – one of the key notions of mathematics, constituting a set, an array of some objects (generally speaking, any) objects – elements of this multitude.

System (Greek σύστημα «the whole consisting of parts; unity») – multitude of elements staying in relations and connections one with another, which constitute a certain wholeness, unity and has characteristics, which are related to the system, but not to each element separately.

In contrast to a multitude a system is characterized by the following: its elements stay in interrelations and interconnections, but not simply unified according to this or that feature. Since a system is a multitude, the systems possess all properties and features of a multitude [10]. It means that a subsystem (sub multitude) can exist, one system can be added to or subtracted from another system, the systems may be integrated into supersystems (multitude of multitudes), etc. In particular, since a multitude of all multitudes does not exist, neither can exist a system of all systems (including all possible systems).

Resource system is a system, to which no external requirements are given and correspondingly there is no necessity for functions regarding meeting these requirements. Resource systems don’t possess any functional-and-targeted features, for example, sand on the beach, electromagnetic field of the Earth, etc.

Self-organizing system is a resource system, in which spontaneously (not in keeping with the requirements of supersystems) the processes take place and the flows appear, which are associated with the changes of system elements and the system as a whole in time and in space, for example, swirls, volcano eruptions, formation of stars and planets, etc.

Functional-and-targeted system is a system formulated for performing the complex of useful functions and attainment of goals in keeping with the requirements of supersystems and operation principle of the given system. Functional-and-targeted system is formed based on self-organization, natural or artificial selection or as a result of targeted actions performed by one of the supersystems. Biological systems, technical systems, social, financial-and-economic systems, scientific and other similar systems can be referred to functional-and-targeted systems.

Empty (zero) system (system vacuum) is a system, which consists of empty multitude of elements. Empty system can be called system vacuum. Since empty multitudes also contain descriptions of these multitudes, for example, «a multitude of horses living on the Moon», «flying lions», the system vacuum should contain a description of what does not exist within this system: physical vacuum, chemical vacuum, biological, social, economic, technical and other kinds of system vacuum (empty systems). In this case an empty system has its characteristics, for example, volume, coordinates in space and in time, shape.

System of multitudes (multitude of multitudes, super multitude) is a multitude, all elements of which are multitudes.

System (complex) of interacting requirements – is a system of requirements coming from the system, supersystem and adjacent systems, interconnected by common elements and fields of interaction. A system of requirements can be looked upon as a self-contained system within a system operator, which means that one can single out a supersystem of requirements, a subsystem of requirements, the past and the future of requirements system.

System AS IS is a system remaining in its source state before the beginning of its being analyzed and transformed into a new system AS TO BE. The model of the system “AS IS” is formed from the system AS IS using some TRIZ models: component-structural and functional models, Su-Fields or El-Fields, description of contradictions or typical pattern of the conflict, etc. Depending upon the selected type of the model, it is later on transformed into the model of the system AS TO BE.

System AS TO BE is a system, which is obtained from the system AS IS via transforming it , also based on the model of the system AS TO BE. Model of the system AS TO BE is formed based on the model of the system AS IS via procedures, which correspond to the selected method for transforming models (functional, Su-Field, El-Field, resolving contradictions of requirements and feature, etc.). Transition according to the line "System AS IS" – "Model of the system AS IS" – "Model of the system AS TO BE" – "System AS TO BE" corresponds to the pattern of "TRIZ Model".

Requirement is a goal, function, restriction or ratio, which are targeted at this or that object (system) and which should be realized. Requirements may come from supersystems, surrounding systems and the system itself, thereby forming a system (complex) of interconnected requirements.

Functional-and-targeted requirements – are requirements, which are targeted at the attainment of the stated goal due to realization of a complex of functions, interrelations within the system and correcting them due to feedback.

Restrictive requirements – are requirements, directed at the prohibition or obligatory presence within the system of certain functions, interrelations, components and their parameters. The requirements may be formulated for a certain field of parameter values or by their exact values.

Function –is a change, stabilization or measurement of certain parameters of the object of the function (or product) via acting upon it with the agent of the function (tool). Model of the function consists of the agent of the function, action upon the function object and object of the function, the parameter of which is varied. It is also possible to indicate the field of interaction, with the assistance of which the action is performed. "Action" is understood as variation-stabilization, increase-decrease or measurement of this or that parameter, characterizing the object of the function. El-Field or Su-Field can be used as a function model. In the functional analysis they single out useful, harmful, insufficient, excessive, absent and other kinds of functions. Function model does not describe the object of the function before its modification.

Operation (part of the process) – is a description of the function performance in time, in which no agent of the function is indicated, however there is an indication of the state of function object before its being modified and the function object, which is modified after operation (process). As it is done with the function, with the process model it is possible to indicate the field, which is used for varying the object parameter. The process consists of a succession of operations. The process describes the variation of a system (or object) parameter in time at the output (exit) of the process as compared to the same system (object) parameter at the input (entrance) of this process.

Fig. 5 shows in the form of a diagram that one and the same system can be described using different models: models of functions, processes, flows or a combination of them.

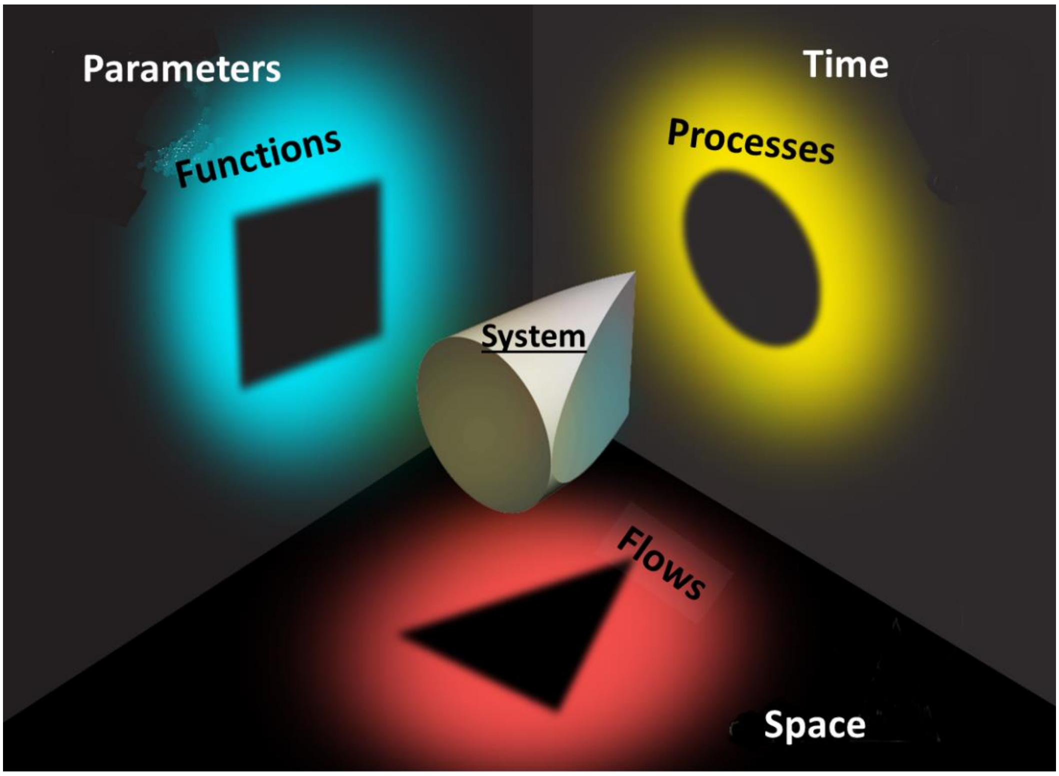

Fig. 5. Schematic diagram showing that one and the same system could be described using different model: models of functions, processes, flows or combination of them all

Flow – is a private case of a process (of an operation), in which the changeable pattern is the position of the object in space. In contrast to the processes, the flows presuppose that the position of the object in space changes. The flow is a directed motion of parts of substance mass in space, as well as the targeted travel of energy or information. The flow has features of double nature: features of a substance, of which the flow consists and the features of a field, which is formed as a result of targeted motion of substance particles. The flow can be useful, harmful and parasitic. The model of the flow contains static components: source (and capacity of this source), the channel, the receiver (and the capacity of the receiver) and the control system.

Goal – model image of the System AS TO BE, which is described in the form of an information image and/or requirements system, and which should be necessarily attained by the subject due to fulfillment of a complex of action programs with feedback. The realization of action programs with feedback is based on fulfillment of complex of functions (processes, flows) and correction of action programs depending upon nearing the set goal or attainment of this goal.

Target-oriented metric –is a metric, which enables to identify the degree of attainment of the set goal.

FORMALIZATION OF THE DESCRIPTION OF ORIGINAL PROBLEM SITUATION

Because of the absence of formalization in the Original problem situation it can be difficult to truly evaluate the completeness and objectivity of this description, which is necessary for identification of inventive problems and formulation of contradictions. In order to single out the main constituents of the description of Original problem situations the analysis was performed of descriptions of Original problems in TRIZ: ARIZ-62, ARIZ-63, ARIZ-64, ARIZ-65, ARIZ-68, ARIZ-71, ARIZ-77 [11]. The evolution of parts of ARIZ, which are directed at the statement of problems took place gradually from ARIZ-62 to ARIZ-77, following the steps and recommendations of the preceding versions of ARIZ. It is possible to single out the main constituent elements of the description of Original problem situations:

- Object of the problem;
- Metric (goal, economic feasibility, required numeric parameter values);
- Characteristics of the object;
- Admissible expenditures and complexity of solution;
- Roundabout way. A more general problem;
- Comparison and selection of problems;
- Supersystems. Comparison with tendencies in branches of industry. External environment;
- Requirements: specification;
- Elements (attributes (features), what can be changed in them, and what can't be changed, product-tool);
- Non-desirable effect (harmful interaction);
- Description of cause/effect connection of elements and non-desirable effect.

Description of a problem situation should be sufficient for analyzing it as well as for singling out inventive problems and solving them. During the analysis and solving the problem situation can be elaborated and augmented.

Structuring these constituents, it is possible to combine a list of basic elements for describing a problem situation. It is possible to propose the following list of elements:

- Object,
- Targeted metric,
- Requirement 1 (function),
- Requirement 2 (function or restriction),
- Ways of attaining requirement 1,
- Ways of attaining requirement 2,
- Element upon which depends the fulfillment of requirement 1 and requirement 2,
- Supersystems.

With each of these elements for describing a problem situation it is possible to evaluate the completeness of information about them according to a five-point scale:

1. No
2. Not clear, if there is or there isn't
3. There are many, but they are not formulated clearly
4. There are many, but it is not clear, which element to choose.
5. There are

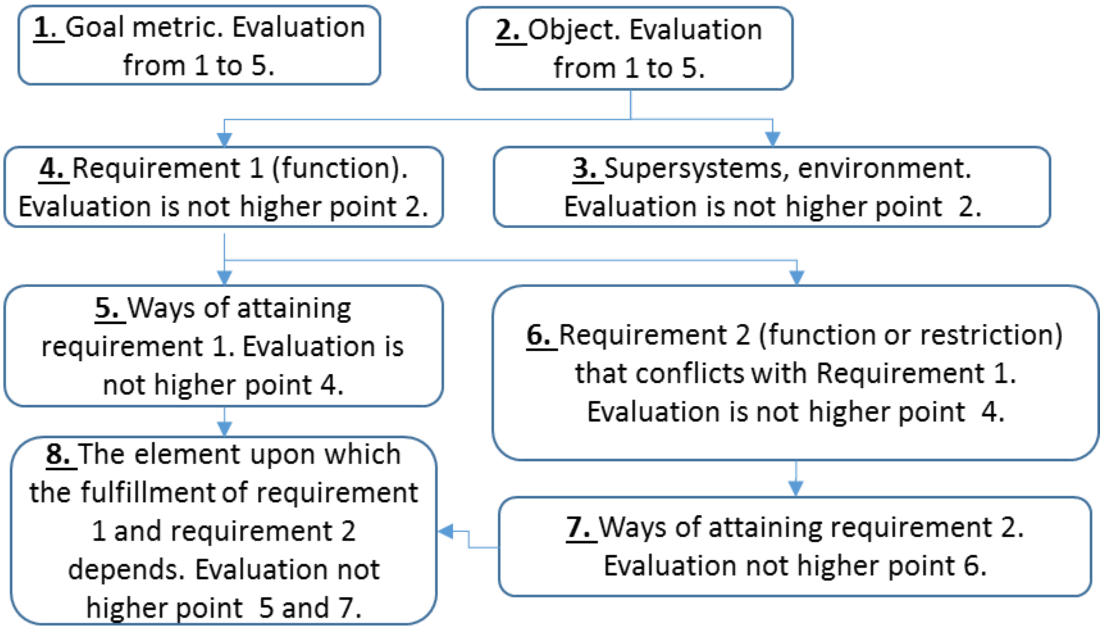

Fig. 6. Interrelation of evaluations of completeness of information concerning the elements of a problem situation

Let us quote examples for evaluation of completeness of problem situations description (Table 3).

Problem 1. Grinding wheel. Example of formulation of a problem situation.

Grinding wheel badly processes the products of complicated shape with recesses and convexities, for example, spoons. Replacing the process of grinding with another type of processing is unprofitable and rather difficult. The use of lapping ice grinding wheels is in this case too expensive. Inflatable elastic wheels with an abrasive surface are also inappropriate in this case – they wear off too soon. What's to be done?

Problem 2. IT company. Example of formulation of problem situation.

IT companies try to create more unique products in order to attract new clients and increase the volume of sales to the current clients. However, the new product costs a lot of money. What's to be done?

Problem 3. Sticky tape. Example of formulation of a problem situation.

The wounds are healed with the aid of a sticky tape, but the skin does not «breathe». What's to be done?

No.	Description elements	Problem 1. Evaluation.	Problem 2. Evaluation.	Problem 3. Evaluation.
1	Object	4. Many, but it isn't clear, which one to choose	3.Many, but not clearly formulated	3. Many, but not clearly formulated
2	Goal metric	3. Many, but not clearly formulated	2. It isn't clear, if there is or there isn't	1. No
3	Requirement 1 (function)	4. Many, but it is not clear, which one to choose	3. Many, but not clearly formulated	2. It isn't clear, if there is or there isn't
4	Requirement 2 (function or restriction)	3. Many, but not clearly formulated	3. Many, but not clearly formulated	1. No
5	Ways of attaining requirement 1	4. Many, but it is not clear, which one to choose (cannot be higher than line 3)	1. No	1. No
6	Ways of attaining requirement 2	3 Many, but not clearly formulated	2. It isn't clear, if there is or there isn't	1. No
7	The element upon which the fulfillment of requirement 1 and requirement 2 depends	2. It isn't clear, if there is or there isn't	1. No	1. No
8	Supersystems	4. Many, but it isn't clear, which one to choose	1. No	1. No
	General evaluation	62%	33%	20%

Table 3. Evaluation of completeness of description of a problem situation based on the completeness of information concerning the elements of this description.

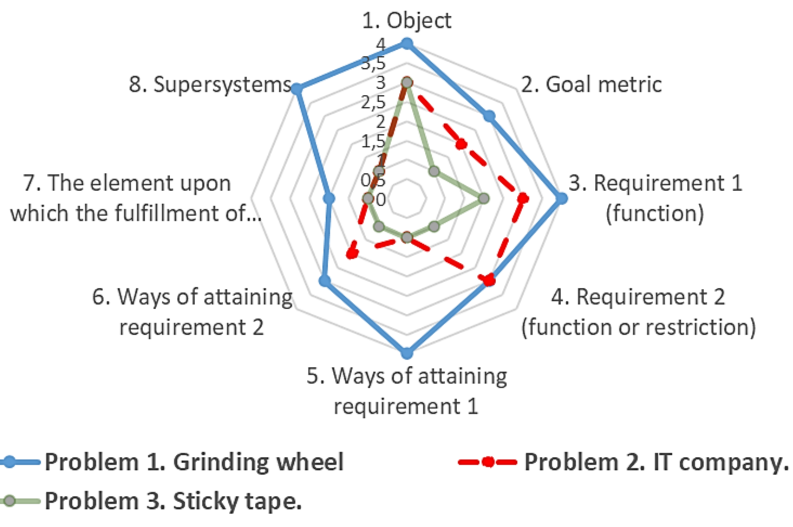

Fig. 7. Diagram of completeness of fulfillment of Original problem formulation for problems of 1–3

Fig. 7 shows a diagram of completeness of Original problem formulation for problems 1–3. It is seen from this diagram that problem 1 is described to a greater extent than other problems and problem 3 has the lowest completeness of description. This diagram also shows, which elements of the problem situation are described insufficiently clearly and completely. In the software complex Compinno-TRIZ [12] beside the diagram recommendations are issued concerning the improvement of description of problem situation elements. (Fig. 8).

Fig. 8. Evaluation of Original problem situation in a software complex Compinno-TRIZ. Recommendations are issued how to improve the description

The evaluations of completeness of information concerning the elements of a problem situation are interconnected (See Fig. 6). For example, evaluation of the fact that there is a description of Requirement 1 cannot be higher than the evaluation of the Object itself, since if the object is not clear, it is impossible to described the requirements, which this object should meet. Evaluation of the method for attainment of Requirement 1 cannot be higher than the evaluation of the description of Requirement 1 proper. And so on. These interdependencies are taken into account in the software complex Compinno-TRIZ in the module «Problem situation evaluation».

A set of elements describing the problem situation, can be enlarged. For example, it could be augmented with the following elements:

- An opportunity (having required knowledge and information) to set up cause/effect chains between requirements;

- An opportunity to set up cause/effect chains between requirements and features of the element;

- Presence of description of different aspects of analyzing the problem situation (physical, chemical, technical, economic, social, etc.).

Detailed description of a problem situation usually contains exhaustive answers to key questions of describing a problem situation with photographs, descriptions of already tested methods for eliminating the problems, references to documentation, experiments and contacts with experts, which could yield additional information. The growth of completeness degree of Original problem situation description will lead to enhancement of clearness and correctness of transition to requirements contradiction or to a set of such contradictions as well as to the increase in chances to expect that these requirements contradictions will be resolved.

CONCLUSIONS

1. The description of the problem to be solved is of fundamental significance for TRIZ. Fairly different terms are used in TRIZ thereby to describe this entity: inventive situation, administrative contradiction, etc. Having analyzed eleven such terms we proposed to use a more correct term in TRIZ: «problem situation» or «Original problem situation».

2. Of greatest interest in TRIZ are such problem situations, which contain system requirements, which are incompatible (controversial requirements), as well as the methods for converting a system AS IS into a system AS TO BE.

3. System of interacting requirements is composed of requirements of supersystems, interacting systems and subsystems. A system of requirements can be analyzed as any other system: let us mention evolutionary analysis, analysis of structure and functions, analysis of supersystems and subsystem, analysis of internal contradictions, etc.

4. Contradiction of requirements relates to any, not only technical systems and therefore is a generalization of the notion «technical contradiction». Contradiction of requirements is associated with the system as a whole, while the Contradiction of attribute – with the element of this system. Contradiction of requirements of the system is associated with the Contradiction of attribute of the element through cause/effect chains. In order to visualize these associations one can, use the model «Sandwich».

5. To provide for a more precise work with the notions of system, supersystem and subsystem it is proposed to consider a system as a multitude, transferring to the system all main features of multitudes. It is possible to single out three types of systems: resource, self-organized and function-and-targeted system types.

6. A system can be described with the aid of three models: processes, flows and functions. There are no functions in resource and self-organized types of systems, however, there is a structure of interconnections between elements of these systems.

7. In order to formalize the description of a Original problem situation it is proposed to use the evaluation of completeness of information concerning problem situation elements using a five-point scale. Such kind of formalization is used in the software complex Compinno-TRIZ.

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A. Kulakov

Automated construction of roadmaps for TRIZ-projects

ABSTRACT

Building roadmaps for TRIZ-project that specify the sequence of application of TRIZ tools, can be compared in terms of importance to ARIZ for solving inventive problems. While there are known methodologies that attempt to describe various universal roadmaps for several types of TRIZ-projects. On the one hand they are too complicated because try to describe possible project options in as much detail as possible. On the other hand, they cannot take into account all peculiarities of a particular TRIZ-project, suggesting the use of analysis types that are insufficiently effective for that project or, conversely, not suggesting the use of TRIZ tools important for that project.

Based on the experience of performing TRIZ-projects, the experience of mass implementation of TRIZ and management of TRIZ-project portfolios at industrial enterprises, the author proposes a new iterative method of building TRIZ-project roadmaps based on the analysis of completeness of the initial and refined problem situation formulation. The algorithms developed by the author formalize (digitize) the level of completeness of the current description of the problem in question and suggest the following types of analysis and application of TRIZ tools, which allow making a more complete description of the initial problem and finding a solution to the formulated contradictions of requirements to the system in question.

The approach proposed by the author allows increasing the efficiency of TRIZ-projects planning in terms of mass implementation of TRIZ at industrial enterprises with low experience of TRIZ-project managers, and opens up the possibility of automating the process of TRIZ project planning, which would result in reducing the time spent on project planning. This paper discloses the essence of the roadmap algorithm developed by the author for TRIZ projects, demonstrates by examples the work of the roadmap designer algorithm based on the developed algorithm, and gives the results of verification of the prototype and the algorithm performance in project activities.

Key words: *Project planning, roadmaps for TRIZ projects, automation of planning, TRIZ implementation*

INTRODUCTION

Successful project implementation involves meeting project objectives within a limited period, which is impossible without planning. This thesis has been repeatedly confirmed in the course of the author's practical activities in aluminum production and refrigeration engineering projects.

The development of a detailed project plan is preceded by an equally important step – the development of a project implementation strategy. It is the strategy that underpins future planning. In turn, the project roadmap is a form of visualization of the project implementation strategy. In other words, building a roadmap that is adequate to the project is key to the project's success.

The roadmaps for TRIZ projects represent visualized sets of subjects: TRIZ tools, results of tool use, links and sequences between tools. Despite the rather simple and straightforward form of the roadmaps, their adequate construction requires that the project manager is highly experienced in implementing such projects and using TRIZ tools in the context of a particular project against a background of information and time deficiency.

The author's experience shows that in the case of mass implementation of TRIZ in industrial enterprises, the number of experienced TRIZ project managers becomes a limiting factor. On the other hand, it takes time to build up an experienced TRIZ project manager. In other words, there is a contradiction, which, if resolved, would allow for a qualitative leap in TRIZ project management when implementing the methodology on a large scale in the activities of enterprises.

In the 'Literature Review' section, the author has collected the major works that to some extent address the topic of road mapping, as well as attempts to resolve this contradiction. However, to date, the methodologies proposed in these papers exhibit a number of shortcomings that hinder their widespread practical application. For this reason, the topic of algorithmicizing and automation of the roadmap process is now still relevant and in demand in practical activities to implement TRIZ projects.

LITERATURE REVIEW

A large body of literature on the development of TRIZ approaches and methodologies was analyzed in the preparation of this article. To localize the scope of influence of this work in general terms, all developments have been divided into three major groups:

- developing selected existing TRIZ tools;
- developing new TRIZ tools;
- developing approaches, methodologies and algorithms that integrate TRIZ tools to create a single logical framework for implementing a TRIZ project.

This classification is not intended to be exclusive, but is merely given as a convenient way of defining the field of literature review and will only use the third identified group of developments in the discussion that follows.

The paper [1] attempts to link TRIZ tools in the logic of a single project. Six stages of value engineering are outlined: preparatory, informational, analytical, creative, research, recommendatory. It should also be noted that the description of the analytical and creative stages contains an indication of the use of FCA (Function-Cost Analysis) and ARIZ-85B. Nevertheless, the stages outlined in the paper may not claim to be a comprehensive roadmap for the project. Among the whole list of TRIZ tools used in modern projects, the methodology contains only FCA and ARIZ-85B, with links and transitions between the stages and tools being difficult to trace and ambiguous.

The paper [2] addresses the problem statement using the FAST method, which is analogous to the Cause-Effect Chains Analysis (CECA). It gives recommendations on the use of the König graph and pays attention to the resource search and utilization. Nevertheless, all recommendations are of a rather general nature, which will undoubtedly be a source of confusion for inexperienced users.

Papers [3, 4] focus on Efficient Solution Technology (EST). The presence of the word 'technology' in the name of the methodology suggests that the proposed approach is algorithmic and standardized. The problem-setting and problem-solving process is broken down into 6 separate sequential segments. The papers present a structural description of each of the segments at the highest level and provides a 'classic technology chain' made up of TRIZ tools, principles and approaches. Without compromising the personal achievements of the methodology inventors in solving problems, the general nature of the description of algorithms, models and sets of recommendations will not allow users to apply the methodology without direct assistance or intervention from the inventors themselves.

The paper [5] suggests a method for pre-selecting a problem-solving strategy and “filling the space between the task set and the formulation of an administrative contradiction “. Based on their own experience, the authors give a classification of problem situations. The definitions of the classes of problem situations presented in the paper are intuitive and allow a user familiar with TRIZ to assign the situation to a particular class. The implication is a different strategy for each class of problem situation and a questionnaire is designed to help the user choose a strategy. Essentially, each strategy correlates with a specific analytical tool. However, there is no clear guidance on the sequence of application of TRIZ tools.

The paper [6] presents a method aimed at assisting the user in the process of improving output in terms of efficiency. The Method of Effective Results comprises 4 stages, all of which are broken down into steps. The steps have explicit wording for actions and outcomes, allowing the method to be used in practice. Yet, the narrow focus of the method prevents it from being used for projects requiring no output improvement.

The paper [7] discusses an algorithm designed to identify and formulate tasks in case of disturbances and disruptions in production processes. The algorithm involves examining the problem for falsity, finding the root cause, analyzing the physical-field resources and engaging them to resolve the contradictions. However, it is worth noting that the steps of the algorithm are not clearly linked, are made in the form of general recommendations requiring direct accompaniment by the authors, and do not involve the use of many modern TRIZ tools. The algorithm given in the paper is challenging the user to draw a roadmap for the project.

The paper [8] provides, for the first time, a roadmap for the implementation of a model product improvement project. The paper also contains general recommendations on specific procedures. The papers [9, 10, 11] develop recommendations on specific procedures.

Among the papers found and analyzed, the one closest to this paper is [11]. The author has developed a methodology for selecting and applying tools for innovation design, including an algorithm linking customer innovation strategy and project type. Detailed roadmaps have been developed for the following types of projects:

- increasing product value;
- improving technological processes;
- forecasting product development;
- creating products not covered by competitors' patents;
- verifying the products developed;
- identifying areas for product improvement by MPV.

Among all the model roadmaps presented in the paper [11], the model roadmap for improving technological processes is of the greatest practical interest based on the specifics of the Russian aluminum industry. Yet, practice has revealed that using the model roadmap approach entails the following challenges:

- when using a model 'as is' roadmap, users often perform unnecessary analytical procedures that do not lead to quality progress in the project;
- the reconfiguration of the model roadmap to fit the available project input requires the user to have experience of TRIZ projects, which is not always possible in the initial stages of implementing TRIZ approaches in project activities.

MAIN PART

Study of practical experience of Road Mapping

In the course of practical work, the author has drawn a number of systematically repeated observations of sub-optimal use of resources by teams of TRIZ projects run using the model roadmaps. This paper has highlighted the following issues:

- Building roadmaps is formal in nature. They are built at the beginning of the project and not used in any way afterwards;

- The projects use TRIZ analytical tools that do not fit the task. The bottom line is wasted time with zero result;
- Untimely use of TRIZ tools;
- Ineffective use of the results of analytical procedures.

To improve the credibility of the model roadmap approach, the author designed and conducted a blind experiment.

A group of TRIZ-trained colleagues (TRIZ competence level no higher than Icarus and Daedalus level 1 and with no more than 3 years project experience) was asked to build roadmaps for 3 pre-selected and already implemented TRIZ projects.

To minimize the influence of socio-organizational factors (personal relationships between the author of the experiment and the examinees, the functional subordination of the examinees, etc.) on the decisions of the examinees, a legend for the experiment was devised. The legend went that the examinees were a control group of trained and more experienced colleagues for another experiment that tested the effectiveness of the new training program.

The results of colleagues' work were then compared with the actual roadmaps of completed projects and an accuracy factor was calculated for each observation based on the following logic:

Potential outcomes of the experiment	The tool is present in the examinee's roadmap	The tool is not present in the examinee's roadmap
The tool is present in the actual roadmap	Hit (+)	Miss (–)
The tool is not present in the actual roadmap	Miss (–)	Hit (+)

Once the experiment results had been processed, the accuracy of the roadmaps among the examinees was 57%. Assuming that examinees will strictly follow the plans formulated, this value is unacceptable in terms of the use of human resources.

The author also proposes this methodology to evaluate ways of creating TRIZ project roadmaps for verification of automated road mapping algorithms, and the author has chosen 80% as the accuracy target for the future algorithm.

Basis for the creation of a roadmap algorithm

Any TRIZ project begins with a description of an inventive situation. This is an asset of background information held by the project team at the start of any TRIZ project and upon which it can rely to take the next steps in the project. Consequently, the development of a project implementation strategy and its formalization in the form of a roadmap is always based on the initial description of the inventive situation. Yet the quality and depth of the description of the original inventive situation may vary. Below you will find some real-life examples from the author's experience, retaining the grammar and punctuation of the authors:

Example 1: 'Wounds are taped over with plasters thus preventing the skin from "breathing". What should we do?'

Example 2: 'Boiler operation generates foam at the water-steam interface. By rising with the steam into the steam lines, the foam reduces the steam dryness, sticks to the surfaces of the steam lines and heat exchangers resulting in a reduction in heat transfer efficiency. The presence of foam comes from the high alkalinity of the water, resulting in alkaline corrosion of the boiler surfaces.'

Example 3: 'Inefficient power generation caused by manual control of turbine generator operating parameters during the heating season.'

Example 4: 'Lining failure of the metal tapping ladle.'

Example 5: 'The alumina point feeder bin is fed by the MZGV machine. When alumina is fed into the bin, the air in the bin is displaced and escapes with the alumina. By reducing alumina feed into the bin, dusting is reduced, yet decreasing the capacity of the MZGV machine.'

Clearly, the number and variety of analytical procedures for the examples above will vary and depend directly on the depth of information contained in the description of the inventive situation. Furthermore, the information contained in the description of the inventive situation is interpreted through the perception of the individual project manager. By virtue of different levels of experience and expertise, project managers will learn different amounts of information from one and the same description of the situation. Which also complicates the creation of unified approaches to road mapping.

So far, the author has presented 'depth of information' as a kind of subjective perception of the description of the inventive situation, which lacks any instrumentality with regard to road mapping.

The paper [12] solves the problem of formalizing the completeness assessment of inventive situation description by introducing and describing an inventive situation model. The model of an inventive situation comprises the following components:

- target metric;
- subject;
- requirement 1;
- conflicting requirement 2;
- ways to meet the requirements;
- element and element property upon which compliance with requirement 1 and 2 depends;
- supersystems.

Any of these elements of the original inventive situation can be assessed using the following scale:

1 – No

2 – Not clear whether yes or no (insufficient information, dubious information)

3 – Plenty, but vaguely worded

4 – Plenty clearly worded, but it's unclear which one to choose

5 – Yes

The author notes that the introduction of an assessment scale of inventive situation components in the context of the task of building a roadmap adapted to the TRIZ project allows:

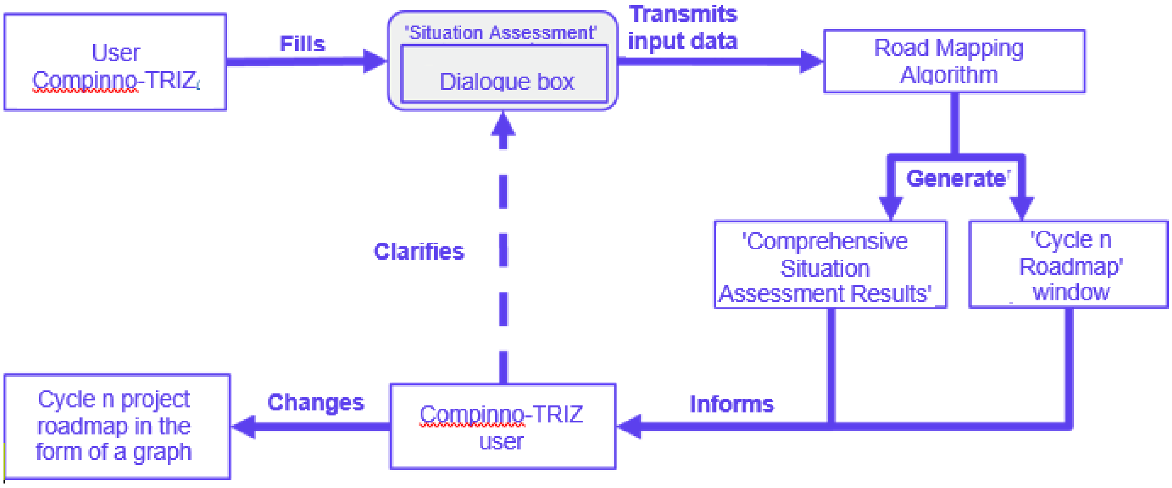
1. Taking into account the influence of the expertise of the TRIZ project manager. A more experienced project manager will surely recognize the components of a problem situation more clearly and will give higher marks. This will result in the roadmap adding the minimum necessary TRIZ toolkit for this particular project manager.

2. Automating the road mapping using software, which will significantly speed up the road mapping and planning process for the project as a whole.

In this way, the textual description of the original inventive situation is given a logically connected formalized digital equivalent, which can be used as input for the road mapping algorithm.

Road mapping algorithm

The road mapping algorithm proposed by the author is broken down into two modules. This modular construction simplifies the algorithm itself, and subsequently simplifies software testing based on the algorithm and error detection. The figure depicts the author's general outline of the project road mapping process based on the proposed algorithm:



The first module of the algorithm relates to the assessment of the initial inventive situation. It can be presented in the form of the following table with estimation rules:

Inventive problem component	**Estimation rule**
Requirement 1, Conflicting requirement 2	The rating may not exceed the rating of the Subject
Ways to meet the requirements	The rating may not exceed the rating of the Requirements
Element and element property upon which compliance with requirement 1 and 2 depends;	The rating may not exceed the rating of ways to meet the requirements

The author has formulated these estimation rules based on the following logic. Since Requirement 1 and the conflicting Requirement 2 are both applied to a specific subject, their wording in an inventive situation may not be clearer than that of the subject. The same approach holds true when formulating rules for the Ways to Meet the Requirements, the Element and the Element Properties.

To illustrate how this part of the algorithm works, let's take a closer look at the process of evaluating the initial inventive situation using examples.

Example 1. 'Wounds are taped over with plasters thus preventing the skin from "breathing". What should we do?'

Below you will find a table with the Subjects rating and the author's rationale:

Situation description component	Wording of the problem situation components	Rating	Rating rationale
Subject	Wounds, plaster, skin	3	Subjects are plenty, but no details are available on subjects. We do not know the plaster type, the degree of wound and the kind of skin, neither we know anything about their characteristics, etc.

Since the Subject has been rated 3, we may not rate Requirement 1 and Requirement 2 higher than 3, but the original situation has been worded in a generalized form, with all the other components missing in the wording, so they can be assigned the lowest possible rating of 1.

Let us take another example, but with a more detailed wording of the inventive situation, leading to higher ratings.

Example 2: 'Boiler operation generates foam at the water-steam interface. By rising with the steam into the steam lines, the foam reduces the steam dryness, sticks to the surfaces of the steam lines and heat exchangers resulting in a reduction in heat transfer efficiency. The presence of foam comes from the high alkalinity of the water, resulting in alkaline corrosion of the boiler surfaces.'

Below is a table with the Subjects rating and the rationale based on the author's analysis of the baseline situation:

Situation description component	Wording of the problem situation components	Rating	Rating rationale
Subject	Boiler, foam, water, steam, steam lines, heat exchangers	4	Subjects are plenty – 6, from the context of the situation description, the subjects are clear and understandable, but it is not clear which one to choose for analysis
Target metric	Steam dryness, heat transfer efficiency, water alkalinity	4	There are three target metrics, they are clearly worded, but it is not clear which one to choose
Requirement 1	-	2	There is a suspicion that Requirement 1 may be 'the foam should not adhere to the surface of the steam pipes'. But since it is not obvious, the author rated it 2
Requirement 2	-	1	Not detected by the author
Way to meet the Rq 1	-	1	Not detected by the author
Way to meet the Rq 2	-	1	Not detected by the author
Element or element property	-	1	Not detected by the author

It is important to emphasize here that these ratings are based on the author's understanding of the available information in the situation description, as well as the author's expertise on the topic of the problem situation. In other words, a different person evaluating the same situation might have different ratings and a different roadmap. Hence, this algorithm accommodates the characteristics of the body of knowledge of the specialist creating the TRIZ project roadmap.

The digitized problem situation from example 2 is as follows: 4-4-2-2-1-1-1. This will be the input for the roadmap creation.

But a mere digitization of the problem situation is not yet sufficient to create a project roadmap that is as tailored as possible.

The author analyses a sample of TRIZ projects in the aluminum industry and highlighted the following problem types: capital intensity, production cost, capacity, yield, reliability, market volume, scope of use, environmental friendliness. The identified problem types were then correlated with the most effective TRIZ tools for a particular type (primarily analytical tools) and their sequencing. The result obtained is summarised in the table below:

Type of problem	The 1-st tool	The 2-nd tool	The 3-rd tool	The 4-th tool
CAPEX	Function Analysis	Function Cost Analysis	Function-Ideal Modeling	-
Cost	Flow Analysis	Limits Evolution Analysis	Function Analysis	El-Field
			Cause-Effect Chains Analysis	-
Performance	Processes Analysis	Limits Evolution Analysis	Function Analysis	El-Field
			Cause-Effect Chains Analysis	-
Quality	Flow Analysis	Subversion Analysis	-	-
Reliability	Cause-Effect Chains Analysis	Function Analysis	El-Field	-
Market size	MPV	Benchmarking	Feature Transfer	-
Scope of use	Function Analysis	Inverse Function Oriented Search	-	-
Environmental friendliness	Function Oriented Search	Benchmarking	Feature Transfer	-

An assessment of the problem situation components is fed into the road mapping algorithm's input. This algorithm represents a set of conditions for adding recommendations, tools and a sequence for adding these tools and is shown as a table below:

Condition	A recommendation is added	Tools are added to the roadmap					
If the Subject is rated 1 or 2	Clarify the subject						
If the Subject is rated 3		Component analysis	Structure analysis				
If the Subject is rated 4		Structure analysis					
If the target metric is rated 1 or 2	Suggest a target metric						
If the target metric is rated 3 or 4	Clarify the target metric						
If Requirement R-1 is rated 1	Select the problem type	Problem density analysis	Tools as per problem type				
If Requirement R-1 is rated 2	Select the problem type	Problem density analysis	Tools as per problem type				
If Requirement R-1 is rated 3	Clarify the Requirement R-1						

If Requirement R-1 is rated 4	Clarify the Requirement R-1						
If Requirement R-2 is rated 3	Clarify the Requirement R-2						
If Requirement R-2 is rated 4	Clarify the Requirement R-2						
If the Method to meet R-1 is rated 1		Function Oriented Search	Contradiction of requirements	Principles			
If the Method to meet R-1 is rated 2		Function Oriented Search	Contradiction of requirements	Principles			
If the Method to meet R-1 is rated 3	Clarify the way to achieve R-1		Contradiction of requirements	Principles			
If the Method to meet R-1 is rated 4	Clarify the way to achieve R-1		Contradiction of requirements	Principles			
If the Method to meet R-1 is rated 5			Contradiction of requirements	Principles			
If the Method to meet R-2 is rated 3	Clarify the way to achieve R-2						
If the Method to meet R-2 is rated 4	Clarify the way to achieve R-2						
If the Element is rated 1		2K analysis	Contradiction of attribute, Ideal Final Result	Standards	Effects Catalogue	Benchmarking	Verification
If the Element is rated 2		2K analysis	Contradiction of attribute, Ideal Final Result	Standards	Effects Catalogue	Benchmarking	Verification
If the Element is rated 3	Clarify the Element		Contradiction of attribute, Ideal Final Result	Standards	Effects Catalogue	Benchmarking	Verification
If the Element is rated 4			Contradiction of attribute, Ideal Final Result	Standards	Effects Catalogue	Benchmarking	Verification
If the Element is rated 5			Contradiction of attribute, Ideal Final Result	Standards	Effects Catalogue	Benchmarking	Verification

This table is worth elaborating on, with a few qualifying comments to gain a deeper understanding of the algorithm's logic.

The underlying assumption of this algorithm is that the roadmap is created based on the information available at the time of creation about the inventive situation and about the things that must be known about the inventive situation to make use of a particular TRIZ tool.

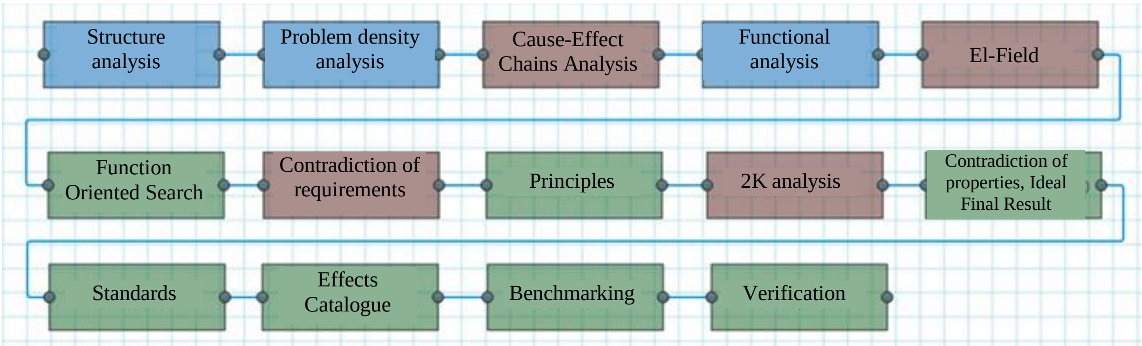
Thus, for instance, in order to formulate a requirement conflict, you need to identify Requirement 1, the conflicting Requirement 2, and the Ways to meet those requirements in an inventive situation. That is, based on what was said earlier, these components of the inventive situation should be rated at least 3.

If Requirement 1 or Requirement 2 are not identified, which means that they have been rated 1 or 2 by the user, then the project will need to identify these requirements using analytical tools, so with these assessments at hand, the 'Problem Type' module is activated in the algorithm and then tools are added based on the selected problem type.

Let's take a closer look at some examples of roadmaps created using this algorithm, based on the wording of the original situations.

Example 3: 'Boiler operation generates foam at the water-steam interface. By rising with the steam into the steam lines, the foam reduces the steam dryness, sticks to the surfaces of the steam lines and heat exchangers resulting in a reduction in heat transfer efficiency. The presence of foam comes from the high alkalinity of the water, resulting in alkaline corrosion of the boiler surfaces.'

The assessment of this initial situation has already been given in detail before, here we will only give the final results: 4-4-2-2-1-1-1. Select 'Reliability' as the problem type. The algorithm yields the following roadmap:

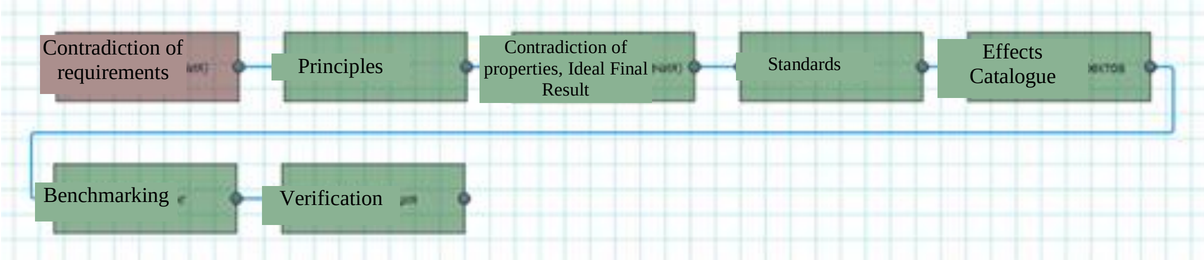


Example 4: Egypt was assisted by the Soviet Union in rebuilding the Suez Canal. During construction work, it was decided to use self-unloading barges. Given the specific conditions, new barges had to be built with a greater capacity and shallower draft, i.e., wider and flatter than existing barges. In order to ensure the right performance, the designers 'opened up' the triangular prism, increasing the angle at its base. A model of such a barge was built and it was discovered that it wouldn't get back to its original position. The keel installed on the barge was no longer able to return it, as the distance to the center of gravity had decreased with the opening of the hull. To bring the barge back to its original position, the keel could have been made heavier, but in that case, you would have to carry a 'dead weight' all the time, which would reduce the useful load capacity. What should be done?

As can be seen, this description is different from Example 3 in terms of the amount and detail of information. Below you will find a table for assessing the inventive situation:

Situation description component	Wording of the problem situation components	Rating	Rating rationale
Subject	Self-unloading barge	5	The subject is clearly defined, throughout the description, the subject is recurrently repeated and clarified in the context of the situation
Target metric	Capacity	5	The target metric is indicated in the problem situation narrative
Requirement 1	The barge must return to its original position	5	Specified in the text of the problem situation
Requirement 2	Ensure that the payload capacity is not reduced	5	Specified in the text of the problem situation
Way to meet the Rq 1	Ensure that the keel is heavier	5	Specified in the text of the problem situation
Way to meet the Rq 2	Barge-mounted keel (as is)	5	Specified in the text of the problem situation
Element or element property	Keel	5	Specified in the text of the problem situation

Final rating: 5-5-5-5-5-5-5. Based on these ratings, the algorithm will give the following roadmap:



It should be noted that the ratings are given by the author, who has gained experience in using TRIZ tools, which makes it possible to effectively detect the components of a problem situation from the description. Where the user is less experienced, the ratings may be set lower and the algorithm will produce a more extended roadmap.

When comparing the generated roadmaps from Example 3 and 4, you can see a significant difference in the number of recommended tools. Since the problem situation in Example 4 has clearly articulated components, there is no need for analytical procedures and we can go straight to formulating and dealing with contradictions. Alternatively, if the problem situation is fuzzy, the length of the roadmap increases, becoming saturated with analytical tools, which will help clarify the problem situation during the TRIZ project process.

The automatic generation of TRIZ project roadmaps significantly accelerates and facilitates the planning phase for users with as yet little experience in TRIZ activities. In this case, automatically generated road maps can be completed manually at the user's request, as well as in case the original situation is reassessed.

CONCLUSION

The project roadmap is a form of visualization of the project implementation strategy and its relevance to the project will ultimately determine the effectiveness of the TRIZ project.

The author's analysis of TRIZ projects in the aluminum industry has revealed that existing methods of road mapping have limited effectiveness. The author's belief is that these methods are highly dependent on the experience of the TRIZ project manager. When TRIZ is massively implemented in industrial enterprises, the experience of TRIZ project managers becomes a limiting factor for growth.

Hence, the road mapping issue poses the following contradiction. An experienced TRIZ project manager ensures a thorough and personalized approach to TRIZ project planning, yet it takes considerable time to train such a TRIZ project manager, which is unacceptable in the mass implementation of TRIZ in industry.

In order to implement one of the solutions to this contradiction, the author has developed an algorithm for road mapping based on the assessment of the initial situation of the TRIZ project.

The intuitive baseline assessment module allows to digitize a particular TRIZ project manager's understanding of the baseline situation and to generate a roadmap based on the baseline situation and the TRIZ project manager's experience. This is expected to boost the efficiency of road maps from 57% to at least 80%.

In designing the algorithm, the author also developed a methodology for calculating roadmap efficiency and a methodology for conducting a blind road mapping experiment, which can be used in later studies.

Logical and desirable avenues for follow-up work on this topic could be as follows:

- Comparison of existing methods of TRIZ project planning with the identification of promising areas for development;
- Implementation of the developed algorithm as software and conducting a large-scale verification with collection and analysis of the data obtained in order to further refine the algorithm.

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Developing TRIZ approaches and methods in IT systems

ABSTRACT

For more than two decades, TRIZ specialists and developers of IT systems have been searching for efficient application of methodological tools in the field of software and hardware development. To date, there is a qualified understanding of when and how the use of TRIZ tools can be effective and fundamentally new. It often happens that such an application directly depends on the formulation of tasks at the business level in IT projects. In this paper, on the one hand, four approaches are identified that differ in the nature of interaction between TRIZ and IT systems, and on the other, business tasks are identified and under what conditions certain tools can be most in demand by the IT development community. The problems and potential of TRIZ application for each of the main information objects of IT systems are considered (Structures and diagrams, interfaces, platforms and systems, hardware architecture, process management\network traffic\big data, algorithms and semantics). Also, a study was conducted on the possibilities of methodological and instrumental integration with specialized technologies in IT systems, similar in their properties to a number of modern TRIZ tools (functional analysis of components and processes, flow analysis), so that their application in this area would be the most productive, would allow to develop and streamline the creative potential of teams developing modern software and hardware solutions and artificial intelligence systems. The article also provides examples and tasks for a better understanding of the specifics of objects and parameters by specialists from other industries. In the final part of the article, the importance of the considered issues is supported by the initiative of the organizing committee of the TRIZ Developers Summit to form research workgroups, in accordance with the previously identified four approaches of interaction between TRIZ and IT systems.

Keywords: *database of inventions, El-field analysis, forecasting, hardware, information, Information technology (IT), instruments, inventive task, IT system, laws of development, methodology, methods, object, processes, software, technologies, tools*

GENERAL INFORMATION ABOUT IT SYSTEMS

Information systems and technologies (conventionally referred to as IT systems) are at the interface between the science of computing systems and business. These are software and hardware products developed with the help of scientific and engineering knowledge in the fields of mathematics, electronics, information theory, engineering of computer systems, complexes and networks, in order to implement information tools in the field of business management and decision-making systems. The tasks and mechanisms of IT systems are to collect, distribute, process, store and extract information. Thus, these systems are designed by scientific and technological approaches and applied as a part of the business infrastructure.

The nature of the development of IT systems is given in the review of evolutionary parameters by class of tasks and by the growth of the volume of processed information, which is growing 10^8 times faster than the total weight of the entire Earth civilization (Table 1)

Table 1. Evolution stages of IT systems

	Before technology	Before computers	1956-	1971-	1980-	1986-	1995-	2010-	2022-
Hardware	Living matter RNA-DNA Nervous system Social connections	Man, signaling systems Languages Writing Documents Libraries Mechanical and electrical devices	Electronic lamps RAM	Semiconductors Magnetic tapes and drums, ADCs.	Integrated circuits Magnetic disks Displays	Microprocessors Computer networks High performance	Personal computer Global networks	Global networks Distributed computing Storage	Cloud technologies Data mining Global data warehouses
Data and data handling	Analog signals Synapse connections Nerve impulses	Signals Speech, Symbols Numbers Input are commensurate with processing	Source data: Numbers, small volume Input faster processing	Character data Object parameters	file systems Databases and integrated use of information.	Databases knowledge bases New data types (date, time, etc.)	Audio Video and other data formats	Data from humans (speech, gestures, images, etc.) and machines	A complete copy of reality: People, businesses, organizations
Tasks	Reproduction, adaptive mechanisms, defense and attack, communication and management	Preservation and exchange of information, formation of social ties	Acceleration of calculations	Complex calculations, construction of mathematical models. Management.	Automated control system, application programs	телекоммуника ции, технология клиент-сервер, виртуальная реальность, мультимедиа	Electronic bidding and attracting customers via the Internet	Managing the behavior of buyers and customers. M2M.	Managing the behavior of large social groups and Govs
Zettbytes	$2{,}6*10^{15}$	0,005	0,02	0,05	0,1	0,2	5	20	100

Under such conditions, the number of problems and tasks in IT systems is millions of times higher than in other technical systems.

A feature of the structure of IT systems is also the presence of a large variety of diverse information entities (Fig. 1).

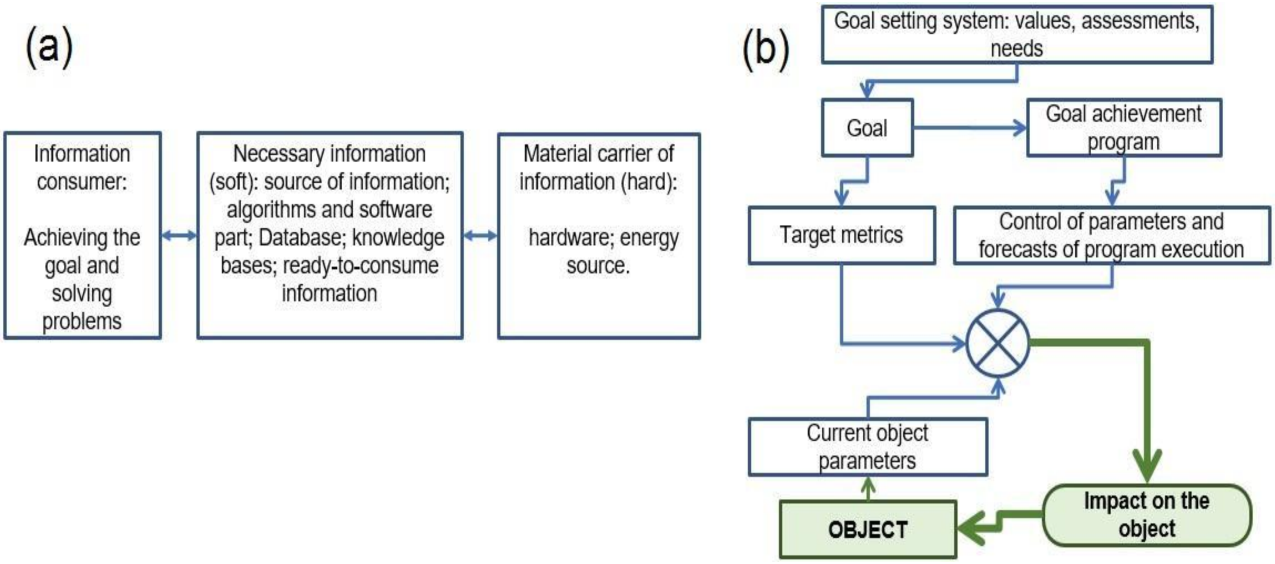

Fig1. a) Information system components, b) Scheme of management and decision making

For typical objects of IT systems (Table 2), TRIZ models were formed based on El-field analysis (Fig. 2).

Table 2. Description of typical objects of IT systems for modeling in TRIZ

	Description	Features for IT system	Samples
Interaction	Two or more components are interconnected in one way or another, relations	The connection between the elements is not material, informational	Database. One variable depends on another variable.
Function (special type of relationship)	Element 1 modifies another element 2 with an interaction field	Field of interaction - informational	Functional relationship between variables, data: formulas, algorithms
Process (special type of function)	Element 1 is modified by influencing it	Original Item 1 can be kept	Replacing letters or numbers, rearranging them, etc.
Flow (special type of process)	A process in which the parameter for changing an element is its location in space	The information flow always has a material carrier flow, which may not move in space.	Movement of information in space, telecommunications
Storage, braking (opposite of process)	Stabilization of the state (parameters) of the element in time	Storage can be dynamic through backups and data recovery	Data storage, data recovery
The transition from material objects to information	Formation of an information image of an object by influencing it with a field or element	Only for IT systems	Sensors of various parameters of material objects
Transition from IT systems to material	Management of a material object based on information	Only for IT systems	Executive bodies of IT systems

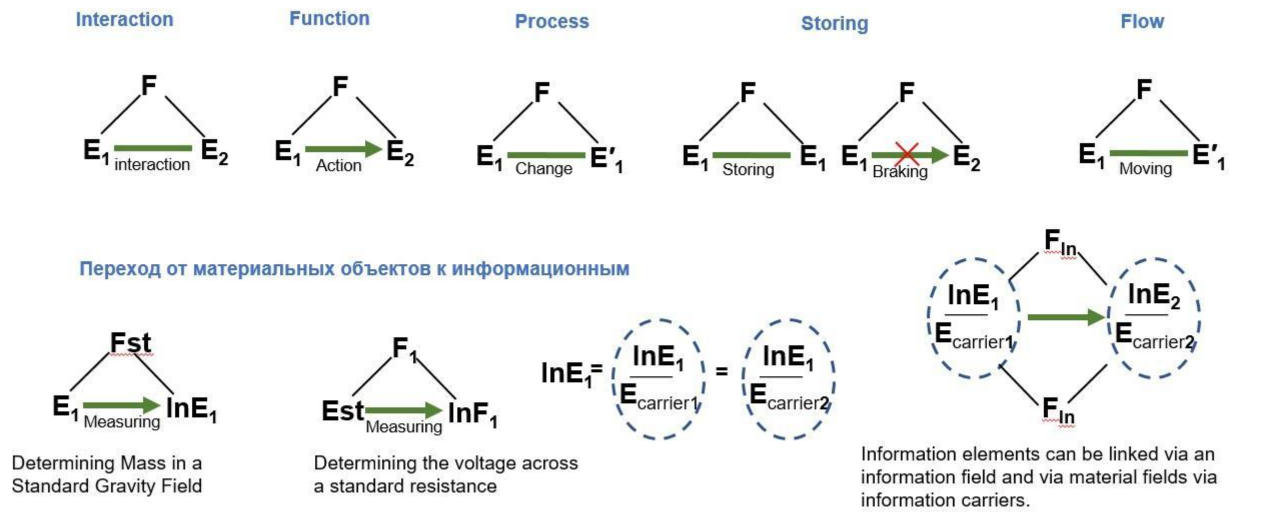

Fig. 2. TRIZ models of typical objects of IT systems via El-field analysis

Approaches to the use of TRIZ with IT systems

1st approach: Transfer of TRIZ for the development of technology to the development of IT systems [1-14]. In this area, it is necessary to: a) expand and systematize the experience of using TRIZ tools in IT, b) adapt the TRIZ laws and tools (El-field analysis, methods and contradiction matrix, etc.) for application to IT, as well as generalize these TRIZ laws and tools for possibilities of their application in IT.

2nd approach: Formation of tools for the development of IT systems based on a file of inventions [15-23]. Systematic file cabinets of inventions in the field of IT systems development and their virtually no analysis. In the literature, one can find no more than a hundred examples of the analysis of inventions in this field by TRIZ methods. This is not enough for the required level of generalizations, allowing to identify new tools for solving problems, techniques and lines of development that are specific to IT systems. One of the systematic sources of information about inventions in the field of IT can be patents for inventions. To do this, we can single out several classes of the IPC, rank the inventions of these classes according to the five levels of inventions accepted in TRIZ, and try to make the necessary generalizations on the tools for solving problems in IT. For example, IPC class G06K – Data recognition; presentation of data; data playback; manipulation of information carriers; information carriers.

3rd approach: Application of general laws of development to IT systems [24-28]. The most complete and instrumental for use in IT is a set of laws for the development of functional-target systems, which, in particular, includes elements of goal setting, decision making and feedback in systems. To conduct research in this direction, it is necessary to analyze the applicability of the proposed set of laws for the development of functional target systems to the evolution of IT systems and the solution of inventive problems in this area. It is also necessary to collect and analyze information about the evolution of IT systems in order to formulate the laws and lines of their development.

4th approach: Application of IT systems for the development of TRIZ and RTV [29-35]. The growth in the practice of using IT systems in the implementation of the TRIZ tool environment in design and consulting activities leads to an increase in options and methods for collecting, processing and visualizing data on the analysis and solution of inventive problems (from different industries). The development and use of IT systems with elements of artificial intelligence, to serve the needs of users in the formation and solution of inventive and creative problems, brings the practice of design and consulting activities in TRIZ to a new level. The development and application of IT systems in the tasks of training and certification of TRIZ helps to scale the practice of mentoring and online coaching.

TOOLS FOR ANALYSIS AND DESIGN OF IT SYSTEMS

To study the potential for applicability and development of TRIZ tools in IT systems, it is necessary to review specialized technologies in the field of IT that have a similar purpose and properties similar to TRIZ methods and tools.

A fragment of such an overview for IT system objects is shown in the table:

Technologies with similar properties of functional analysis \ Function cost analysis	**Technologies with similar properties of Process Analysis / Functional Process Analysis**	**Technologies with similar properties of streaming analysis**
(IT Objects: Structures and Diagrams) Conducted by specialized visualization tools for object-oriented programming (for example, UML technologies). The cost of information entities is not of decisive importance for a software product, unlike material objects.	(IT Objects: Process Management) Specialized information systems are used in the construction and analysis of processes (for example, business process modeling programs).	(IT Objects: Network Traffic) Process modeling for intangible objects is often directly related to the analysis of information flows, based on the collection and processing of a set of statistical data. For these purposes, other specialized tools can be used in parallel (for example, network traffic analyzers, monitoring and analysis of complex data structures).

(IT Object: Interfaces) Produced by specialized tools for developing interfaces and building links between them (for example, interface design technologies).	(IT Objects: Algorithms and Semantics) Specialized information and software tools are used (for example, Automata Theory, coding languages, flowcharts, neural networks, etc.)	(IT Objects: Protocols and Standards) A system for documenting IT systems based on organizational and managerial business processes. The process of documentation has some similarities with the description of justification of decisions and concepts in TRIZ.
(IT Objects: Platforms and Systems) Management of the development of software and hardware platforms and systems is carried out by specialized tools for managing the architecture and interactions of components (for example, DMTF technologies)		(IT Objects: Big Data in AI Systems) The design of AI systems is associated with high costs (for example, computing power), where constant control and optimization of data flows is required (in processor modules, in storage systems, in communication channels, etc.). (routing algorithms)
(IT Objects: Hardware Architecture) The design of the topology of the interaction of components and the architectural development of electronic devices is carried out by specialized tools (CAD technologies of microcircuits)		

Further, the problems and potential of using TRIZ tools in setting tasks in IT are considered:

	Issues	**Potential and objectives of TRIZ application**
Structures and diagrams	The terminological base of functional modeling in TRIZ differs from that used in object-oriented programming (OOP) and has an additional level of abstraction for objects and entities, which reduces its practical expediency.	Evaluating the usefulness and harmfulness of functions/interactions between components can help architects and software developers evaluate solution options. For this purpose, it is possible to expand the functionality of specialized OOP visualization tools.
Interfaces	Functional modeling in TRIZ is not designed to take into account the need for interface prototyping, which is the main purpose of using such technologies.	Conducting functional modeling in interface design can be the most effective among other IT objects. For this purpose, you can expand the functionality of specialized interface development tools.
Platforms and systems	Modeling of components of systems and software and hardware platforms is carried out in the form of text diagrams and classes (parametric objects), which complicates their visualization and the introduction of new options for function analysis	To carry out functional modeling of software and hardware platforms and systems, you can create a special mode of visualization of objects, in which redundant information will disappear for conducting a classic functional cost analysis

Hardware architecture	These tools lack the functionality for conducting function and function cost analyses (FA\FCA), and the TRIZ FA\FCA software does not contain libraries of components and electronics systems.	There is a need to expand the functionality of CAD for microcircuits and hardware solutions for conducting FA\FCA on TRIZ
Process Management \ Network Traffic \ Big Data	The use of function analysis processes without analyzing big data flows sharply limits the scope of implementation. Decision-making tools for operational optimization of processes have not been developed.	Combination of real-time streaming analysis tools with functional process analysis tools, indicating how the ranking of functions changes in dynamics.
Algorithms and semantics	The evolution of languages and programming tools comes from emerging shortcomings and challenges, depending on the development lines of computers and network technologies, which is characterized by big data and the use of AI tools, which greatly complicates the tasks of forecasting.	Forecasting the lines of development of computer technology, to determine new types and programming tools. Investigation of system deficiencies at the design level.

EXAMPLES OF INVENTIVE PROBLEMS FOR IT SYSTEMS

<u>Example 1:</u> PLC (programmable logic controllers) interface code for human interaction must be located in the controller device to ensure its autonomy, but this overloads its functionality when implementing specialized industry solutions.

<u>Example 2:</u> The hardware interface between network devices, which are imbedded inside sensitive systems, should perform one main function for reliable usage, but it leads to multiplication of interfaces and bulkiness in systems of different purposes.

<u>Example 3:</u> The user interface of smartphone should inform the user, anticipating his possible actions with applications, but it can take a lot of screen space and user time. With the growth of multitasking, the problem of developing a user-friendly interface is getting worse.

CONCLUSION

A study of the cumulative experience in four approaches to the interaction of TRIZ and IT systems for their further development showed the need to:

• form a card file for solving inventive problems for gaining experience, developing TRIZ tools for IT systems and implementing TRIZ in IT practices.

• R&D the potential of TRIZ application for the development of specialized tools for the development of IT systems.

• forecast the lines of development of computer technology to predict the problems and shortcomings of information systems.

• often use IT systems in the tasks of training, mentoring and online TRIZ coaching for the development and implementation of TRIZ tools and for the development of a creative personality.

• develop specialized IT systems with artificial intelligence for the development of design and consulting activities in TRIZ

In the direction of TRIZ in IT, at the international public organization of the TRIZ Developers Summit, a working group was formed to launch systemic development on the identified approaches for the interaction of specialists from both areas. The primary task of the functioning of this working group will be the formation of a file of inventions and solutions in IT systems.

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Use of TRIZ tools in biomedical research

ABSTRACT

Goal. To show that TRIZ tools in existing or adapted form can be effectively used in biological and medical research.

Novelty. This topic is still insufficiently described and covered in the worldwide TRIZ community. In the past, the use of TRIZ in biology was mainly represented by the use of bionics, an approach proposed back in his time by G. Altshuller.

Method. We applied the tool comparison method, studied the patterns of development of biology and medicine with TRIZ tools and adapted some TRIZ tools for the needs of biomedical research.

Results. Methodological recommendations on the use of specific TRIZ tools as well as examples of their successful use are provided.

The article provides an analytical review of this topic, comparing the tools, methods, and patterns in the development of biology and medicine with TRIZ tools. Implementation of TRIZ tools for biomedical research. Examples of the use of various TRIZ tools in biomedical research are provided, including examples from the personal experience of the authors.

Keywords: *TRIZ, biology, medicine, biomedical research.*

1. INTRODUCTION

Leonardo da Vinci was the first to use the principles and mechanisms of work and forms of animals in technology.

In the 1950s, the American biophysicist and polymath Otto Schmitt developed the concept of "biomimetics" (Bionics – Wikipedia material). The term "bionics" was coined by Jack E. Steele in August 1958 while working in the Aeronautics Division at Wright-Patterson Air Force Base in Dayton, Ohio[2], where Otto Schmitt also worked. Steele defined bionics as "the science of systems that have some function copied from nature, or that are characteristics of natural systems or their counterparts"

Bionics (from other Greek βίον "living") is an applied science about the application of technical devices and systems of the principles of organization, properties, functions, and structures of living nature, that is, the forms of living things in nature and their industrial counterparts.

G. Altshuller in [1] proposed using the principles and mechanisms of the work of animals, especially ancient ones, for the development of technical systems.

The term Biomimicry has been around since 1982. Biomimicry was popularized by scientist and scientific author Janine Benyus in her 1997 book Biomimicry: Innovation Inspired by Nature... Benyus proposed to look at nature as a "Model, Criterion and Mentor" and emphasizes sustainability as a goal of biomimicry. Biomimetics could in principle, be applied in many areas. Due to the diversity and complexity of biological systems, the number of characteristics that can be imitated is large. Biomimetic applications are in various stages of development, from technologies that may become commercially viable to prototypes.

Today, the development of bionics (biomimetics) is going quite rapidly.

Burton's book Modeling and Differential Equations in Biology [2] describes how differential equation stability theory is used in modeling microbial competition, predator-prey systems, humoral immune response, and dose and cell cycle effects in radiotherapy, among other areas, which include population biology and mathematical ecology.

In mid-1976, V. Petrov conducted research on the possibility of transferring the laws of biology to create a system of laws for technology development. The results were reported at the TRIZ conference in Leningrad in 1977. Later, a book [3] was published based on these materials.

The papers [4] – [19] describe the application of TRIZ to biomimetics and the use of the Altshuller matrix for solving problems in this area.

The purpose of this article is to show a broader application of TRIZ tools in biomedical research. The authors will show this with various examples.

2. EXAMPLES OF THE USE OF TRIZ IN BIOMEDICAL RESEARCH

2.1. History of PCR development

A sample is taken for various DNA tests and for the diagnosis of diseases. However, there are cases when it is not possible to take a sample in the second time and this is the only material that can be used.

What to do?

The answer is obvious – we need to duplicate (amplify) DNA – this is done by using DNA replication (Replication (from lat. Replicatio – renewal) is the process of creating two DNA subsidiaries based on the parental DNA molecule. DNA replication is carried out by a complex, consisting of 15-20 different protein-garments, called a replica. With the help of special enzymes, the double spiral of maternal DNA is covered with two threads, the second thread is completed on each formed thread, forming two identical DNA molecules, which are then twisted into separate spirals. During the subsequent division of the mother cell, each subsidiary receives one copy of the DNA molecule, which is identical DNA to the original mother cell. This process provides accurate transmission of genetic information from generation to generation. The replica is a complex molecular machine that carries out DNA replication. The replica first spins a double-tension DNA into two single threads. For each of the obtained single threads, a new complementary DNA sequence is synthesized. The final result is the formation of two new dual-chain DNA sequences, which are accurate copies of the original dual-chain DNA sequence).

This was done for the first time by the Norwegian biochemist Kjell Kleppe in 1971. To do this, he used the enzyme DNA polymerase, which was first isolated in 1956 by the American scientist Arthur Kornberg from the bacterium *Escherichia coli*.

Some clarification needs to be made.

DNA exists in the form of a double helix, consisting of two separate DNA molecules.

Synthesis of DNA in a living cell is carried out by an enzyme – DNA polymerase, using small RNA molecules as a primer

In 1983, American biochemist Kary Mullis invented PCR and received US Patent 4,683,195 on July 28, 1987. For PCR reaction, before each new cycle of synthesis, a new portion of the enzyme DNA polymerase had to be added to the mixture, because it was quickly denatured due to the high temperatures used in PCR.

A new problem has arisen.

How to make DNA polymerase enzyme be more robust and work longer?

In such cases, TRIZ uses function-oriented search (FOP), which is a technology transfer.

Thus, you need to find an area where this function is performed in difficult conditions and massively. It means that you need to find the ‘thermostable’ DNA polymerase where it would work at high temperatures.

In 1985, Cary Mullis at Cetus Corporation began using thermostable Taq polymerase (isolated from the extremely thermophilic bacterium *Thermus aquaticus*) in PCR reactions, which greatly simplified the work. Taq polymerase was isolated in 1976 by US scientists Ellis Chien, David Edgar, and John Trela. This enzyme remained active even at temperatures above 75 °C.

В 1991 году ученые во главе с Эриком Матуром из биотехнологической компании Stratagene, (Калифорния), обнаружили ДНК-полимеразу Pfu (from *Pyrococcus furiosus*), которая демонстрирует значительно более высокую точность репликации, чем ДНК-полимераза Taq. In 1996, they received patents for exonuclease-deficient Pfu and for complete Pfu (U.S. Patent 5,489,523, U.S. Patent 5,545,552).

The advantages of Taq polymerase are its high speed of work (high processivity).

The disadvantage of this polymerase is the rather high probability of introducing an erroneous nucleotide, since this enzyme lacks error correction mechanisms (3'→5'-exonuclease activity).

The advantage of Pfu polymerase is a much more accurate copying of DNA molecules that significantly reduces the number of mutations in replicated DNA.

The disadvantage of Pfu polymerase is the low speed of polymerization (low processivity).

The contradiction of requirement 1 (CR – 1) for Taq polymerase is the high speed of their work (processivity), but the high probability of introducing an erroneous nucleotide (low proof-reading activity).

CR – 2 Pfu polymerase has a low probability of introducing an erroneous nucleotide (high proof-reading activity), but has a low polymerization rate (processivity).

Property contradictions (PC -1). Why is Taq polymerase likely to introduce an erroneous nucleotide, since this enzyme lacks error correction mechanisms (3'→5'-exonuclease activity).

Ideal Final Result (IFR). High speed of work and high exact copying of DNA molecules.). High speed of work and high exact copying of DNA molecules.

The solution is hybridization. Using them together. Only advantages are remained while disadvantages are compensated.

2.2. PCR apparatus

The PCR apparatus should cycle through the following temperatures – 95, 55, 72 degrees Celsius.

The first PCR machines operated on the basis of heating with a thermal heating element, and cooling was carried out using a fan and air flow. PCR, especially for long DNA fragments, lasted 4–6 hours.

How to shorten the heating and cooling time?

As a solution to the problem, it was proposed to use the Peltier effect or the thermoelectric effect. A Peltier element was installed in the PCR apparatus, which quickly heated and cooled the reaction. It made possible to significantly shorten the process, and PCR reaction began to last 0.5–1.5 hours only, which furthermore made a revolution, especially in molecular diagnostics, particularly, in determining the presence of the coronavirus.

2.3. Quality and concentration of DNA and RNA

Spectrophotometry was used to check the concentration and quality of DNA and RNA (Spectrophotometry – from Wikipedia). To do this, it was necessary to use special quartz cuvettes that let through and did not refract ultraviolet light (230-320 nm). Each quartz cuvette costs $100. It was very expensive. In addition, a lot of scarce and expensive biomaterials were required to fill the cuvette. What can we do?

The contradiction of requirement (CR). Checking the concentration and quality of DNA and RNA requires an expensive cuvette and a large amount of biomaterial, which is not always available. . Those are a contradiction between the need to check and the high cost of the cuvette, and the amount of biomaterial.

Ideal Final Result (IFR). The check is carried out, the cuvette is cheap and the biomaterial costs are low.

Property contradictions (PC). To test, you need to use a large, expensive cuvette and a lot of biomaterials, and to reduce the cost of testing and to reduce the consumption of biomaterial, you need to have a small cuvette and a small amount of biomaterial.

Let's allow PC in the structure.

Solution. They began to use quartz capillaries, which cost $1 only, as compared to $100 of a cuvette.

A new problem has arisen.

If it took a lot of checks and, accordingly, a lot of quartz capillaries were used. In addition, each test required a minimum of 5 microliters of biological material, which was not always available.

Ideal Final Result (IFR). Do not use cuvette or capillary. Biomaterial is not overspent.

Solution. Scientists began to use the technology of holding the sample, which uses only surface tension to hold the sample onto place. This eliminates the need for bulky and expensive cuvettes. A 1 μl sample is pipetted onto the end of the fiber optic cable (receiving fiber). The second fiber optic cable (source fiber) is then brought into contact with the liquid sample, causing the liquid to bridge the gap between the fiber ends. A flash xenon lamp serves as the light source and a spectrometer using a linear CCD array) is used to analyze the light after passing through the sample.

3. CONCLUSION

The article showed the possibility of using TRIZ tools for solving problems in biomedical research.

This approach allows not only a significant reducing the time for solving problems in biomedical research, but also to obtain qualitatively new results and predict new ways of biomedical research.

The authors tried to draw the attention of specialists in biomedical research and TRIZ specialists to further research in this area.

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A. Beliakou

Further prospects for the development of TRIZ

ANNOTATION

The correlation of inductive and deductive logics in TRIZ methods and “tools”, application and comparison of different ways of thinking in TRIZ and artificial neural networks are considered. The tendency to reduce inductive forms of thinking to deductive ones in TRIZ. The identification of the heuristic potential, through various stages of human thinking, for the search, design and study of the properties of a new system is considered. The possibility of formalizing an abstract model of the TRIZ methodology in terms of first-order logic is considered.

Keywords: *ARIZ, TRIZ, system, paradigm, problem, contradiction, logic.*

INTRODUCTION

With the development of such sciences as philosophy, logic, cognitive psychology, the psychology of creativity, as well as the study of various teaching methods and the operation of artificial neural networks, it became possible to better understand the forms of thought processes at various stages of creativity.

METHODS

1. Relationship between inductive, deductive and other logics in TRIZ methods and “tools”. The tendency and necessity of bringing inductive (heuristic) forms of thinking to deductive (rational) ones.

1.1. Forms of managing ideas (abstract concepts)

At various stages of solving a problem, various forms of managing ideas (abstract concepts) can be used – deduction, induction, adduction, tradition, abduction.

1.1.1. The doctrine of how to acquire reliable knowledge was systematized by Aristotle (384-322 BC) in the form of a science of knowledge, deductive logic, set forth in his work "Organon".

Deduction is a logical and methodological procedure through which the transition from the GENERAL to the PARTICULAR is carried out. (See Fig. 1, 2).

Table 1. Deductive method for "Non-Technical" Systems (subject to exact execution)

Field of activity	GENERALIZED KNOWLEDGE – SUBJECT	PRIVATE USE – OBJECT
Administrative and bureaucratic activities	The system of acts of legislation and service instructions.	An official of a administration.
Jurisprudence	The system of acts of legislation and service instructions.	Lawyer.
The science	Already confirmed laws, patterns, theories, hypotheses.	Scientist.
Education	The system of legislative acts, curricula, rules, instructions, orders, legislative acts.	Administrator, teacher, student.
Production	The system of legislative acts, technological maps, service instructions, orders.	Administrator, engineer, technician, worker.
Paramilitary structures	The system of acts of legislation, service charters, instructions, orders.	An official of a paramilitary structure.
Linguistics (from the Latin lingua "language"), linguistics, linguistics.	Morphology, Phraseology, Syntax, Grammar, Semantics, Word formation, Punctuation and much more.	Written and oral speech.

Table 2. Deductive Method for "Technical" Systems

Field of activity	GENERALIZED KNOWLEDGE – SUBJECT	PRIVATE USE – OBJECT
Various technologies	CURRENT SCIENTIFIC PARADIGMS	TECHNICAL SYSTEMS
IT technologies (for example, to the section of various technologies)	CURRENT SCIENTIFIC PARADIGMS	OS, browsers, drivers, programming languages of different levels, algorithm. programs for various purposes.
TRIZ	ARIZ	Part of the steps of the algorithm, (work according to a given instruction, algorithm).
TRIZ	Rational, deductive methods. TRIZ "tools" related to evaluation, comparison, analysis of structure and processes.	Private application to the selected system.
TRIZ	FOS-IFOS – Functionally oriented information retrieval and inverse (reverse).	Private application to the selected system.
TRIZ	AHM – 'Harmful system'. Analysis of the 'harmful machine'.	Private application to the selected system.
TRIZ	DA – Diversion Analysis.	Private application to the selected system.
TRIZ	FA – FUNCTIONAL ANALYSIS OF TECHNICAL SYSTEMS.	Private application to the selected system.
TRIZ	SA – Flow Efficiency analysis. Stream analysis.	Private application to the selected system.
TRIZ	FCA – Functional cost analysis.	Private application to the selected system.
TRIZ	MDMS – Method of decimal matrix search.	Private application to the selected system.
Development of rational forms of thinking	Logic, mathematics.	Solving logic puzzles.

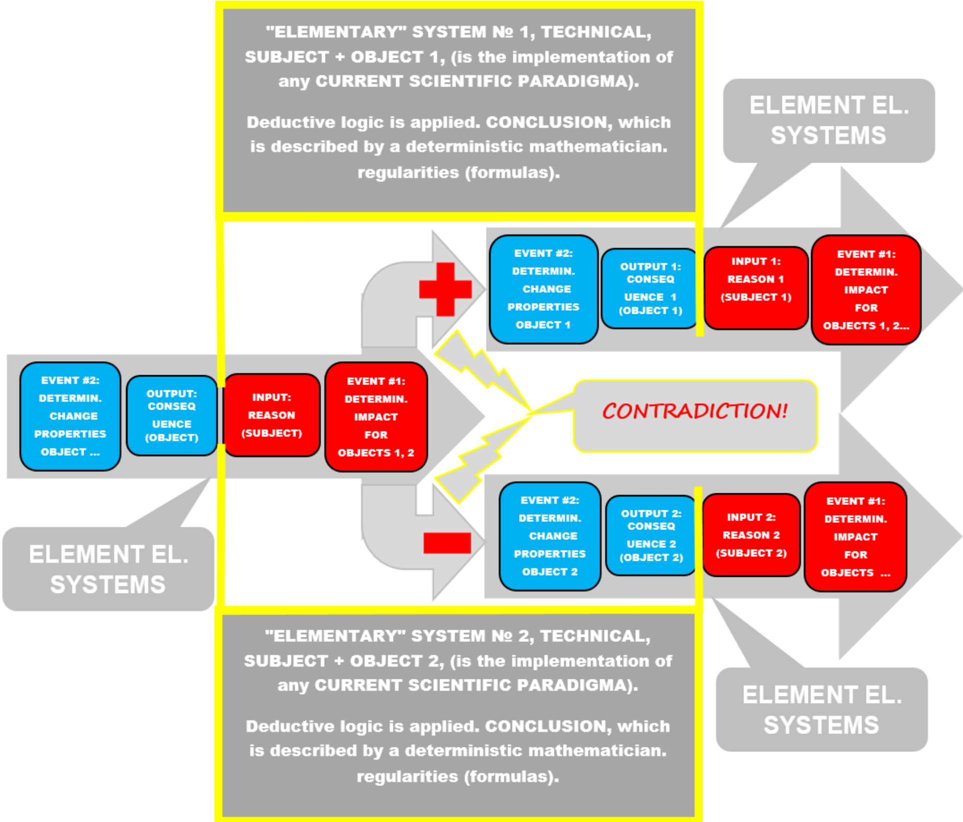


Figure 1. "ELEMENTARY" SYSTEM, TECHNICAL – The system, as much as possible simplified for the purpose of convenience of research; considered as a whole, the formalization of some really existing or projected System. An algorithmic way is used, a deductive logical inference, used in some TRIZ methods, when solving problems. One of the "links" of the CHAIN OF CAUSE AND EFFECT RELATIONSHIPS. An element of an "elementary" System can play the role of a Subject when it acts on an Object, and vice versa, it can also play the role of an Object when another Subject acts on it.

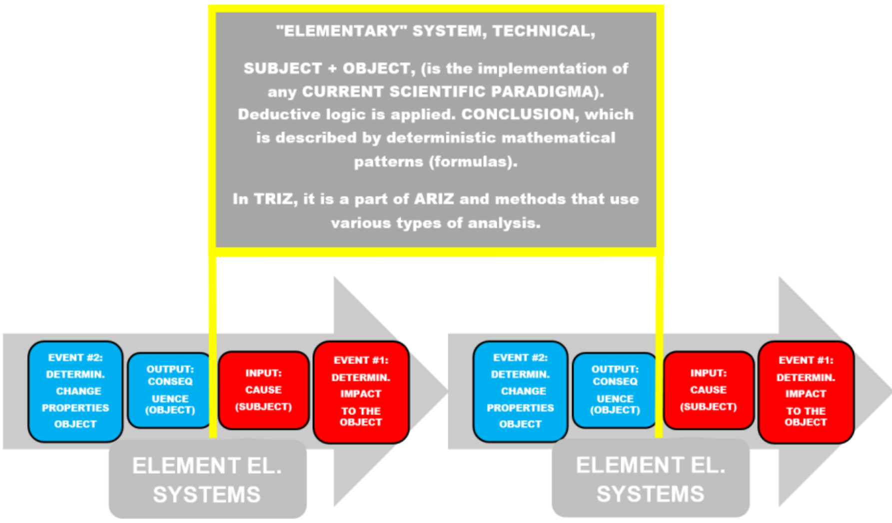


Figure 2. The System in TRIZ has a common Subject and 2 Objects, consists of 2 "elementary" Systems. The 1st "elementary" system produces the desired action for Object 1. The 2nd "elementary" system produces an undesirable action for the Object 2. Between the two results (Consequences 1 and Consequence 2) in the System, a contradiction arises, both Consequences are determined. The exceptions are interactions in quantum mechanics: quantum effects are mainly

manifested on a microscopic scale, and the predictions of quantum mechanics can differ significantly from the predictions of classical mechanics. (The formulation of a contradiction is possible only when deductive logical conclusions are formed in both "elementary" systems.)

1.1.2. The inductive method of cognition, inductive logic – was introduced by the English. philosopher, historian, publicist, state. figure, founder of empiricism and English. materialism by Francis Bacon (1561-1626), in The Great Restoration of the Sciences and The New Organon (1620). Induction – (introduction, guidance, from particular to general, empirical testing of hypotheses put forward or consideration of hypotheses and measuring the degree of their agreement with the facts. Later, such scientists as JOHN FREDERICK WILLIAM HERSHEL (1792-1871), JOHN STUART MILL (1806-1873), William Whewell (1794-1866), Augustus de Morgan (1806-1871), William Stanley Jevons (1835-1882), Pierre-Simon de Laplace (1749-1827). (See Fig. 3).

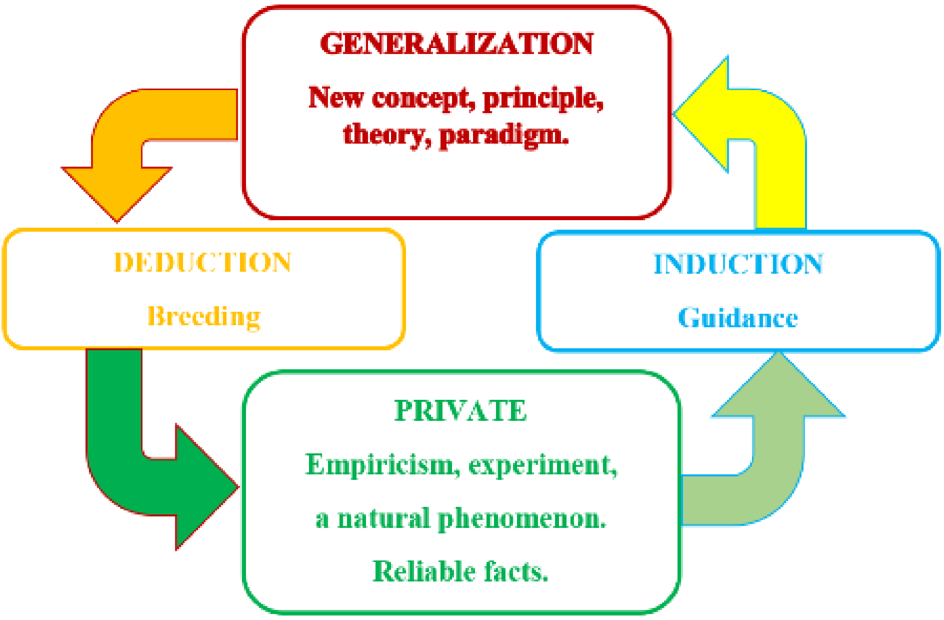


Figure 3. Scheme of the classical representation of the connection between theory, empiricism, induction and deduction

Complete induction – when the generalization refers to a finitely visible field of facts.

Incomplete induction – when the generalization refers to an infinitely or finitely vast field of facts, the conclusion gives probabilistic knowledge. Incomplete induction is divided into two types:

a) Popular induction (enumerative), induction by simply enumerating similar cases), in the absence of a contradictory case, is not reliable.

b) Scientific induction (the transition to general knowledge is made on the basis of identifying the necessary features and the necessary connections between objects and phenomena of nature and society): (See Fig. 4).

* "Selective" (induction on a representative sample) (from the Latin – "I choose") – scientific induction, in which the conclusion about the belonging of a feature to a class of objects is based on the study of samples methodically selected from different parts of this class.

* "Eliminative" (induction on a typical representative) (from Latin – exclude) – scientific induction, in which typical representatives are selected for premises, i.e. items that are fundamentally different from one another.

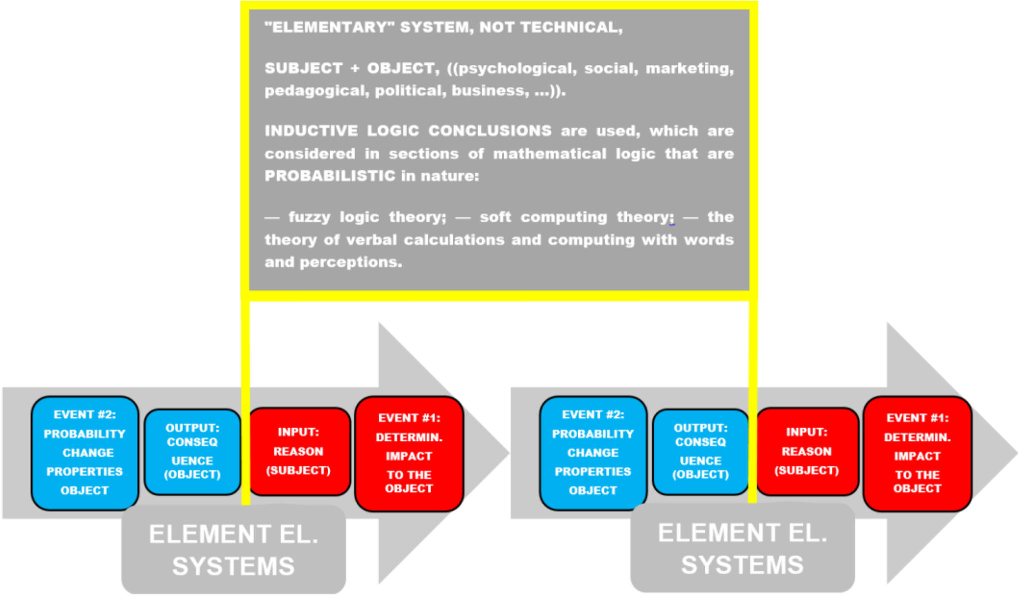


Figure 4. "ELEMENTARY" SYSTEM, NOT TECHNICAL. In some TRIZ methods, when solving problems, a logical inference based on incomplete induction is used. Methods of fuzzy logic theory and the like are used for Event 2 and are designed to calculate the result (Conclusion, Consequence), the occurrence of which has the highest probability from the set of options.

Table 3. INDUCTIVE “TOOLS” and METHODS in TRIZ

"Tools" and methods of TRIZ, activating creative, figurative (eidetic) thinking (suggestive, INDUCTION METHODS):		
Reduc.	**PRIVATE USE – SUBJECT**	**GENERALIZED KNOWLEDGE – OBJECT**
MLP	Method (simulation) of Little People	Principle, axiom, theorem, theory.
SFA	Su-field analysis and its analogues	Principle, axiom, theorem, theory.
STC	Operator Size Time Cost	Principle, axiom, theorem, theory.
SO	System operator	Principle, axiom, theorem, theory.
MSB	Method – a step back from IFR	Principle, axiom, theorem, theory.
MFO	Focal Object Method	Principle, axiom, theorem, theory.
MAU	Method to admit the unacceptable	Principle, axiom, theorem, theory.
MGF	Method "Goldfish"	Principle, axiom, theorem, theory.
MSB	The "Snowball" method (the opposite of the MGF)	Principle, axiom, theorem, theory.
MRC	Method of "Robinson Crusoe"	Principle, axiom, theorem, theory.
RIS	Restoration of an inventive technique method or situation	Principle, axiom, theorem, theory.

The method of mathematical induction and transfinite induction uses complete induction for infinite countable and uncountable sets of objects, respectively, and is not used in TRIZ.

In practice, the researcher, considering a complex System, deals with a chain of cause-and-effect relationships, consisting of non-technical and technical “elementary” systems (See Fig. 5). In order to optimize a complex System, the researcher consistently analyzes each link in its chain (each “elementary” System) and finds “weak links”.

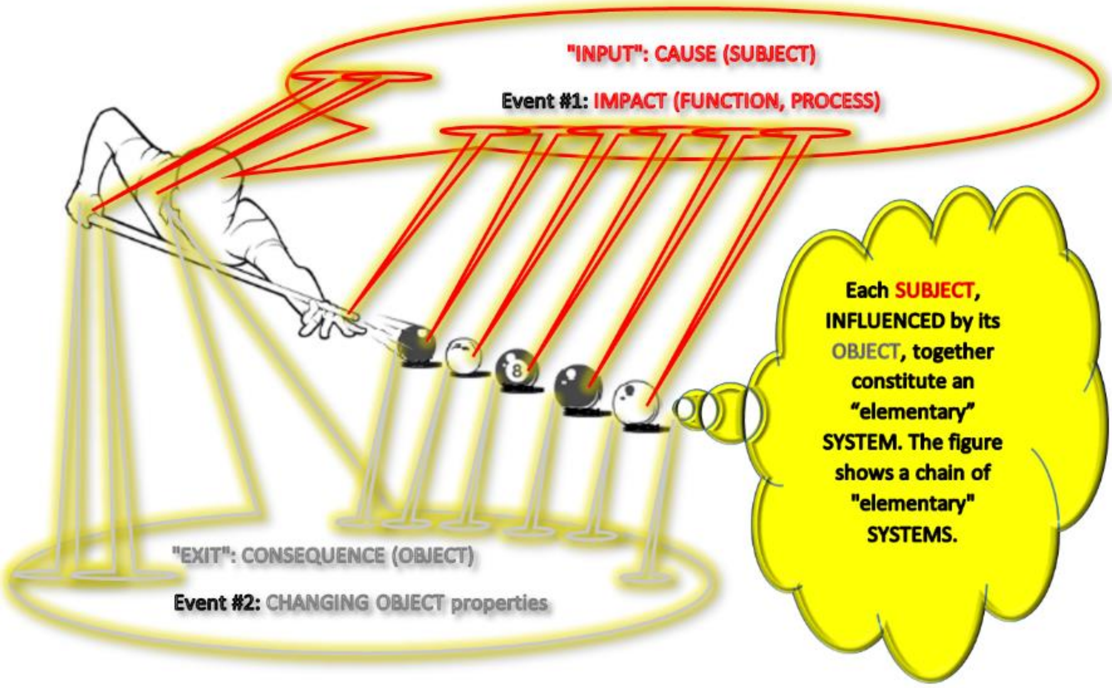


Figure 5. A chain of cause-and-effect relationships, consisting of 2 non-technical and 7 technical "elementary" Systems

Further, in such an "elementary" System or its environment, he searches for Object 2 (an "elementary" System 2 is being built), on which the influence of the Subject has a negative effect (Object 1 with a positive effect is already known in the "elementary" System 1). After that, a "root" contradiction is formulated between the two results in "elementary" Systems 1 and 2 (hereinafter, the ARIZ solution).

1.1.3. Adduction (bringing, attraction, attachment, notation when deduction is attached to induction). In TRIZ, creative, heuristic, "tools" and methods with incomplete induction can be used inside deductive, algorithmic methods, for example: in some steps of ARIZ or inside some stages of the analysis of the structure and processes in the system under consideration. The creator of TRIZ, G. S. Altshuller sought to transform (find common features, generalize, classify), as far as possible, heuristic (inductive, "suggestive") methods of thinking into algorithmic (deductive, "according to the algorithm", "according to instructions"), so that the search for new solutions was more accessible, objective, determined, logically justified, produced in the shortest possible time, by any interested researcher of the problem.

1.1.4. Tradition (movement (analogy (ancient Greek analogia – correspondence, similarity)). Traditive inference is an analogy. According to the nature of the premises and conclusion, tradition can be of three types: a) Conclusion from singular to singular; b) Conclusion from particular to particular; c) Conclusion from general to general.

1.1.5. Abduction ((from lat. ab – "from" and lat. ducere – "lead") (in English abduct – take away by force, kidnap) – a cognitive procedure for putting forward hypotheses. Syllogism, type of reductive inference, abstraction, class of plausible reasoning, search and justification, explanatory hypotheses or the study of facts and the construction of a hypothesis that explains them. The idea of abduction in the form of apagoge goes back to Aristotle. In modern times, abduction was first considered by the founder of pragmatism and semiotics C.S. Peirce, who has been using the term systematically since 1901.

1.2. TRIZ and scientific discoveries.

Experimental methods, and the most radical of them is the "Trial and Error Method" (TaEM), with the correction of the intermediate result by "Error", expand the boundaries of the search for possible solutions and have been used in science for centuries. These methods usually require large material and time costs, but lead to better results (On the scale of G.S. Altshuller – 4, 5 levels of solution quality – discoveries).) In TRIZ, when searching for a new paradigm, it is necessary to replace the outdated system with new, and such a transition is necessary already at the initial stage of solving the problem. (See Fig. 6, 7).

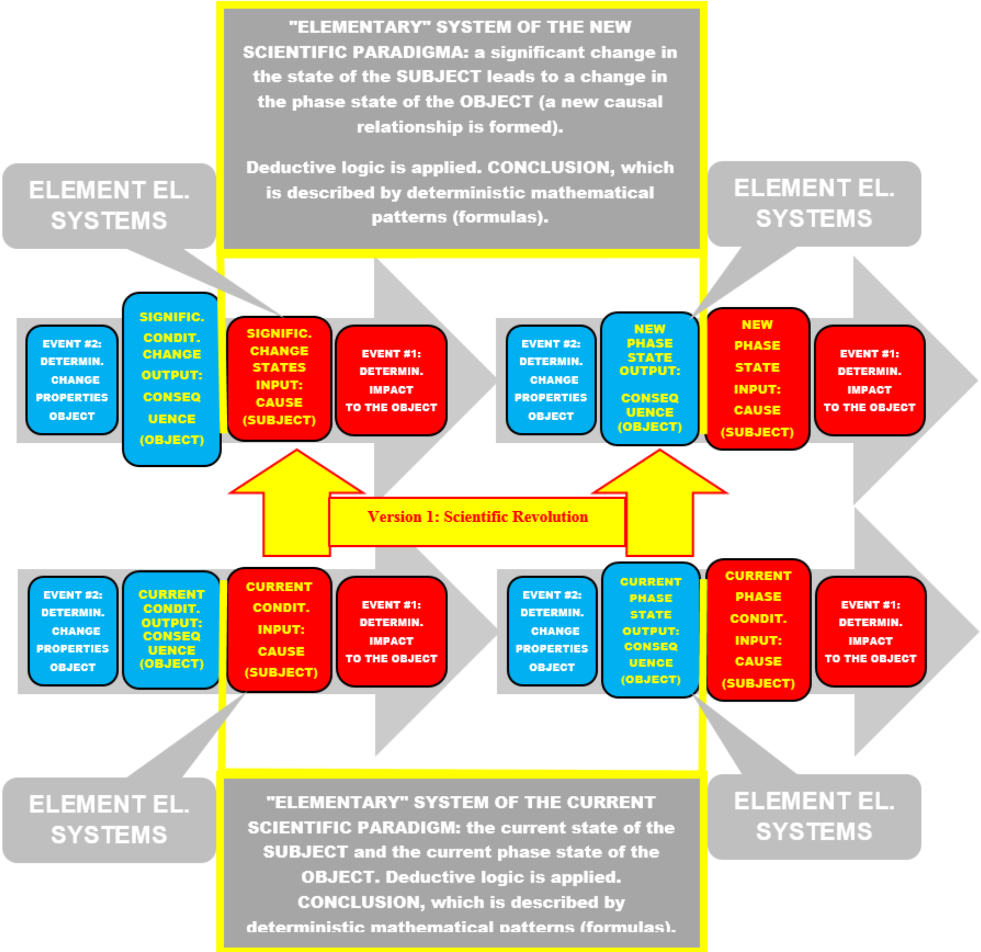


Figure 6. The structure of the scientific revolution (version 1, level 4 of the H.S.A. scale, the transition of the properties of the Object through a critical phenomenon (phase transition point) to a new phase state with a significant change in the state of the Subject): a jump is a transition to the "elementary" System of the NEW SCIENTIFIC PARADIGMA

Each technical "elementary" System is a private implementation of the CURRENT SCIENTIFIC PARADIGMA, i.e. the SCIENTIFIC PARADIGMA is also represented by the "elementary" System, but in a generalized form. The scientific revolution is a transition from the "elementary" System of the OUTDATE CURRENT SCIENTIFIC PARADIGMA to the "elementary" System of the NEW SCIENTIFIC PARADIGMA. At the same time, there is a significant change in the state of the Cause (Subject), the transition of the properties of the Consequence (Object) through a critical point to a new phase state, and a new causal relationship appears between them.

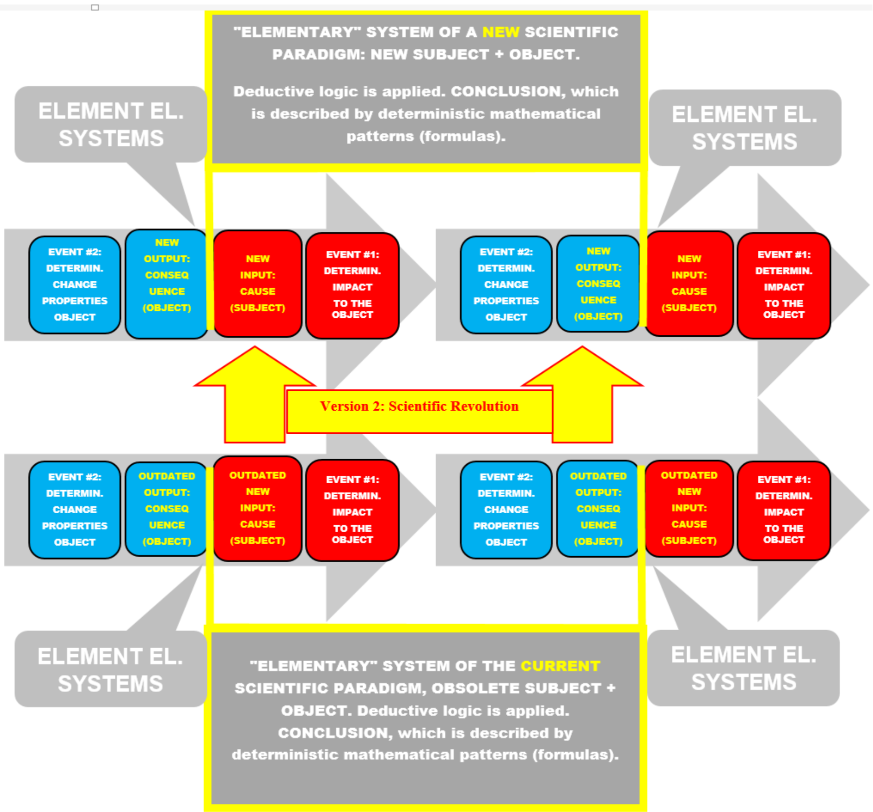


Figure 7. The structure of the scientific revolution (variant 2, level 5 of the H.S.A. scale, complete replacement of the Subject and the Object): a leap is a transition to the "elementary" System of the NEW SCIENTIFIC PARADIGMA

A complex technical System consists of a multitude of "elementary" Systems connected by cause-and-effect relationships. Each technical "elementary" System is a private implementation of the CURRENT SCIENTIFIC PARADIGMA, i.e., the SCIENTIFIC PARADIGMA is also represented by the "elementary" System, but in a generalized form.

At the same time, the Cause (Subject) and Consequence (Object) are replaced, and a new causal relationship appears between them.

1.3. In the scientific method, in the process of observing any natural phenomena or artificially constructed experiments, various facts are recorded. In methods where incomplete INDUCTION is used, logical formalization is carried out by fuzzy logic methods and the results are of high probability. For the complete determinism of the result (Consequence) in the "elementary" System, it is necessary to translate such methods and "Tools", first into methods using full INDUCTION, and then into DEDUCTION (by algorithm, by instruction). Such a transition makes it possible to make the decision process more objective, scientifically substantiated, excluding the subjective factor and programmatically modeled.

2. Identification of the heuristic potential, through various stages of human thinking, to search and explore the properties of the new system.

The founder of the research tradition of studying higher psychological functions, Lev Semyonovich Vygotsky (1896-1934) and the creator of The Theory of Cognitive Development, Genetic Epistemology, and the Operational Theory of Intelligence, Jean William Fritz Piaget (1896-1980), single out "BEFORE CONCEPTUAL" and «CONCEPTUAL" periods of thinking as carriers of the heuristic potential of human thinking.

2.1. The "PRIOR CONCEPT" period has an independent value, it lays the foundations of irrational – creative structures of human consciousness, which have a fundamental PROJECTIVENESS or PROBABILITY.

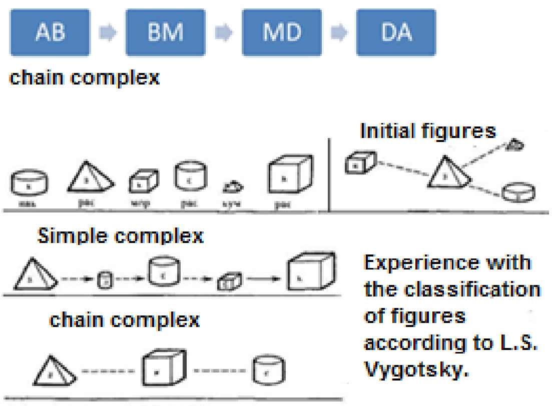
2.2. First, the undifferentiated thinking of the “SYNCRETIC” period is described. In an overabundance of subjective ideas and assumptions lies the potential for heuristics that has always distinguished the thinking of those people whom we call outstanding and brilliant.

2.3. Later, the implementation of intellectual interaction with the world is described not with the help of concepts, but with the help of mental COMPLEXES (the period of “thinking in COMPLEXES” – it lays the fundamental foundations for a creative – variable attitude to the object).

2.3.1. Figure 8. "ASSOCIATIVE COMPLEX" – any associative connection with any of the signs noticed by the researcher in the object, which in the experiment is the core of the future complex. It is possible to build a whole complex around this core, including in it a variety of elements, united by some identical feature.

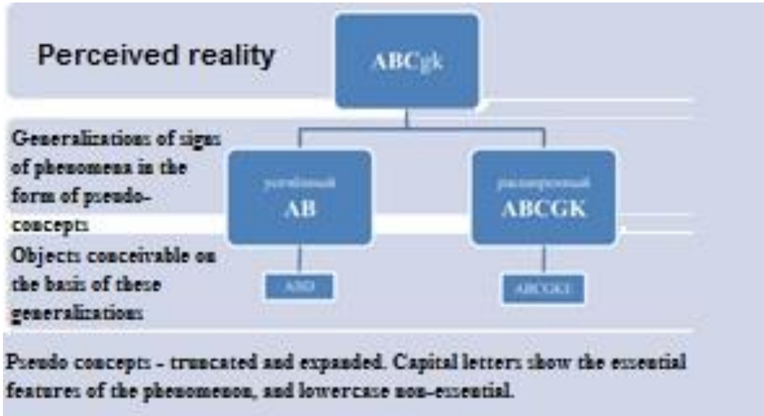
Complex-collection
(Sign - 3 capital letters)

2.3.2. Figure 9. "COLLECTION COMPLEX" – various objects are combined on the basis of mutual complementation on one basis and form a whole consisting of heterogeneous parts.



2.3.3. Figure "CHAIN COMPLEX" – is built on the basis of a dynamic, branching chain of associations. The researcher to the sample – an object with a sign (property, parameter) "A" and "B", selects objects with an analogue. features, and then, if the last of the selected objects is with feature "A" without feature (property, parameter) "B", the researcher selects other objects with feature (property, parameter) "A" and "C", but without sign (property, parameter) "B".

2.3.4. Figure 11. "DIFFUSE COMPLEX" – a sign that associatively unites individual specific elements and "COMPLEXES", as if diffuses, becomes indefinite, spilled, vague.



2.3.5. Figure 12. "PSEUDO CONCEPT COMPLEX" – is formed by the researcher whenever he selects a number of objects for a given sample that could be selected and combined with each other on the basis of some abstract concept.

2.4. Any theoretical thinking, as scientific studies have already shown in the 20th century, has at its foundation a certain "IMAGERING LINING. There is no universal generality of the "CONCEPT" in this "SHAPED LINING", but there is a coiled spring of huge cognitive interest, functioning according to the laws of inaccurate, approximate, vague, incorrect thinking – thinking in "COMPLEXES". At first, thinking is characterized by "COMPLEX" thinking with a predominance of "PSEUDO CONCEPTS" (which corresponds to the boundaries of concrete operational thinking), and only then do "CONCEPTUAL" structures develop (the stage of formal operations arises), "thinking in CONCEPTS".

Based on the concepts of operational thinking by L. Vygotsky and J. Piaget, it is possible to create a software package that will help the researcher and the neural network to create new "CONCEPTS" in various areas of human activity. (See Fig. 13).

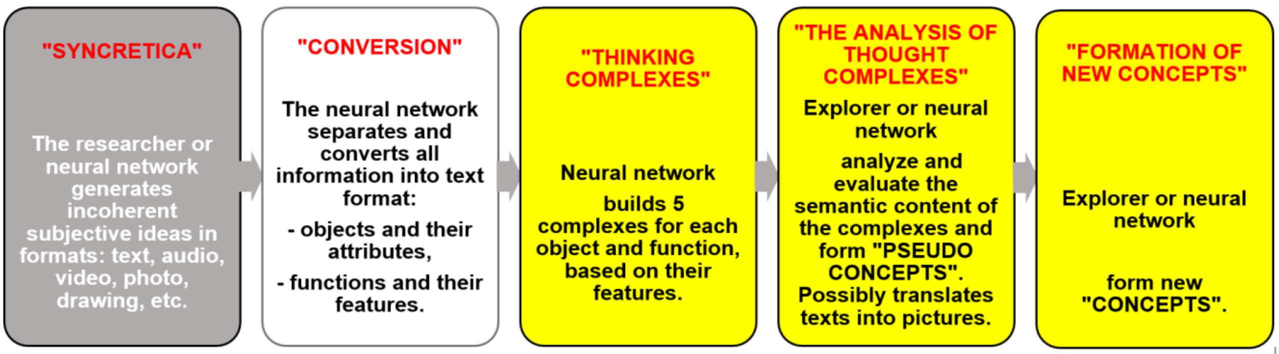


Figure 13. Possible structure of the software complex based on the concepts of operational thinking by L. Vygotsky and J. Piaget

3. Alternative approaches to revealing more methods and "tools" of TRIZ.

3.1. Generalization of methods for solving inventive problems using the world patent base.

3.2. An alternative linguistic approach to determining the possible number of TRIZ TECHNIQUES. The set of stable verb-forming roots in the language is about 400, which gives 400 basic VERBS=ACTIONS=TECHNIQUES for resolving contradictions in the problem under consideration.

3.3. Linguistic approach to the transformation of TRIZ "tools" using the method of incomplete induction into a deductive method (actions according to an algorithm, according to instructions). It is necessary to formalize the possible actions and states of the "Subjects" of a particular TRIZ "tool" through 400 verb-forming roots in the language (Site info: https://pandia.ru/text/77/340/34506.php).

3.4. A possible classification of methods of action is by groups of verbs (See Tables 4, 5, 6, 7).

Table. 4. A group (type, class) of verbs, with the meaning: "ACTION AND ACTIVITY"

PREDICTS EXPRESSED BY A VERB WITH MEANING "ACTION AND ACTIVITY" IN MONOSUBJECT SENTENCES (https://grammatika-rus.ru/)		
1.	Verbs of motion denote an independent action. Their meaning is always based on the starting point of the movement:	run, wash, fly, fall, trudge, fall out, jump, ride, squeeze in
2.	Object movement verbs – they always have a dependent form (someone, someone, somewhere):	carry, carry, drag, take out, push out, fish out.
3.	Room verbs (a kind of movement):	put, hide, hammer (nail), throw, wrap, dress, close
4.	Verbs of physical impact on an object (often destructive):	beat, press, prick, touch, cut, plan, dig, weld, break
5.	Creative verbs:	compose, invent, decide, build, mold, prepare, write, fix
6.	Verbs of intellectual activity:	to understand, to know, to think, to decide, to compare, to compare, to choose, to suppose
7.	Verbs of speech activity:	whisper, tell, negotiate, gossip, command, apologize, congratulate
8.	Verbs of social activity:	to strive, to make friends, to work, to resist
9.	Verbs of physical action:	drink, breathe, See
10.	Sound verbs:	ring, hum, tick, gurgle, sing

Table. 5. A group (type, class) of verbs, with the meaning: "RELATIONSHIP" ("RELATIONAL")

PREDICTS EXPRESSED BY A VERB WITH MEANING "RELATIONS" IN MONOSUBJECT SENTENCES (https://grammatika-rus.ru/)		
1.	Relationship verbs	
1.1.	Relationships:	marry, meet, interact
1.2.	Substitutions:	replace
2.	Ownership verbs	
2.1.	Object search:	search
2.2.	Acquisition verbs:	get
2.3.	Verbs of getting at your disposal:	accumulate, pluck
2.4.	Getting an object in def. quantity:	take, win, borrow

2.5.	Alienation:	snatch, take away
2.6.	Offset Acquisition:	rent, change
3.	Possession verbs:	to own, to have
4.	Conservation verbs:	save, save, spare
5.	Loss of object verbs:	lose
6.	Deprivation verbs:	deprive, plunder
7.	Object transfer verbs:	give, reward
8.	Verbs of interpersonal relations:	pamper, believe, fall in love, honor, thank, greet, get along, tame
9.	Social relation verbs:	induce, lead, command, influence, terrorize, draw in, agitate, depend on, protect

Table. 6. A group (type, class) of verbs, with the meaning: "BEING, STATE, QUALITY".

PREDICTS EXPRESSED BY A VERB WITH MEANING "BEING, STATE, QUALITY" IN MONOSUBJECT SENTENCES (https://grammatika-rus.ru/)		
1.	Verbs of life:	to be born, to appear, to appear, to exist, to live, to live, to disappear, to dissolve, to perish
2.	Quality verbs:	develop, decrease, turn white, grow old, grow wiser, settle down, take offense, grieve, get drunk, annoy, get sick, sleep, work, move, start

Table. 7. A group of verbs, with the meaning: "IMPACT ON THE WILL OF ANOTHER PERSON"

Predicials expressed by a verb with meaning semantics "impact on will of another person", in monosubject sentences (https://grammatika-rus.ru/)		
1.	Verbs of speech activity:	allow, forbid, adviseorder, ask
2.	Social impact verbs:	compel, help, teach
3.	Movement verbs:	let in, carry

4. Comparison of the search for a solution to a problem in neural networks (of natural or artificial origin), with the search for a solution in an abstract TRIZ model, what is common and what is different.

4.1. Neural network – stage 1 (training). The Inductive method ("induction", incomplete induction) is used. The signal (information) "repeatedly" moves through the multilayer structure of an artificial neural network with a given (or flexible) feedback architecture between network elements, for the purpose of technical training. Learning consists in finding the coefficients of connections between neurons ("weights of connections"). In the learning process, the neural network identifies complex relationships between input data and output data, performs generalization. To limit the search space in the training mode of the neural network, the TASK is set to MINIMIZE THE ERROR of the objective function of the neural network.

4.2. Neural network – stage 2 (working). The deductive method ("inference") is used. Promotion and selective change of signal parameters ("filtering"), according to the already configured and verified set of "weights" of neural connections (parallel use of multiple algorithms, "instructions"), in order to search for patterns and other tasks.

4.3. The question often arises: how do artificial intelligence systems built on the architecture of neural networks (NN) (digital or analog) and TRIZ tools compare?

An abstract model for solving a problem in TRIZ, uses DEDUCTION METHODS ("derivation", according to an algorithm, according to instructions) with "interspersed" as necessary, IN-

DUCTIVE (guiding) methods and "tools". tasks that can be solved by artificially created neural networks in artificial intelligence systems is the restoration of the original data set (signal, image) in terms of information (from noisy or damaged input data. Such a task can be described as an inverse process to identifying relationships between various parameters – (auto-associative memory It is possible to apply to search for the best method, technique, standard, VLOOKUP for TRIZ in a specific problem – THE TASK OF MINIMIZING THE ERROR of the objective function of the key parameter.

Neural networks work according to principles similar to those of ARIZ – achievement (IFR), but they use not one (or several), but many micro-algorithms by Trial-and-Error Method (TaEM). A set of micro-Ideal Final Results (micro-IFR) is achieved by correcting the weights of the links of the NN and obtaining the output value of the parameter, which, when compared with the target parameter, will have an error (Target function), which will be minimized with each iteration cycle of the NN until a minimum is reached, which will match the final IFR.

5. Disadvantages of TRIZ systematization.

5.1. Insufficient classification of methods, tools, techniques, resources used in TRIZ. Possible classification through groups of verbs that describe actions. (See 3.2.)

5.2. Insufficient hierarchy – methods, tools, techniques, resources used in TRIZ. It is possible to create structure through groups (classes) of verbs that describe actions. (See 3.3.).

5.3. In the root classification, it is necessary to divide the methods, tools, techniques, resources used in TRIZ into deductive (algorithmic, deterministic) and inductive (guiding, figurative, probabilistic) methods).

5.4. Some experts have an opinion that techniques and functional resources, derivative resources are one and the same, which will allow them to be combined as functions (See 3.2.,3.3.).

5.5. Analysis of the evolution of systems (and scientific paradigms) in accordance with empirical patterns and lines of development used in TRIZ, for greater scientific objectivity, requires the definition of a more rigorous quantitative mathematical formalization. (For example: Moore's empirical law, by doubling the number of semiconductor elements every 2 years (and according to David House from Intel, every 1.5 years).

6. Formalization and development of the logical and mathematical apparatus of TRIZ.

6.1. To formalize inductive methods and TRIZ tools in non-technical systems, it is necessary to use fuzzy logic methods. Lutfi Zadeh's "fuzzy logic" was an attempt to relate mathematics to an intuitive way of communication that people access, are guided in communication and interact with the world. There are more than 100 methods for converting fuzzy inferences at the linguistic level into computational schemes. Using formulas, a fuzzy production rule can be represented graphically.

6.2. Transition, where possible, to the full formalization of deductive methods in terms of first-order logic (on the example of ARIZ):

WFF G1: P(f(C), O1), true. P (Positive) – a predicate that reflects the desired effect of the Subject (C) on the Object 1 (O1) (Cause / Effect).

WFF G2: N(f(C), O2), true. N (Negative) – a predicate that reflects the undesirable effect of the Subject (C) on the Object 2 (O2) (Cause / Effect). A contradiction arises between the predicates P and N, one Subject performs the desired action on Object 1 and an undesirable action on Object 2.

WFF G3: M(f(CX), C), true. M (Modifer) – a predicate that reflects the modifying effect of the Subject X (CX) (Cause) on the Subject (C) (Consequence), to eliminate the contradiction between the predicates P and N.

WFF G4: M(f(CX), C) ∧ N(f(C), O2) → MN(f(CCX), O2), true. MN (Modification Negative) – a new predicate that displays the conjunction of two predicates M(f(CX), C) and N(f(C), O2), which takes the value "true" for some desired values of CX from the set T, for which the predicate N(f(C), O2) takes the value "false". The truth set T for a predicate is the intersection of the truth set of the predicate M(f(CX), C) – T1 and the set of false values N(f(C), O2) – T2, that is, T = T1 ∩ T2.

WFF G5: MN(f(CCX), O2) ≡ ¬N(f(¬C), ¬O2), true, logical equivalence or equivalent, reflects the positive result achieved.

7. What is TRIZ lacking to become an interdisciplinary science or a new logic in the group of non-classical logics?

7.1. " "De facto", Geinrich Saulovich Altshuller created "CLASS LOGIC bypassing (eliminating, avoiding) the contradiction (conflict) existing in the system", which, with the appropriate mathematical formalization, should take its place in science (perhaps in the group of non-classical logics).

7.2. Science is an activity aimed at developing and systematizing objective knowledge about reality. (Subjective assessment of the TRIZ path covered – See Tables 8, 9).

Table 8. Science. (Subjective assessment of TRIZ compliance with the following criteria: (48/80) *100% = 60%).

Table 8

№	Science suggests	Score	TRIZ
01.	Collection of facts.	10	Collection of patent and inventive solutions.
02.	Regular updates of facts.	8	Correction, expansion, updating of methods for solving inventive problems in printed publications, articles on websites and magazines, at conferences.
03.	Systematization.	5	The systematization of patent and inventive solutions is insufficient (the number of patents and applications in the world is approaching 20 million).
04.	Critical analysis.	3	G.S. Altshuller criticized harshly and constructively, upon presentation of clear evidence, he agreed. The current state of criticism of TRIZ “bottlenecks” is not perceived constructively by everyone.
05.	Generalizations.	5	Generalizations of patent and inventive solutions, to develop methods for solving problems, are already starting to lag behind the pace of development of science and technology. Generalization of the ARIZ methodology to logical chains in the works of V. Petrov. Generalization of empirical experience in the patterns of systems development.
06.	Synthesis of new knowledge that describes observed natural or social phenomena and indicates cause-and-effect relationships, which allows forecasting.	7	There is a forecasting of the development of systems, but these are mostly empirical patterns, based on previous experience, mathematical formalization is sorely lacking.
07.	Hypotheses that describe a set of observed facts and are not refuted by experiments are recognized as laws of nature or society.	7	There are no refutations, but the regularities are mostly empirical, there is an acute lack of mathematical formalization.
08.	Recognition by the scientific community.	3	The absence of a deterministic mathematical apparatus. Ideally, when the determinism of the theory is formed by unambiguously defined causal relationships. Although there are examples (quantum field theory, for example, when causal relationships are probabilistic, the same applies to fuzzy logic theory).

7.3. Scientific method – a system of categories, values, regulatory principles, methods of justification, samples, etc., which guide the scientific community in its activities.

Table 9. Scientific method. (Subject evaluation according to TRIZ criteria: (95/120) *100% = 79.17%)

№	The scientific method includes	Score	TRIZ
01.	Ways to study phenomena.	10	Identification of the problem and understanding of the situation. Documentation, goal setting and planning, modeling. Decomposition of the selected task, division into separate subtasks. Synthesis – generation of ideas for solutions. Evaluation and selection of the optimal solution idea. Evaluation of the evolutionary potential of the system. Evaluation of various risks associated with the practical implementation of the solution.
02.	Systematization of new and previously acquired knowledge.	7	There is some incoherence of individual methods, isolation from each other.
03.	Correction of new and previously acquired knowledge.	7	Correction of knowledge is difficult due to the lack of a unified base (library) of TRIZ knowledge.
04.	Inferences and conclusions are made using the rules and principles of reasoning based on empirical (observed and measured) data about the object.	7	There is subjective perception of the observer.
05.	Observations and experiments are the basis for obtaining data.	10	Yes, definitely.
06.	To explain the observed facts, hypotheses are put forward and theories are built.	7	Yes, but there is a lot of subjectivity, depending on the level of knowledge and experience of the researcher.
07.	On the basis of hypotheses and theories are built, a model of the object under study is built.	7	Yes, but there is a lot of subjectivity, depending on the level of knowledge and experience of the researcher.
08.	The requirement of objectivity, excluding the subjective interpretation of the results.	5	The objectivity of the interpretation of the results is difficult; there is subjectivity, depending on the level of knowledge and experience of the researcher.
09.	Any statements should not be taken on faith, even if they come from reputable scientists.	5	In teaching, students can take on faith any not entirely correct statements coming from the teacher, due to the logical model of the subject that has not yet developed.
10.	To ensure independent verification, observations are documented, and all initial data, methods and research results are made available to other scientists.	10	Yes, of course, no one hides the secrets of how the process of solving the problem went.

11.	Independent verification allows not only to obtain additional confirmation by reproducing experiments, but also to critically assess the degree of adequacy (validity) of experiments and results in relation to the theory being tested.	10	Yes, undoubtedly, the reproduction of observation (experience, experiment) is the basis.
12.	The philosophical basis of the modern scientific method is logical positivism (neopositivism) and postpositivism. Both of these directions consider observation (experiment, experiment) to be the criterion of truth, but they differ in interpretations of which hypothesis can be considered scientific.	10	Yes, undoubtedly, observation (experiment, experiment) is the basis.

CONCLUSION

The article considered the key provisions of possible forms of information processing in TRIZ, artificial neural networks, as well as possible directions for further development of TRIZ:

● The need to reduce inductive methods and TRIZ tools to deductive ones;

● The use in thinking of the heuristic potential inherent in mental pre-conceptual structures and complexes according to L. Vygotsky and J. Piaget. The possibility of creating a heuristic software package based on the concepts of operational thinking;

● The structure of scientific revolutions from the point of view of TRIZ;

● The ability to search for new techniques, methods, "tools" of TRIZ, using neural networks to summarize the information contained in the world's patent databases;

● Possibility of expansion, classification, formalization, hierarchy of the structure of techniques, methods, "tools", TRIZ resources, using an alternative linguistic approach;

● Initial formalization of ARIZ in terms of first-order logic.

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Industrial Parks: Problems and Solutions with TRIZ

ABSTRACT

This article shows a case study of TRIZ application in Urban Construction Management. In China, there are many traditional industrial Parks built in the late 20 century in some large cities, especially in the urban district. After several decades, poor infrastructure and fiscal revenues making them difficult for the parks to play a role in promoting urban development. So, these old parks are unutilized and need to be transformed and upgraded timely. In this article, this problem was solved by TRIZ tools, such as Inventive Principles, Trends for systems evolution and Su-Field analysis, and a new transformation model called "zero-cost entrepreneurial community" was proposed to promote the transformation for traditional industrial Parks in the large cities and upgrading into "new enterprise communities".

Key words: *TRIZ; industrial park; large city; construction mode*

1. Background of the problem

In China, there are many traditional industrial Parks in some large cities, especially in the urban district. These parks are built in the late 20 century and have made a great contribution to the development of cities for many years. But after several decades, many parks are starting to fall into operational difficulties because of the poor management, poor infrastructure and poor fiscal revenues. So, these parks are difficult continuing to play a role in promoting regional development. Specifically, there are several questions: for example, The industrial Parks are scattered, small and the layout is disorganized, Lack of impetus for traditional industries in the park, For the Park administration, they are just as Property Service providers and rent collection with bad service. So, it led to the departure of many companies originally in the park, and many carriers will also be idle. These problems reflect that there are some difficulties of regional development by relying on the industrial Park. For example, Existing industrial Parks cannot carry new functions to promote the development, and the new industrial Park needs a lot of input, but for abilities limited, especially lack of money. So, a new mode for these traditional industrial Parks should be designed to adapt to the current development environment.

Here a word “carrier” needs to be explained. In this article, carrier means a small unit supporting industry agglomeration and regional development. In fact, the carriers have many forms, such as a building, a plant, an incubator, all can be regard as the carriers of the industrial Park. For example, an industrial Park consists of ten buildings, and each building can be regard as a carrier.

In China, there are some researches on the construction mode of the parks from both the theoretical and practical levels. For example, A mode was proposed that the symbiosis of agglomeration effect and industrial Park construction as an evolutionary game of dynamic matching of institutional supply and demand based on the automobile industry in Jilin, China [1]. Four modes for industrial Park construction all over the world are summarized, and four strategies to the upgrading for Chinese industrial Parks are proposed [2]. The four kinds of carriers under the Headquarters Economy have been sorted out and the construction mode of the Beijing Fengtai Advanced Business Park in

China is summarized [3]. The construction mode, operation and maintenance, and business model of intelligent industrial Park has been discussed [4]. But in general, this research is basically based on the Industry Organization and Institutional Economics to design the construction mode of the industrial Parks, focusing more on the macro level and less on the micro level.

2. BRIEF INTRODUCTION OF TRIZ

TRIZ, known as the Theory of Inventive Problem Solving, was proposed by G.S. Altshuller in the former Soviet Union in 1946, based on the analysis of 2.5 million patents around the world [5]. Altshuller found that many seemingly unrelated inventions and creations actually follow the same or similar innovation principles or laws. More and more practice show that TRIZ is not only a theory for solving invention problems, but also a paradigm for thinking problems. With the widespread application of TRIZ, TRIZ is now gradually applied in other fields, such as natural science, social science, management science, biology and other fields [6]. Now TRIZ has proven to be a knowledge-based, human-oriented and systematic innovation method.

With the expansion of TRIZ application, the optimization of the solution mode and process based on Classical TRIZ have been researched according to the disciplinary characteristics of management science and the needs of problem research [7–10], in order to making them more suitable for solving management problems.

3. PROBLEM ANALYSIS

The industrial Park in the large cities can be regarded as a system, and a Function model of the industrial Park in the large cities is shown in Figure 1. Generally, the main function of the industrial Park is "promoting development", including industrial development, employment promotion, and commercialization of scientific and research findings, while general auxiliary functions can be realized through social service.

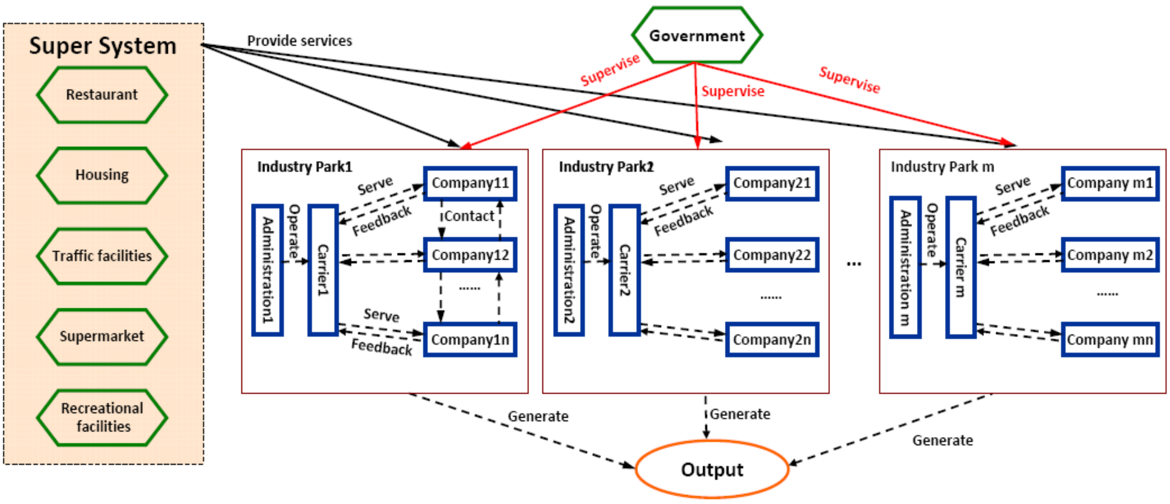

Fig. 1. Function Model for an Industrial Park

The function model shown in Figure 1 is relatively complex. For ease of analysis, the function can be simplified as shown in Figure 2.

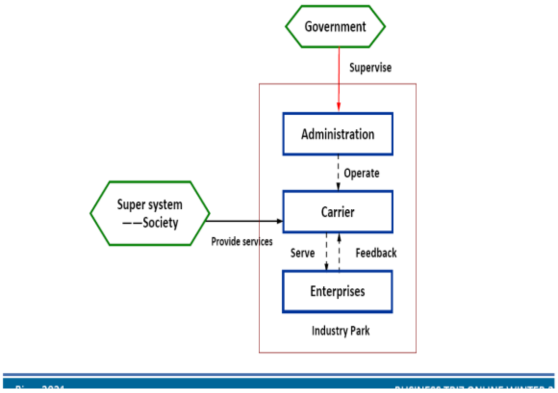

Fig. 2. Simplified Function Model

In this model some function disadvantages are clearly presented including some harmful function and insufficient functions. Then the key disadvantages can be determined by deeper analysis as "administration could not operate the carriers very well", which is an insufficient function.

To solve this problem, the Ideal final result of the problem can be determined firstly: For this problem, the Ideal final result is: A park that can play the role of promoting the development of cities and boosting innovation by itself. Therefore, the better way for achieving the Ideal final result is building a new park, everything starts from scratch and everything is new. But the realistic problem is there is not sufficient land in the urban district of large cities to build a new park. If it's in a suburb, may be totally different. So, a more suitable way for the cities is transforming the existing parks, which is easier to achieve the Ideal final result, but in fact, it is more difficult to reconstruct existing parks than building a new one. Thus, a contradiction is appeared.

IF: reconstructing existing parks

THEN: it is easier to achieve the Ideal final result

BUT: more difficult for reconstruction

Next, the contradiction can be expressed with the typical parameters by Altshuller. The improving parameter is Ease of operation, and the worsening parameter is Ease of manufacture. In this way, the Contradiction Matrix can be used to find proper invention principles to solve the contradiction.

4. PROBLEM SOLVING

4.1 Inventive Principles

After defining the technical contradiction, the available inventive principles are identified as NO.2 Taking out, NO.5 Merging, and NO.12 Equipotentiality from Contradiction Matrix. Therefore, some solutions can be got by these inventive principles, see Table 1.

Table 1. Solutions from Inventive Principles

Inventive Principles	Solutions
No.2: Taking Out	Selecting the idle carriers from all the industrial Parks in the urban districts of lager cities.
No.5: Merging	Combining the idle carriers as a whole park by merging in time.
No.12: Equipotentiality	Establishing interconnected links within the combined idle carriers.

By integrating the above solutions, a feasible solution can be obtained as: The existing idle carriers in the large cities, which can be transformed to satisfy the expected functions, can be integrated as a whole “new” park. Since the location of the carriers could not be changed, all the carriers can be “gathered” together for unified planning, unified operation and unified management, which can be regard as “Chain Mode”. By this mode, the same or complementary functions will be done for the carriers on different locations in this new park, and to achieve uniformity in service. Thus, the enterprises can enjoy the same quality of service no matter what carriers they are in.

4.2 Secondary problem solving by Trends

The secondary problems were appeared when solutions are generated by inventive principles: Should the functions of the carriers be unified? How to define the functions for each carrier of the “new” park on different locations?

Here the Trends for Business can be used to solve the secondary problems. For this problem, the line of “Diversity Increase” of the trend “Structure Evolution” can be used define what should the park develop. see Table 2.

Table 2. Solutions from The Line “Diversity Increase”

Lines	Example
A homogeneous system of identical objects	Software industry in all the carriers
A homogeneous system with a different but similar object(s)	Software industry for this park except IT Outsourcing in one carrier
A heterogeneous system of different objects	Software and Integrated Circuit Design in different carriers
A system of objects with opposite properties	Software and Hardware in different carriers

Here is an example for the solution: An industrial Park want to build the software cluster. In the Homogeneous system, software will be in all the carriers. If the system is Homogeneous with shift part, one carrier can be chosen to develop IT outsourcing, and software in others. Next Heterogeneous system, the park can attract software and IC Design companies. And Inverse system, Software and Hardware are simultaneously developed which is called “IT innovation industry” in China. So, the government can determine what kind of companies they should attract into the park.

4.3 Su-Field and Standards

A Su-Field Model can be derived on the basis of Function Analysis. See Fig.3. Here the administration and carrier can be regarded as two kinds of substances. The operations and services from the administration to the carrier can be regarded as a field (F). The administration (S_2) operates and provides services to the carrier (S_1), which should be an effective role under normal conditions. But in fact, administration are lack of the professional capabilities and talents to operate and provide services to the multi-spatial carriers of the park, which is resulting in insufficient role.

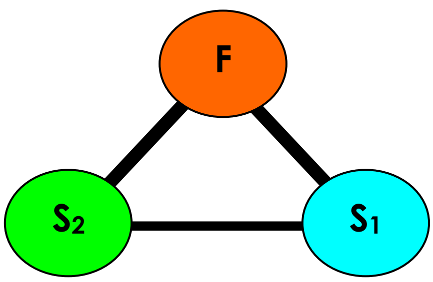

Fig. 3. Su-Field Model

Now this Su-Field Model can be solved by Inventive Standards 1.1.3. Here a new substance can be introduced as an intermediary (S_3), which can be a professional organization or team. See Fig.4. This is because the professional organization or team has extensive expertise and capabilities on park operation and services, and also familiar with the law of industry development. Which can provide specialized and customized services for different parks and carriers. The government can invite professional organization or team to help the administration operate the carriers. Even instead of administration operating the carriers. When the administration itself has the capabilities to operate and provide services for the carrier, it can also solve the problem without introducing a professional team.

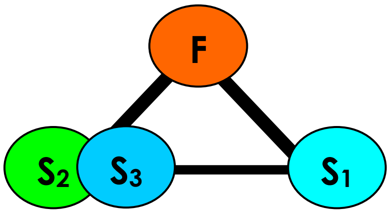

Fig. 4. New Su-field Model by Inventive Standards

5. DERIVATIVE PROBLEM SOLVING

Here is another situation: Nowadays a surge of entrepreneurship can be seen in China, and there is a very popular word said in China: "Mass Entrepreneurship, Mass Innovation". Many people start their life of entrepreneurship, especially the college students. When they just finished their undergraduate or graduate school, they come to the large cities and become makers. The goal for them is very simple, that is: Living in Peace and Working in Contentment.

In large cities, they can choose to work in the carriers. But their living are provided by super-system. Because in the large cities, the industrial Parks have not enough lands and money to carry out the living function. And the society, as a super-system, can provided the wonderful living infrastructures. But as is known to all, the living cost in large cities are very high and the makers have no stable income to support. So, it is necessary to reduce their living cost. Therefore, "How to reduce the living cost of makers" has become a derivative problem of this project.

This problem can also be solved by Su-Field analysis and Inventive Standards. Here a Su-Field model is derived which S_2 representative's carrier and S_1 representative's maker, also an insufficient model.

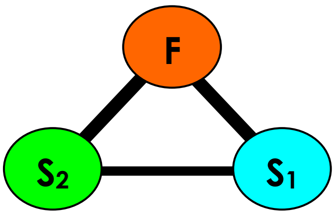

Fig. 5. Su-Field Model for makers

Here this problem can be solved two Inventive Standards: S3.1.1 and S3.1.4. First a bi-system will be built by S3.1.1, carrier for living (S_3) can be added into S2 as a "new" system. Then the bi-system convoluted to a mono-system by S3.1.4, thus the carrier itself has the functions of working and living at the same time. For the makers, It means their startup is also their home. In this way, some measures can be taken to reduce their living cost, in order to attract more makers to start their entrepreneurship in carriers.

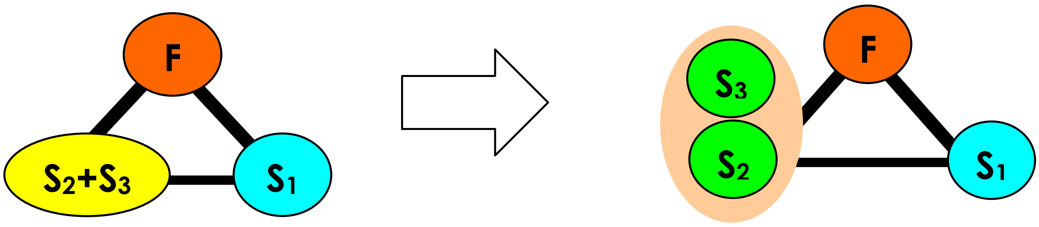

Fig. 6. New Su-field Model for makers by Inventive Standards

6. FINAL SOLUTIONS

The final solution can be obtained through the above solution.

1. Integrating all the idle parks and operate them as one park, and a new administration can be established for all the idle parks. Then the Chain Mode can be used and professional teams will be introduced for operation. In addition, the function of the carriers on different locations can be moderately differentiated the according to the actual situation of the park.

2. The function of the government should also be transformed from supervising and intervening to helping the companies, in order to change the harmful function to the useful function.

3. For the makers, some apartments can be built, and supporting measures can be taken for reducing their living cost, such as tax incentives and waivers, one-stop services system, building some infrastructure for public service, service for the basic necessities of life, such as a small restaurant, café, laundry, and gym. In this way, makers can be encouraged to start their journey of entrepreneurship through the apartments. Such the apartments can be called "Zero-cost entrepreneur community".

In recent years, this solution has been applied in some large cities in China and achieved good results.

7. SUMMARY

In the future, the way of expanding the scale for industrial Parks are not suitable for the future development. So, the new possible ways should be found for development, for example, changing business model, adjusting industrial planning, Improving the competitiveness of industrial Parks, and Balancing Economic development and people's livelihood.

By solving this problem, a new transformation mode is proposed as "Zero-cost entrepreneur community". This mode means the park can be transformed into a community integrating work, life, leisure and entertainment. And some Start-up Apartments can be built which can unify the location of home and company for makers. Finally, the professional team should be introduced for Industrial Park operation. This shows the new construction mode based on TRIZ in this article also provides a reference for park construction and development in large cities.

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V. Petrov, D. Petrov

Using the patterns of system evolution to solve business problems

ANNOTATION

The latest worldwide events significantly affect the development of the business ecosystem in the world. The war in Ukraine, changes in supply chains, the energy crisis, and other processes create uncertain conditions for business to develop and even exist. The tools that will allow company's owners and managers to make quick and correct decisions are being raised more and more acutely. It has been repeatedly proven how TRIZ tools help to find contradictions, create innovations and solve complex business problems. But the needs are also in the development of companies, the creation of the future state, and forecasting. These issues are closely related to a company's willingness to invest in the right areas.

In this article, the authors propose to expand the set of tools and apply the patterns of systems evolution not only for business solutions but also for the development of business and companies in general.

Keywords: *TRIZ, business tasks, patterns of development of business systems*

1. INTRODUCTION

There is no need to talk about the difficulties that business has been facing lately. Every year there are new challenges, restrictions, competition, and also destabilizing factors.

A few years ago, it was shown how TRIZ tools help to solve business problems and find ways of development. But little attention was paid to the laws and patterns of systems development, although this toolkit deserves special consideration, as it can help find a quick solution to business problems.

The development of the laws of development of technical systems (LDTS) has been carried out for a long time. The first work known to the author on the late development of technology was written by G. Hegel in the paragraph "Mean" of the work "Science of Logic" [1]. "Technique is mechanical and chemical, because it serves the goals of man, that its nature (essence) depends on its features (laws of nature)."

In 1843, W. Schultz describes the prototype of the *law of the completeness of the parts of the system. He wrote that "it is possible to make a transit between the tool and the machine: a spade, a hammer, a chisel, etc." etc., systems of levers and rifles, for the use, however skillfully they may be, of the driving force of the servant man ... all this fits the call to accept; meanwhile, a fork with its moving life force, wind cabinets should be counted among machines"* [2].

A little later, some laws of the development of technology were described by K. Marx and F. Engels.

K. Marx described these laws in the section "Development of machines" [3, p. 382–396]: "... *the difference between a tool and a machine is established in that with a tool, a person serves as a driving force, and the driving force of a machine is a force of nature that is different from human power, for example, an animal, water, wind, etc." [3, c. 383]. Further, K. Marx writes: "Any developed machine device consists of three essentially different parts: a machine-engine, a transmission mechanism, and finally, a machine-tool, or a working machine. The engine-machine acts as the* *driving force of the whole mechanism. It either transmits its motive power itself, either as a steam engine, caloric engine, electromagnetic engine, etc., or it receives an impulse from outside, from some ready-made force of nature, like a water wheel from falling water, a windmill wing from the wind, etc. e. The transmission mechanism, consisting of flywheels, movable shafts, gears, eccentrics, rods, transmission bands, belts, intermediate devices, and accessories of various kinds, regulates movements, changes, if necessary, its shape, for example, turns it from perpendicular into a circle, distributes it and transfers it to working machines. Both of these parts of the mechanism exist only to impart movement to the tool-machine, thanks to which it captures the object of the labor and expediently changes it. ... Initially, the "machine-tool" (working machine) represented, in a very modified form, all the same apparatuses and tools that an artisan or manufacturing worker works with, but these are no longer tools of a person, but tools of a mechanism, or mechanical tools"* [3, p. 383–384]

Some additional material can be found in the works of F. Engels on the history of the development of military equipment and warfare. These are the works of 1860-1861, in particular: "About a rifled gun", "History of a rifle", "Defense of Britain", "French light infantry", etc. [4]. Some rudiments of the laws of development of technology and its interaction with man and society are set out in the works of K. Marx [5].

A certain contribution to the understanding of technology and its laws was the creation of a "philosophy of technology" [6]. This term was introduced by German scientist Ernst Kapp. In 1877, he published the book "Main Lines of the Philosophy of Technology" [7]. The main development of this trend took place at the beginning of the 20th century. The development of the "philosophy of technology" was carried out by German scientists F. Dessauer [8], M. Eit [8], M. Schneider [9], and others. In Russia, this topic was developed by P. K. Engelmeyer. In 1911, he published the book "Philosophy of Technology" [10]. All these works discussed the theoretical and social problems of technology and technical progress.

P. K. Engelmeyer in the first issue of "Philosophy of Technology" gives an overview of ideas about technology, in the second he shows the connection of technism with philosophy, and the last two issues are devoted to human activity and technical creativity.

The questions of the history of technology, classification, and definition of the concepts of technology were dealt with by many scientists in different countries: K. Tussman [11] and J. Müller [12] (in Germany), V. I. Svidersky [13], A. A. Zworykin [14], I. Ya. Confederates [15], S. V. Shukhardin [16] (in Russia), and others. In 1962, a fundamental work on the history of technology was published [17]. Questions about the philosophy of science and technology are set out in a book with the same title [18].

Based on the study of the history of technology, K. Marx formulated some laws of technology development [18]: *The law of the emergence and growth of needs; The law of accelerated development of the means of production; The law of continuous development of new types of industry*.

Various scholars have described the requirements for the development of engineering and engineering sciences. Attempts were made to classify the laws and patterns of technology. These include the works of J. Bernal [19], D. Killefer [20], J. Klaucho and E. Duda, L. Tondle [21], I. Müller, D. Teichmann [22], K. Tessman [23], L. Styribinga [24], B. M. Kedrova [25], O. D. Simonenko [26], V. M. Rozina [27].

Philosopher V.P. Rozhin singled out two types of laws of development of any systems [28]: *Laws of the structure and functioning of systems; Laws of systems development*.

Thus, we can say that the first group of laws is needed to build a system and its systemic functioning, and the second one determines how the system will develop. In our opinion, this is the most correct representation.

Yu. S. Meleshchenko created the most fundamental work of that time on the laws of technology development [29]. The researcher identified two main and largest groups of laws and patterns: *Laws of the structure and functioning of technology; Laws of technology development*.

In addition, Yu. S. Meleshchenko [29] identifies two large groups of patterns in the development of technology:

1. Internal patterns of development of technology (the system of technology itself).

2. External patterns of development of technology. Patterns in the development of technology, emerging as a result of its interaction with other social phenomena (the system of society as a whole).

The system of laws of technology was developed by A. I. Polovinkin [30]. He divides them into two groups: the *laws of the structure of technical objects and the laws of the development of technology*.

E. M. Balashov described the patterns of evolution of **anthropogenic (artificial)** systems in his monograph [31].

More details about this can be found in the work of V. Petrov [32]

J. Diskson [33] shows how systems can be designed without applying the laws of development of technical systems (LDTS).

For the first time, the LDTS system was developed by G. Altshuller [34]. He described ways to predict the development of a technical system in the future. B. Zlotin and A. Zusman [35], using the system (LDTS) of G. Altshuller, created chains of patterns in the development of technical systems. On the basis of the above works, V. Petrov developed his own system of laws and patterns of system development (since 1984), constantly improving it, which is finally presented in [36]. In this work, he showed on a large number of examples from different fields of knowledge how systems can be developed.

B. Zlotin, A. Zusman, and L. Kaplan outlined the patterns of development of teams [37]. The patterns of development of a creative personality were described by G. Altshuller and I. Vertkin [38]. D. Mann [39] described the application of laws in business. Teong San Yeoh [40] described the application of various TRIZ tools in business and management. These are interesting attempts, but, unfortunately, there are still few examples of using patterns to solve business problems.

In this article, the authors propose to expand the set of tools and apply the laws of system evolution not only to solve business problems but also to develop business and companies in general. We will consider only some of the patterns of system evolution [36]:

In this article, we will consider only some of the patterns of the evolution of systems:

1. Pattern of change in the degree of the ideality of systems;
2. Pattern of change in the degree of controllability and dynamism of systems;
3. Pattern of transition to the supersystem and subsystem.

2. PATTERN OF CHANGE IN THE DEGREE OF IDEALIZATION OF THE SYSTEM

The pattern of change in the degree of ideality is the main pattern of the evolution of systems.

The pattern of change in the degree of ideality includes two patterns:

1) the pattern of increasing the degree of ideality;

2) the pattern of decreasing the degree of ideality (anti-ideality – the tendency to reduce ideality).

2.1. General concepts of the pattern of increasing the degree of ideality

The pattern of change in the degree of ideality is the main pattern of the evolution of systems.

G. Altshuller wrote: “The concept of the ideal machine is one of the fundamental for the entire methodology of the invention.”

The general direction of the development of systems is determined by the law of increasing the degree of ideality. This is the most important law of the evolution of systems.

G. Altshuller formulated this law:

The development of all systems goes in the direction of increasing the degree of ideality.

The authors slightly changed this wording.

The law of increasing the degree of ideality is that any system in its development tends to become more ideal.

The general direction of the development of systems is determined by the pattern of increasing the **degree of ideality**. This is the most important pattern in the evolution of systems.

The pattern of increasing the degree of ideality lies in the fact that any system in its development tends to become more ideal.

One way to increase the degree of ideality is to minimize redundancy. Redundancy reduction refers to the reduction of functional and **structural redundancy**.

The reduction of functional redundancy means the maximum possible reduction of additional functions, such that it does not affect the performance of the main function of the system, i.e., the functionality of the system would be performed at the same or better level.

The reduction of structural redundancy involves the reduction of "extra" parts and connections in the system. At the same time, the system should not only remain operational, but functionality should not suffer – it should be performed at the same or better level.

Redundancy can be reduced by using a convolution pattern.

Example. Crisis in the company.

When during a crisis in a company, consulting companies (Big Four: E&Y, PWC, Deloitte, KPMG, and others) offer to remove several levels of managers, that is, remove several links between performers and top management. Thus, the company reduces functional redundancy and removes additional functions (in this case: management functions).

2.2. Types of degrees of system idealization

Conventionally, four degrees of idealization of the system can be distinguished:

1. Appear at the right time in the right place;
2. Self-execution;
3. The ideal system is a function;
4. The function becomes unnecessary.

2.2.1. The system should appear at the right time in the right place

The ideal system *should appear at the right time in the right place and carry the full (100%) design load*.

During the rest (non-working) time, this system should not exist (it should disappear) or perform *other useful workload (function)*.

The right action should appear at the *right time in the right place or under the right condition*.

Let's give an example of an ideal impact (process) performed in the *right place at the right moment, without harming the environment*.

Example. Bank card

Bank cards are often lost or numbers fall into the hands of scammers. Apple Pay and Google Pay cards appear on your phone at the time you need to make a payment.

The subject or object should appear only at the right moment in the right place.

Example. Service outsourcing

Outsourcing of services in different directions. For example, outsourcing IT services is very popular now. The company does not host IT specialists but hires a third-party company to provide IT services. Thus, the developer (or ultimately the service) appears at the right time in the right place. There are many types of outsourcing services.

2.2.2. Self-execution

An ideal system should perform all processes (actions) independently (by itself) without ***human intervention***.

Example. Robotization of processes

UiPath has become a European "unicorn" (a startup with a capitalization of 1 billion USD) by offering market solutions for robotic business processes. The company offers solutions to change human work to robots (robotic process).

Cybernetization of labor saves a person from managing the process. Higher degrees of cybernetization are automation (computerization) of mental activity. This process is sometimes referred to as *intellectualization*.

Example.

Google Assistant.

You can set a task, for example, to book a restaurant or a hairdresser, and the assistant will find a place, call to the company and book a table or service.

The ideal information should appear ITSELF, without spending time and effort searching for it.

Example. Advertising business

Sometimes people are surprised when they discuss any topic with their phone close to them (items, trips, new things, and so on), then the search engine or social network will make recommendations for these items. There is nothing surprising here, even if the phone is locked, the microphone can “hear” the conversation, and then the application makes recommendations.

2.2.3. The ideal system is a function

The ideal system should not exist, and its work should be carried out as if by itself, by the wave of a “magic wand”.

The function must be performed without funds.

An ideal system is a system that does not exist, *and its functions are performed at the right time, in the right place (and at this time the system bears 100% of the calculated load), according to the necessary condition, without spending any substances, energy, time and finance*.

Example. Google Cloud Solutions.

Companies host their applications on Google Cloud. When more users appear, the number of resources (required servers) increases proportionally. As soon as the number of users decreases, unnecessary resources are simply turned off. In fact, for a company that buys a Google service, there are no servers, and functionality appears when necessary.

Thus, an *ideal system* should perform *useful functions* at the right time, in the right place, according to the necessary condition, *have zero costs,* and *have no undesirable effects*.

The information usage has no cost if it does not require financial resources. The system is ideal when it uses more free information.

Trend: *The material system is being replaced by a virtual or software system*.

Example.

Cryptocurrency has become an alternative replacement for fiat currencies. Now in several countries, the purchase of goods and services with Bitcoin is allowed.

2.2.4. The feature is no longer needed.

The limiting degree of idealization is the rejection of the function – the function becomes unnecessary.

Example. Taxi call

Previously, when calling a taxi, the client used the services of a dispatcher (who suggested where the car was when to leave the house, and so on). With the advent of the Uber app, the dispatcher function became unnecessary.

2.3. Anti-ideality

Anti-ideality is a tendency opposite to the pattern of increasing the degree of ideality, i.e., a tendency to decrease the degree of ideality.

In an anti-ideal system, the number of functions tends to 1, and in order to achieve the goal, time and money are not taken into account. An anti-ideal system can cause harm.

Often, in an anti-ideal system, they strive to achieve the highest possible quality of a function, regardless of the costs, and possibly the harm caused (undesirable effect).

Anti-ideality is **super-redundancy**.

Anti-ideal systems are typical for achieving political and military goals, for creating military equipment and security equipment, in particular, for fighting terror, and for creating unique objects and prestige.

Wars are a unique example of anti-ideality, as they illustrate both very high costs and colossal harm.

Unique objects, luxury items, and prestige, in addition to their main purpose, can be considered examples of anti-ideality, especially if we take into account the material and human resources spent on their creation.

Example. Enron

The collapse of Enron is a good example. Enron was the leader in the energy market. Top managers of the company used private jets, received large bonuses, and thus showed the high status of the company. The company went bankrupt in 2007.

Thus, the pattern of anti-ideality manifests itself when goals are achieved, where they do not take into account costs or harm. The development of mass-produced goods and mass technologies is subject to the law of striving for an ideal system.

3. Pattern of change in the degree of controllability and dynamism of the system

3.1. General concepts

The pattern of change in the degree of controllability and dynamism is the main pattern of systems evolution.

This pattern contains two trends: increase and decrease in controllability and dynamism (Figure 1).

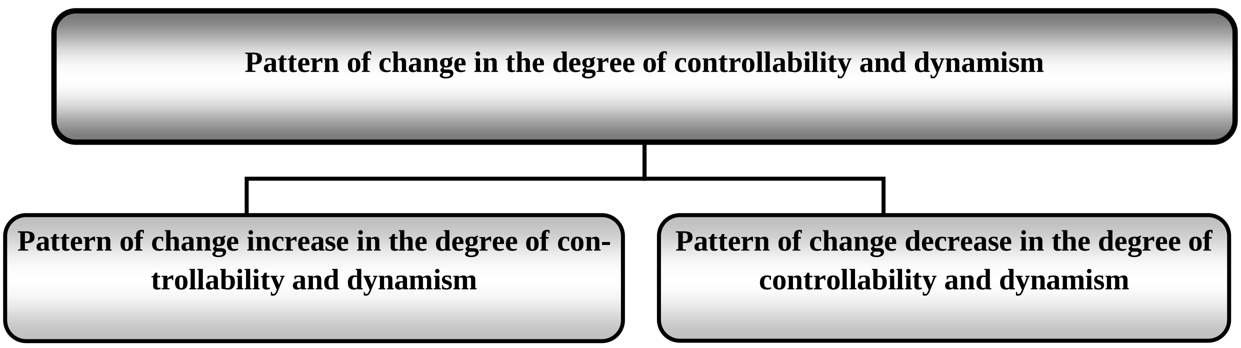

Figure 1. The pattern of change in the degree of controllability and dynamism of systems

The main of these trends is an increase in controllability and dynamism. The second tendency is auxiliary.

Increased controllability and dynamism are two interrelated trends that allow for increasing the degree of the ideality of the system.

• A more ideal system should be more manageable and more dynamic.

• A more manageable system should be more dynamic.

• A dynamic system can adapt to external and internal changes by changing its parameters, structure, and functions:

- in space;
- in time;
- by condition.

The pattern of increasing the degree of controllability and dynamism lies in the fact that any system in its development tends to become more controllable and more dynamic, i.e. the system must increase its degree of controllability and dynamism.

3.2. The pattern of increasing the degree of controllability

3.2.1. The general trend

The development of the system goes in the direction of increasing the degree of controllability.

A system can be controlled if and only if it contains elements with connections between them, capable of receiving control signals, converting them into control actions, and adequately perceiving information about internal changes in the system and external influences on it. This property is often referred to as responsiveness.

The general trend of increasing the degree of controllability (Figure 2) is the transition:

• from unmanaged to controlled system;

• non-automatic (manual) control to automatic;

• direct control to remote;

• from central control to distributed and self-organizing control (network management).

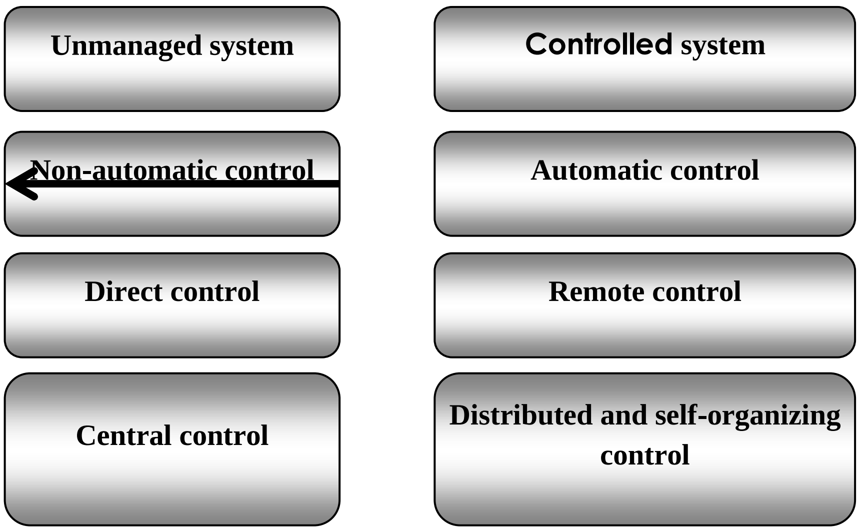

Figure 2. The general trend of increasing the degree of controllability

Examples for each transition.

• from unmanaged to controlled system;

Example. Startup

A startup is an unmanaged (or little-managed) system. When a startup receives investment, investors often recommend taking on a manager so that the company and processes become more manageable. So, Eric Schmidt appeared at Google.

• non-automatic (manual) control to automatic;

Example. SAP Company

SAP has earned millions of dollars on a software product for automating financial, business processes and managing company resources.

• direct control to remote;

Example. Pandemic

At the beginning of the pandemic, it was difficult for managers to manage people remotely, but now business processes have changed in such a way that almost any team has become distributed and managed remotely.

• from central control to distributed and self-organizing control (network management).

Example. The principle of operation of a transnational corporation

The main office of the company, for example, is located in the United States. But the business is structured in such a way that in each country there is a separate office that operates according to the rules, but nevertheless is not controlled by the Head Office.

The pattern of increasing the degree of controllability is also called the *pattern of displacement of a person from the system* since an increase in the controllability of the system reduces the degree of human participation in the operation of the system.

Previously, we considered the consequences of this pattern when considering the degrees of idealization:

• the system appears at the right moment in the right place, according to the necessary condition;

• the system does everything by itself – self-execution (Figure 3):

- mechanization;
- automation;
- cybernetization (intellectualization).

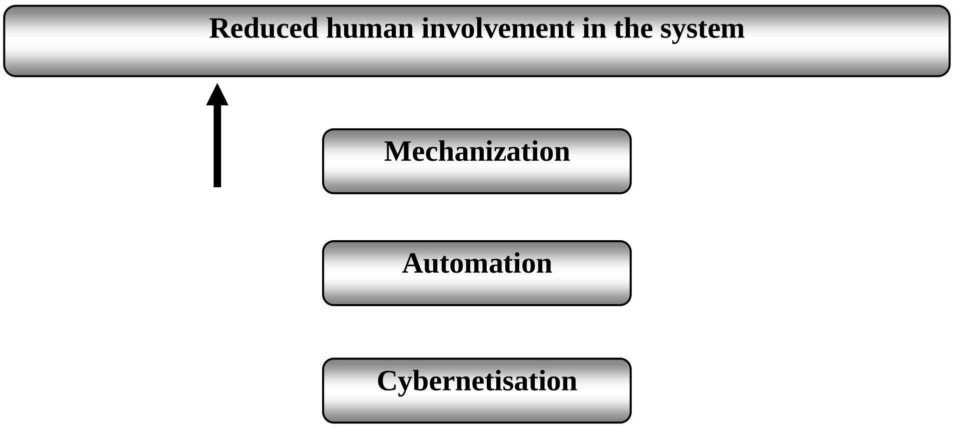

Figure 3. Reduced human involvement in the system

Example. Harvesting

At first, harvesting took place mechanically, then it was automated. But Tevel Aerobotics Technologies has proposed using drones and an AI system to determine fruit ripeness and harvest.

Example. Ore mining

Glencore uses Automatic Process Control solutions at its enterprises, when one enters the conveyor, the process of crushing, grinding ore, adding chemicals, and so on occurs automatically.

Example Ore mining (optimization)

And to optimize the process of obtaining ore, AI is used, which is able to determine the quality of the ore and, depending on various indicators, optimizes the process of adding the chemical. reagents, reprocessing, and so on.

The tendency of self-fulfillment is also called a decrease in the participation of a person in the work of the system or the displacement of a person from the system.

First, a person is displaced (replaced) at the level of the working body, then at the level of the source and converter of matter, energy, and information, then at the level of connections, and finally, at the level of the control system, which includes automation and cybernetization (Figure 4).

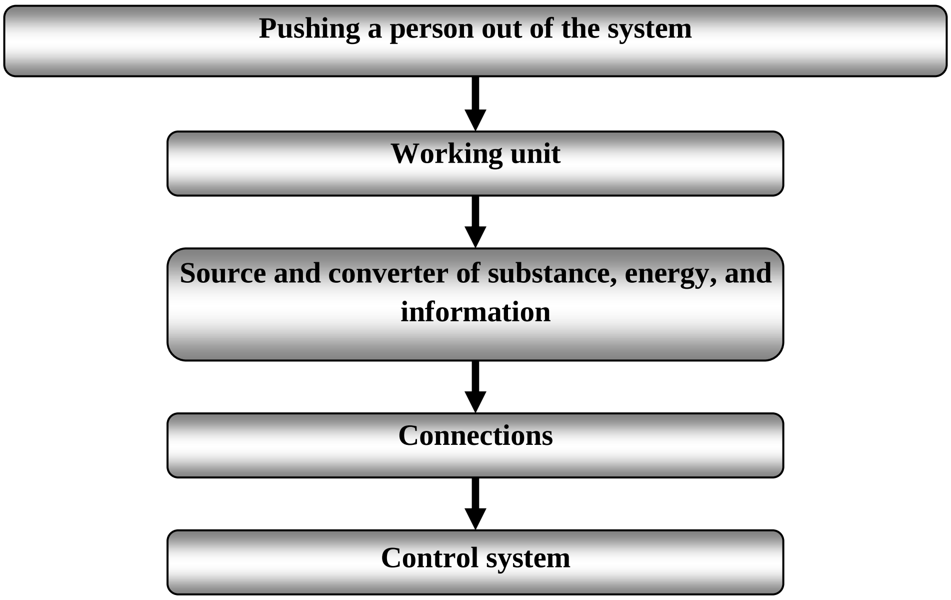

Figure 4. Human displacement from the system

Example. Sandvik

Sandvik is developing an autonomous mining solution. First, the operator controls the machine and the AI system remembers the actions. Further, the system can work autonomously and/or under the supervision of an operator.

The trend of transition from an unmanaged to a managed system is shown in Pic. 5.

This is the transition from an unmanaged system to open-loop control, then to a transition to a feedback system, to an adaptive (self-tuning) system, to a self-learning and self-organizing system, and, finally, to a self-developing and self-reproducing system.

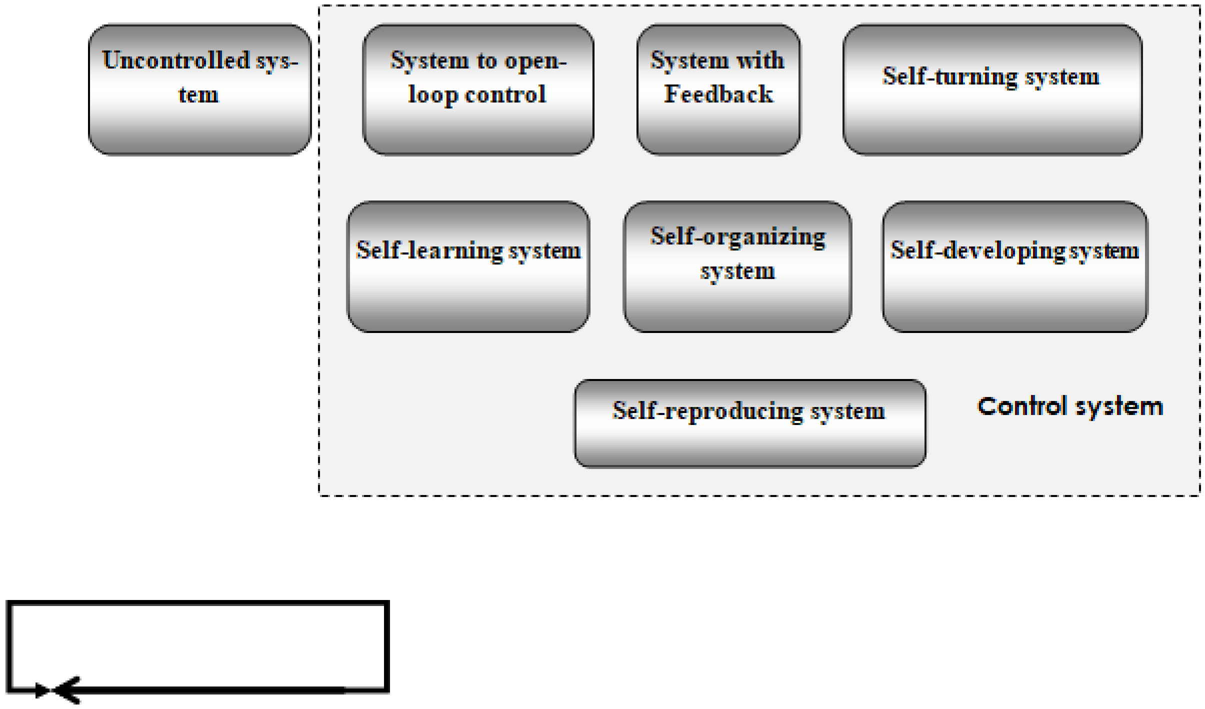

Figure 5. The transition from an unmanaged system to a managed one

Example: IT solutions

Companies are increasingly using AI solutions (like derivative chatbots, voice assistants, etc.)

One of the largest retailers in Europe (operating in 20 countries). The task is to improve the quality of customer service (reduce churn, etc.). One of the service channels is the contact center, where customers apply. To increase quality, more Contact Center agents are needed, which increases the company's costs.

Using this pattern, the company decided not to increase the number of agents, but to implement a solution with a virtual assistant: chatbot, voice assistant, Automated Contact Center.

Thus, the company has increased exponential customer satisfaction by 25%, and reduced costs by 20%.

3.3. Reducing the degree of controllability

The pattern of reducing the degree of controllability indicates a tendency to create simple devices without mechanization and automation. This pattern is opposite to the pattern of increasing the degree of controllability.

Webex Example (now a Cisco product)

Cisco is one of the leading manufacturers of video conferencing solutions, but the company was late with the PC solution. At this time, the solutions of Google Meet, MS Teams and others were already known. The company has created a division to develop this software product. Further, in order to reduce costs and reputational risk (in the event of an unsuccessful product), the company brought this division into a separate company – thereby reducing the degree of manageability for the company and development. Once the product became successful, Cisco bought Webex.

4. The pattern of increasing the degree of dynamism

4.1. The general trend

The development of the system goes in the direction of increasing the degree of dynamism.

A dynamic system can change its parameters, structure (in particular, form), algorithm, the principle of operation, and functions in order to most effectively achieve the goal and satisfy the need. A dynamic system in its development can also change its purpose and need, adapting to external and internal changes.

Changes may occur:
- in time;
- by condition.

Consequences of the law:

1. Static systems tend to become dynamic;

2. Systems are developing towards increasing the degree of dynamism.

Let's give an example of **increasing the degree of dynamism.**

Example. Amazon Web Services

Companies are changing their business processes, strategies, and even goals. Amazon was created as a platform for selling used books. It is now #1 in e-commerce and Amazon Web Services is the world leader in providing cloud services.

4.2. The main line of increasing the degree of dynamism

Degree of dynamism increases

Changes of the parameters of the system – one of the simplest methods to increase the degree of the dynamism of the system with the goal of its adaptation to internal and external changes.

Any parameter of the system can change, for example, the goal of the company (mission, core business, product, and so on), the market or consumers (previously it was B2B, now B2C and vice versa), competition and partnership (companies can unite to solve a common problem)

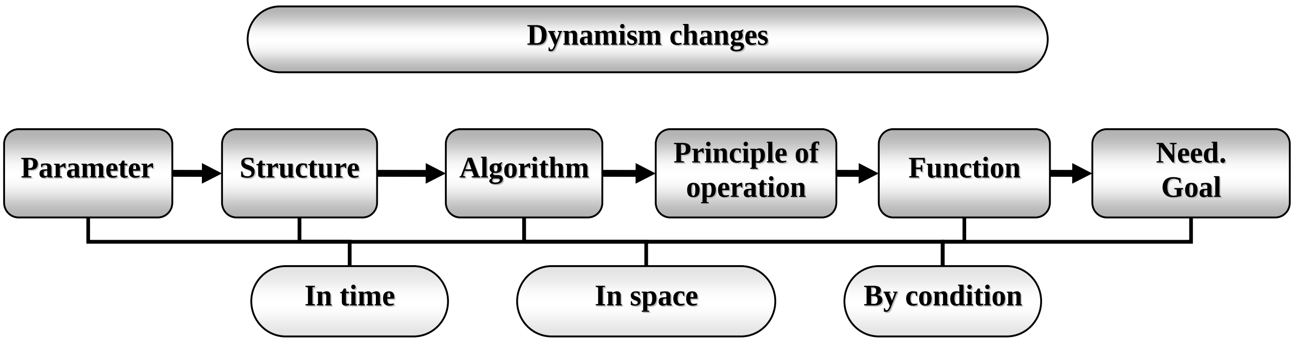

Figure 6. Line of increasing the degree of dynamism

Increasing the degree of dynamism of the system can be done by **changing the structure** of the system – this is a more complex way to make the system dynamic than changing the parameters. By changing the structure, we also mean changing the shape of an object.

Example. IBM company

IBM was the leader in the production of personal computers. But this line of business was sold, and the company focused on providing IT services.

An increase in the degree of dynamism of the system can be carried out by changing the algorithm of work.

Example. Marvel Company

The Marvel Company was one of the leading providers of comics. Now the company's main business with the film industry.

An increase *in the degree of dynamism of the system* can be carried out by **changing its principle of operation**.

Example. carshare

Carshare is a service that allows you to rent a car without a rental agency. Instead of an agency, the company offered to use the application and user registration.

ncreasing the degree of dynamism of the system can be carried out *by* **changing the needs**.

Example. Robinhood Company

Robinhood allows you to buy shares for small amounts and not use the services of expensive brokers. The company's approach has changed the way securities are traded in the US.

A*n increase in the degree of dynamism of the* system can be carried out *by* **changing the goals**.

Example. Company HP

The company HP (Hewlett-Packard) at the beginning of its creation made measuring instruments. HP is now the world leader in servers, storage systems, and software.

The more **dynamic** the system is, the **more it is controlled**.

The dynamism of the system *increases* with an increase in the speed and accuracy of *adaptation to external and internal changes*.

The rate of increase in dynamism increases taking *into account changes* not only in a certain *parameter* but also in its derivatives.

Ideally, when the system is ready for changes in advance, that is, it has the ability to predict changes in advance. To this end, the system must use and/or identify and *use trends, patterns, and laws of development* of the system, supersystem, and environment.

The adaptation accuracy can be increased if the integral of all changes is taken into account in the system control law or if previous changes are taken into account.

Example. Amazon

Amazon has adopted the rule of 2 pizzas for itself: the team (parameter) for optimal control should be no more than the number of people who will need 2 pizzas for a snack.

Static systems are quite stable, but not mobile. Mobile systems are often unstable. To give the system maximum mobility and stability, it is performed **dynamically static**.

The dynamic static nature of the system is carried out due to the *constant control* of the most *mobile system*.

5. Pattern of the transition of a system into a supersystem

5.1. The general trend

The pattern of the transition of a system into a supersystem was developed by G. Altshuller. He formulated it as follows:

"*Having exhausted the resources of development, the system unites with another system, forming a new, more complex system*".

Systems are combined into a supersystem not only when they have exhausted the resources of their development, so we have reformulated this pattern.

Systems are combined into a supersystem, forming a new, more complex system.

Example. A merger of companies.

Known examples of mergers to offer greater value to customers: Nokia-Siemens, Alcatel-Lucent, and others.

Combining systems into a supersystem can take place in two ways (Fig. 7):

• Merging into a new more complex system with one function (monofunctional system);

• Transition of the system from monofunctional to polyfunctional.

Example: Amazon

Amazon opens self-service stores or Google makes autopilots for cars.

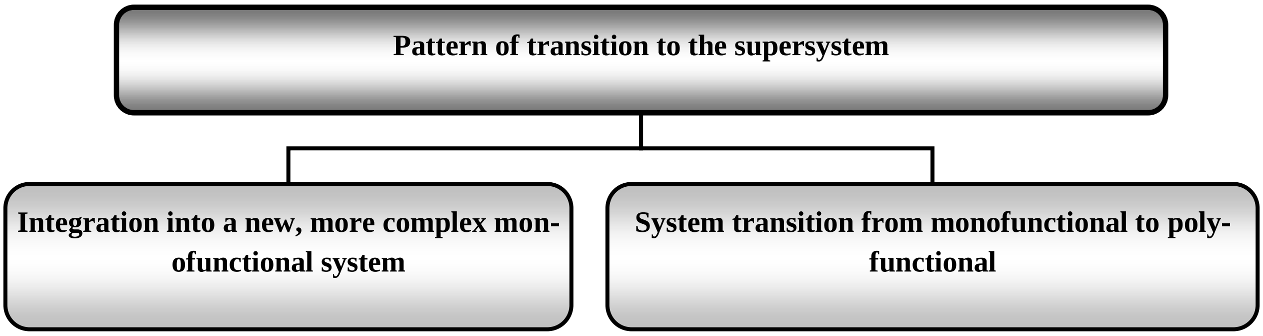

Figure. 7. Pattern of transition to the supersystem

The transition of a system from monofunctional to multifunctional is initially carried out by identifying a more general function and then giving additional functions, often using new technologies.

5.2. Element Combination Trend

Systems combine in a specific trend. Let's describe it (Figure 8).

Initially, there is one – **mono-system**. Then combine two original systems to obtain a **bi-system**. Combine three or more systems to form a **poly-system** at the following stage. The next stage of development is when the bi- and/or poly-system form a new combined system (mono-system), which performs all the functions of its constituent systems. This operation is called convolution.

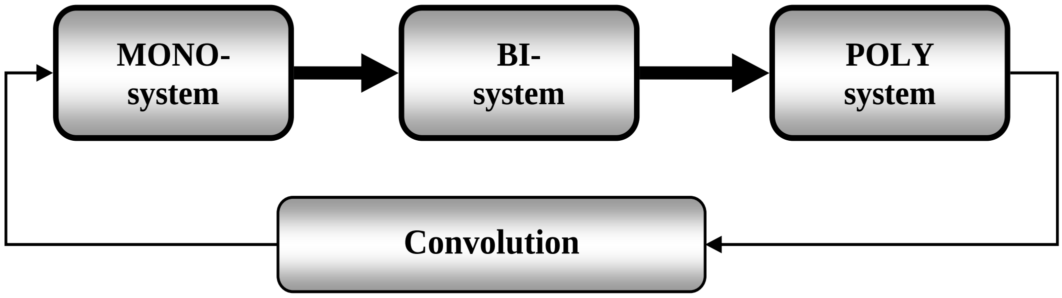

Figure 8. The trend of combining systems

The transition of "**mono-bi-poly**" is an inevitable stage in the development of all systems.

After the systems are combined into a bi- or poly-system, some change in the new system takes place, requiring the coordination of the components and parameters of the system. At the same time, auxiliary elements are reduced, and a closer connection between individual systems is established. Such systems are called partially collapsed. Further development leads to completely collapsed systems in which one object performs several functions.

A completely collapsed system can be thought of as a new mono-system. Its further development is connected with the movement along a new turn of the spiral. Sometimes a partially folded system can act as a new mono-system.

Mechanisms for combining elements

The creation of a supersystem by combining into a bi- and poly-system may include the following types of elements (Figure 9).

1. Homogeneous

1.1. Identical.

1.2. Homogeneous elements with shifted characteristics.

2. Heterogeneous

2.1. Alternative (competing).

2.2. Antagonistic – inverse (elements with opposite properties or functions).

2.3. Additional.

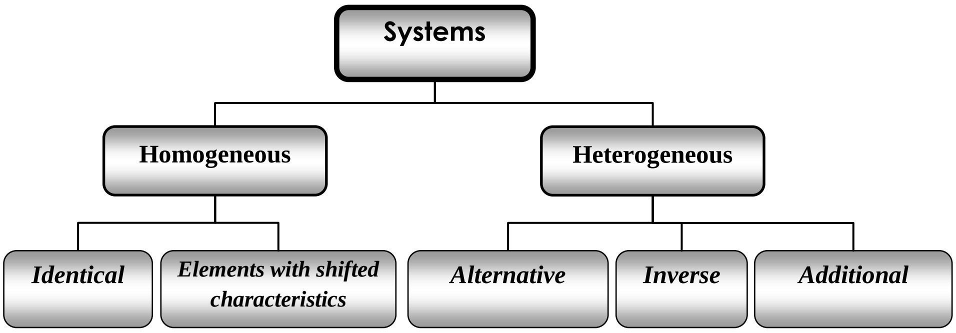

Figure 9. The pattern of transition to the supersystem

A complete diagram of the pattern of the transition of a system to a supersystem is shown in Figure 10

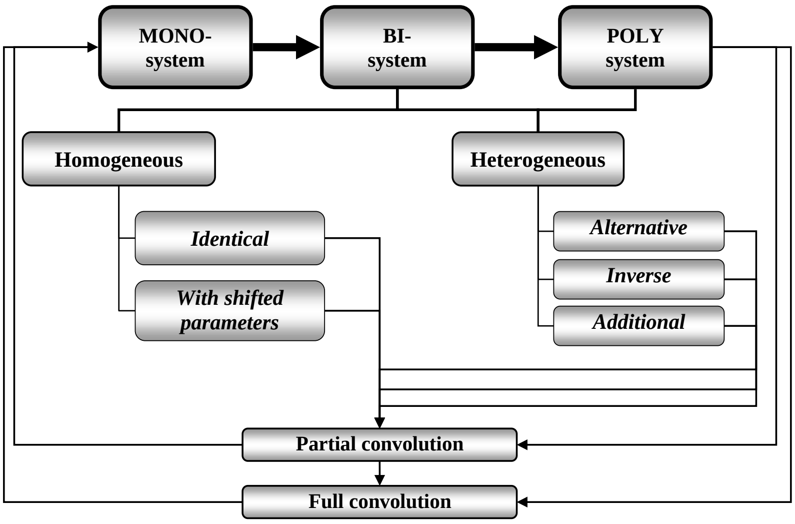

Figure 10. The pattern of transition to the supersystem

The combination is carried out in such a way that the useful (necessary) qualities of individual elements are added up, enhanced, and the harmful ones are mutually compensated or remain at the same level. A combination of this type is possible both for fairly highly developed systems, as well as for simple elements.

Further development of new systems goes by increasing their efficiency in two directions.

1. Increasing the difference between the elements of the system.

2. Development of connections between elements.

2.1. A system of practically independent, unrelated elements that do not change when combined.

2.2. A system of partially modified, coordinated elements that function only together and only in this system. This is a partially collapsed system.

2.3. A system of completely modified elements that work only in a given mono system and cannot be used separately.

Example. Buying a company

When a company begins to stagnate (a decrease in profitability, a decrease in profits, a lack of new ideas, etc.), a company buys another company, and there is a transition to a supersystem.

The company wants to reach a new level (a new business where it has not worked before) – the same is happening with the purchase.

For example, the purchase of RedHat by IBM. Over the past few years, the company's revenue has been declining, it has become increasingly difficult to compete, and new players have emerged who were more innovative, offered non-standard business models, and simply selected IBM customers. The question of the future of the company became acute. That's just the purchase of RedHat and became a necessary element in the development of the company.

6. CONCLUSION

In this article, the authors have shown how patterns of change in the degree of ideality, changes in the degree of controllability and dynamism of systems, and the transition to a supersystem and a subsystem can be used to solve business problems. Sometimes there are situations when there is no need to use the TRIZ algorithm or complex tools for solving problems, but you can apply patterns and quickly find a suitable direction for solving the problem. This is especially true for building new or improving existing business systems.

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A. Trantin, M. Rubin, N. Schedrin

Lines of evolution of function-and-targeted systems in business

SUMMARY

The article deals with the upper level of structure and specific features of function-and-targeted systems. The general laws and lines of evolution of function-and-targeted systems are described in short. Also, the thesis is proved that business-systems are a private case of function-and-targeted systems and are subjected to the laws of their evolution. Specific features of laws and lines of evolution of function-and-targeted systems in the sphere of business are shown. The novelty of the work consists in the formation of the complex approach, which demonstrates that the more general laws and lines of evolution of function-and-targeted systems are fully applicable to business-systems.

Key words: *function-and-targeted systems, trends of evolution of function-and-targeted systems, lines of evolution of business-systems.*

INTRODUCTION

Quite a number of authors devoted their publications to the topic of forming and actualization of Laws of evolution of systems, first of all, of technical systems. In spite of the fact that the Laws of technical systems evolution (LTSE), developed by G.S.Altshuller in 1977 [1], became a basis for forming the theory of inventive problem solving, (TRIZ), LTSE remain one of the most important parts and the basis of TRIZ. These laws enable not only to research the process of technology evolution, but also to forecast the trends of this evolution. In this article the authors don't set the goal to deeply analyze different approaches and different variants of LTSE (and other variants of laws, trends and lines of evolution), but concentrate on applicability of Laws of evolution of functional-and-targeted systems, developed by M.S.Rubin, N.A Schedrin and I.L.Misiuchenko to business-systems [2].

Before we pass over to the laws, it is worth to begin with quoting a number of definitions, which can illustrate the specific features of the described approach. Function-and-targeted system is a system, which is formed for the purpose of performing a set of useful functions and attainment of goals in keeping with the requirements of supersystems and operation principle of the given system. Function-and-targeted system is formed based on the principle of self-organization, natural or artificial selection or as a result of a targeted actions of one of the supersystems. The following systems can be related to function-and-targeted systems: biological systems, technical systems, social, economic, scientific and other systems. Thus, the word combination function-and-targeted systems is fundamentally a more universal term, which enables the authors to apply laws and lines to a broader circle of phenomena.

Sets of LTSE are not characterized by the necessary level of generalization, however, extensive experience is accumulated concerning the practical use of these trends for evolution of technical systems and solving inventive problems. To unite the generalizing quality of these laws with their instrumentality, according to the opinion of the authors, is possible as a result of formulating the laws of evolution for function-and-targeted systems.

The essence of this approach can be worded in the form of the following basic theses:

- The main object of description in the set of laws proposed by the authors is the evolution of function-and-targeted systems, not the technical systems and their evolution;
- The key issue in the description of function-and-targeted systems will not be the main useful function of this or that object, but its operation principle, which implies not one function, but a set of functions, which is characteristic of this object;
- Complex of laws of evolution of function-and-targeted systems will contain laws, conclusions from the laws and the lines of system evolution;
- It is proposed to use not only the lines of system evolution, but also the planes of evolution (combination of two evolution lines as axes of a plane) and the space of evolution (combination of three and more lines as axes of space of evolution).

Law of evolution of function-and-targeted system (LEFTS) is an objective law, which contains a description of a sustainable direction of evolution of function-and-targeted system, providing for enhancement of its competitive ability at the level of system phylogenesis.

Laws of evolution of function-and-targeted systems are internally non-controversial. Each law can have its elaboration in the form of consequences from the law. LEFTS offer a basis for formulating the lines of evolution of function-and-targeted systems, methods of analysis of function-and-targeted systems and forecasting their development. Hierarchy of LEFTS complex is based on the supremacy of a law of increasing ideality.

BASIC PART

Approaches to formation of trends and lines of evolution in business

Based on the existing methods, which can be used for formation and use of evolution lines in business, the authors single out three methods 3 (Fig.1).

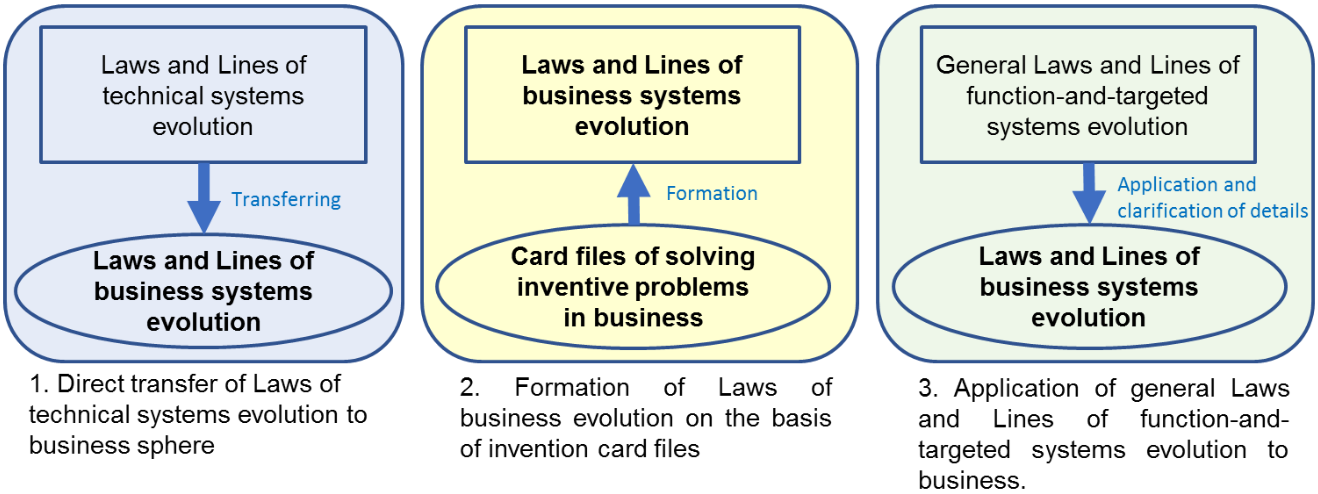


Fig. 1

Each of the said methods has its advantages and disadvantages. For example, direct transfer of LTSE into the sphere of business looks fairly simply, however, the fact is not taken into account that business is a complicated socio-technical system, which is essentially different from a simple TS. The second method, which presupposes the work with collections of cards with inventions (as it was presupposed from the outset, when they started to develop TRIZ), looks more precise from the standpoint of underlying doctrines, however, is rather problematic, since it will require colossal time expenditures, developing a method of work with a collection of cards, etc. Based on the above, the authors decided to take the third way in their research and applied general laws and lines of evolution of function-and-targeted systems to business-systems with corresponding elaboration of details.

Model of line of evolution of function-and-targeted system

The work with lines of evolution could be presented diagrammatically in keeping with Fig. 2.

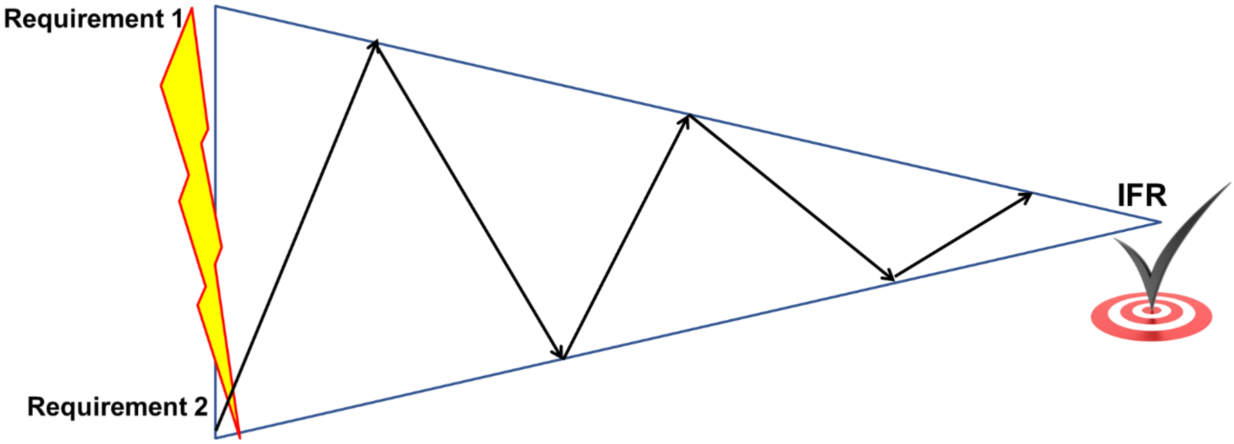


Fig.2

If the laws of system evolution needn't contain internal contradiction, the line of evolution should necessarily contain a contradiction. Here is a pattern for describing each evolution line:

- ✓ Laws, constituting the basis for evolution line
- ✓ Requirements of contradictions within evolution line
- ✓ IFR for the line of evolution – direction for resolving requirements contradiction
- ✓ Steps along the line (there should be no less than 3 of them: meeting Requirement 1, meeting Requirement 2, step towards IFR for the purpose of solving contradiction of requirements).

Example of line of evolution for business-systems

The authors propose the following set of evolution lines for business.

Lines of forming an organization (manufacturer and distributor):

BUS.4.1. Lines of forming the chains of creating values (CCV) in an organization

BUS.4.2. Line of forming an organization structure

Lines of product:

BUS.4.3. Line of business objects

BUS.4.4. Line of price and payment

BUS.4.5. Line of assortment

BUS.4.6. Line of market development

BUS.4.7. Line of customer development

As an example, let us quote the description of a line of product assortment. Based on the logic of above-described work, let us describe each of the steps one after another. Since the detailed description of LEFTS is not given in the present article, let us omit step 1 and immediately pass over to formulation of contradictions.

For example, contradiction of the line can take the following form: the Assortment should be broad, in order to satisfy and to predict the wishes of the customer, and should be narrow, in order not to avoid using large resources of the manufacturer and distributor. Further on, let us formulate IFR. For example, IFR 1: Large assortment of products ITSELF creates an opportunity to avoid using large resources of manufacturer and distributor.

IFR 2: Narrow assortment of products ITSELF predicts all wishes of the customer and provides for fulfilling them.

Based on the above, we may formulate tentative more detailed variant of a sequence of steps of the assortment evolution line:

- ✓ Single product, no assortment
- ✓ Product with a «shift» of characteristics and price. Assortment groups.
- ✓ Increase of a number of assortment groups and their price range.
- ✓ Saturation of assortment. Full coverage of the selected niche.
- ✓ Partnership of suppliers and manufacturers for the sake of regulating the assortment.
- ✓ Formation, structuring and dynamization of assortment policy depending upon the territory, place in the shop, season of the year and time of the day.
- ✓ Instead of part of the assortment – copies of the goods used for identification of the demand and analysis of competitors' assortment.
- ✓ Use of Internet technologies enabling the user to form a necessary assortment set independently.

Movement along the evolution lines on an example of blog

Blogging is a widely known occupation, which gradually grew into a multimillion business. Blog = Web (Internet) + log (journal of events). It is a web-site, the main content of which are entries regularly added by the user and containing text, pictures or multimedia (Fig. 3.)

Fig. 3

Disadvantage of this activity is the fact that any person can conduct his or her blog on any topic, which interests him or her (or his or her potential audience). The readers evaluate the degree of caused interest/usefulness of articles by pressing ♥ and leave comments, which embraces a broader audience and in general helps the author of the blog to correct its content depending upon the reaction.

The most important method for monetization of the blog, which enables to assert that this is really a business-system, is the advertising, which is either logically incorporated into the entry, or is added separately. It can also be a built-in tool of the host, at which the blog exists, etc. (for example, Fig. 4). Depending upon the number of readers or retrievals the conditions and the price of advertising can vary; the success of the blogger (acting as an enterpriser) depends on that.

Fig. 4

Let us analyze the way, which the blog may pass on an example of Lines of evolution, quoted in the preceding section.

BUS.4.1. Lines of forming chains of creating values (CCV) in the organization

Contradiction: Development, manufacturing, design, expenditures, advertising/brand, system and place of sales should be own (in order to control the situation) and should be «alien» (in order not to waste own resources).

Possible way of attaining IFR:

✓ At first all functions (writing an article, attracting the readers, placing contracts for advertising, etc.) are fulfilled by the author of the blog.

✓ After that professional writer, experts, market specialists, specialists on advertising, lawyers, etc. are invited to cooperate.

✓ As a rule, the beginning blogger is paid % from the sales of the advertised goods or he or she is paid for each attracted ccustomer.

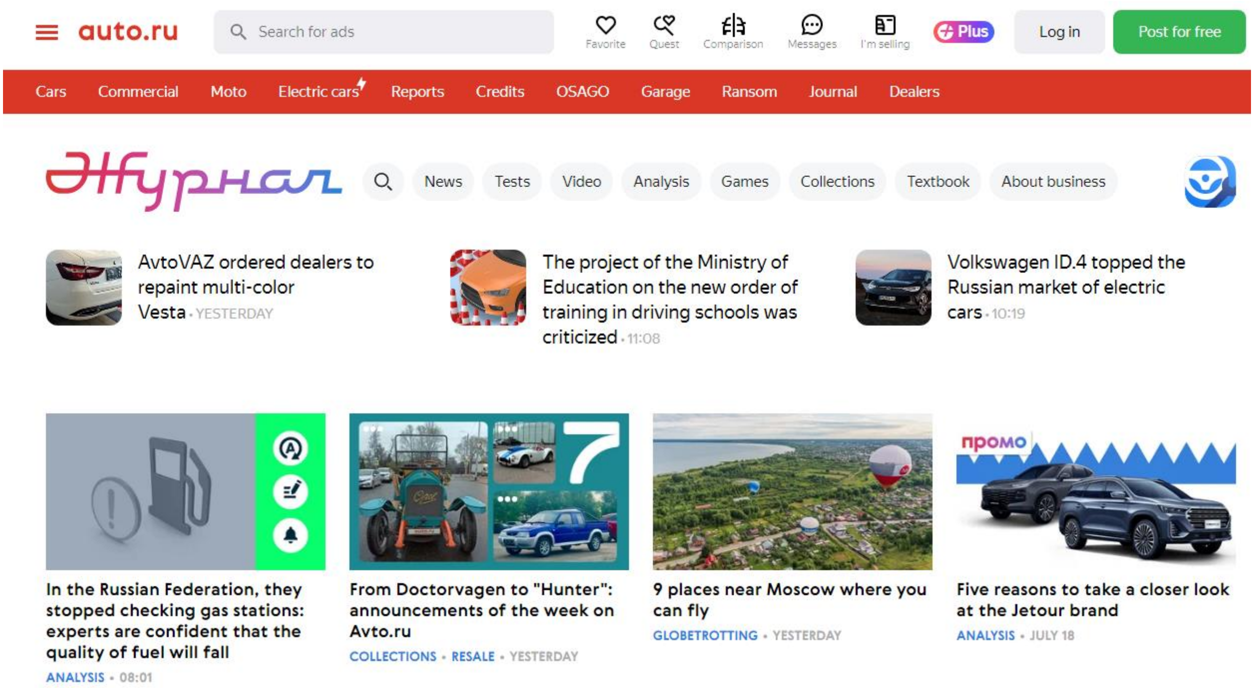
✓ After that advertising is paid for prior to its being placed in the blog (i.e., before the article is written).

BUS.4.2. Line of forming structure of organization

Contradiction: It is necessary to unite, in order to save resources for realization of this or that function and it is impossible to unite, in order to a) preserve individuality and own profit; b) not to waste resources on creation and support of the community.

Possible way of attaining IFR:

✓ For a less expensive and more effective involvement of a target audience the authors place their blogs on topical platforms (For example, Fig. 5).



https://mag.auto.ru

Fig. 5

BUS.4.3. Line of business objects

Contradiction: Characteristics of the product should be standard/invariable, so that copying might be less labor-intensive and the perception might be more reliable, and should be personalized/changeable in order to take into account the wishes of the customer. The object of business should be finished, easily accessible and should be unique and difficult to reach.

Possible way to attain IFR:

✓ With the evolution of the blog the authors can start to advertise their own marketable goods. For example, plaids. (Fig. 6)

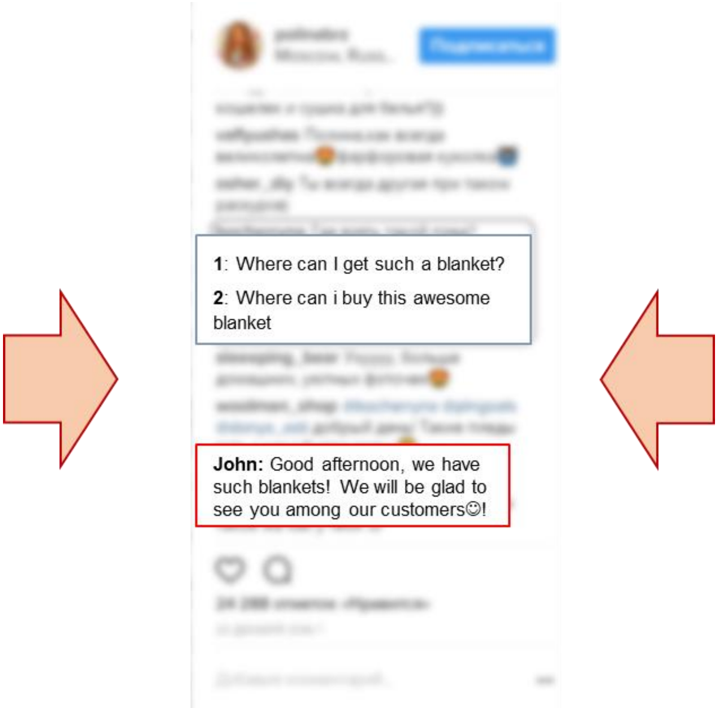


Fig. 6

BUS.4.4. Line of price and payment

Contradiction: The price should be high and should be low; stable and variable. The payment should be affected before selling (for manufacturer and seller) and after selling (for the customer).

Possible way to attain IFR:

✓ The price of advertisements may vary depending upon placement time, required focus audience or other parameters.

✓ Tariffs of volume and type of advertisements may be formed.

✓ Bloggers may organize mutual exchange of advertisements.

✓ The promotion of other people's blogs (protection) is also popular among the bloggers.

✓ The cost of advertising may also be different depending upon the platform, where the advertisement is placed. One and the same article may be placed on different platforms.

For example, of analysis see Fig. 7.

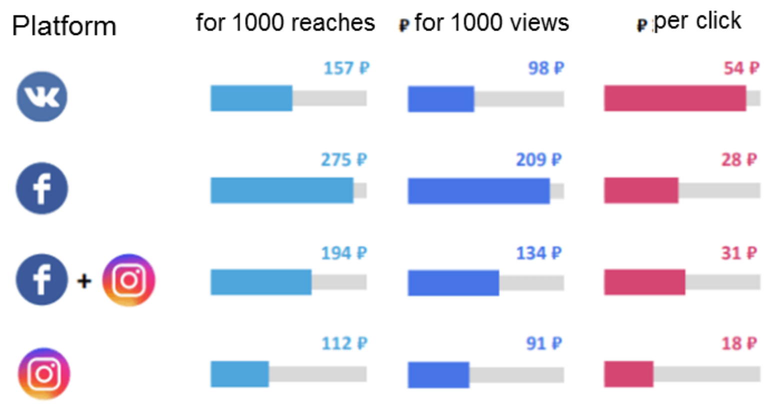


Fig. 7

BUS.4.5. Line of assortment

Contradiction: The assortment should be broad in order to meet the wishes of the customer and should be narrow, in order not to involve great number of resources of the manufacturer and seller.

Possible way to attain IFR:

✓ The more profitable of the blog business, the bigger the group of experts is, who take part in writing articles and the broader the topical palette of the articles is.

✓ The tools for analysis of the audience are involved in order to classify the tropics according to the interests of the customers.

BUS.4.6. Line of market development

Contradiction: The market should be stable and regulated, local and global, stable and changeable.

Possible way to attain IFR:

✓ Topical palettes of the blogs are practically nor restricted in any way. The development of the society interests contributes to creating new directions in blogging.

✓ Charismatic bloggers with a great embrace of the audience can themselves create popular trends.

BUS.4.7. Line of customer development

Contradiction: The number of customers should be low, so that it might be known what to sell and to whom, and this number should be high, so that the embrace should be always enlarged.

Possible way to attain IFR:

✓ In order to enter international markets, popular bloggers translate their article sinto different languages and place them in different platforms.

✓ Neural networks (and even the translators, which are incorporated into the browser) enable to automatically translate blogs into the languages, which are not native for the author.

CONCLUSION

As of today, the topic presented in this article, is insufficiently developed, because of restricted number of examples, which might form a collection of cards and prove complete applicability of approach, described by the authors in the present article. However, based on the quoted examples, the authors might draw a conclusion concerning a possibility to use General laws and lines of evolution of function-and-targeted systems in the sphere of business.

The team of authors has the following plans for the future:

- Use of the method for forming forecasts at the enterprises of different sectors of economy;
- Generalization of experience concerning the application of this method and identification of «grey zones» of using this method;
- Correcting/augmentation of already analyzed lines of development for the purpose of taking into account specific features of particular trends in business.

The authors will be thankful for feedback and critical remarks concerning the described topic.

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V. Petrov

The general structure of laws and patterns of development of business systems

ABSTRACT

Business systems are currently are rapidly developing. In this regard, it is very important to identify and use the patterns of their development. This will allow you to make fewer mistakes in the development of a particular business system and see the path of development.

Research was initially conducted on natural systems (the laws of biology), then on technical systems, and later on business systems.

Identification of patterns of development of business systems was carried out by analogy with the system of laws and patterns of development of systems developed by the author and their subsequent verification with business systems. As a result of the study, a hypothesis of a system of laws and patterns of development of business systems was put forward.

Keywords: *TRIZ, business systems, development laws, and patterns, innovations, forecast*

1. INTRODUCTION

Every day, business development is at an ever-faster pace and with more and more competition. In this regard, it is necessary to know as quickly as possible and more accurately how the business system will change and how it will change in the future. To this end, it is necessary to identify and use the laws and patterns of development of business systems. This is what shows the relevance of the topic we have chosen.

The author has been engaged in identifying the patterns of development of systems for almost 50 years. Initially, the author tried to systematize the laws of the development of nature and try to adapt them for the development of technical systems (TS). The first system of laws for the development of technology in TRIZ was developed by its author G. S. Altshuller in 1956 [1]. At the next stages, Altshuller improved individual patterns [2] and [3]. In the mid-70s of the 20th century, Altshuller developed another system of laws of technical systems [4]. In the future, the author improved and systematized the laws of technology development proposed by Altshuller, thereby creating his own system for the development of technical systems. The next step was the creation of a system of more general laws and patterns, which the author called "laws and patterns of systems development" [5]. In this paper, the author tries to adapt this system for the development of business systems. To this end, the author uses the method of analogies, analysis of the literature on this topic, as well as the experience of colleagues and his own.

This system was tested in specific projects for the development of certain business systems by the author and his students. The proposed system for the development of business systems has shown its effectiveness on specific business systems.

In the future, the author will try to develop this system of laws and patterns for other types of business systems.

2. LITERATURE REVIEW

In [6], different models are considered for different cases, for example, "created for", "sold" or "forced".

In [7], an innovative system of business model templates and a program suggesting which template to use in which case are considered.

The work [8] contains a series of articles under the general editorship of Professor Robert Winter on the topic of using patterns in programming and the experience of transferring them to business.

In [9], a comparison of business processes and IT systems is made. An integral business process pattern and structure has been developed that covers the entire value chain, with methods adapted to small and medium-sized companies.

Work [10] considers business intelligence systems.

The work [11] presents the results of the analysis of the functional completeness of ten intelligent video analytics systems. It is shown how the video analytics systems selected for comparison have similarities or differences according to the criterion of functional completeness.

The paper [12] shows the advantages of a network-centric company management system, which is a universal info communication environment.

Works [6] – [12] represent the prehistory of identifying and using the laws and patterns of development of business systems.

In [13], an attempt was made to apply Altshuller's laws of development of technical systems to business systems. Its author only indicated the names of the laws without defining them, describing patterns and trends, and gave some examples for each of the laws.

In this article, the author tried to apply his system of laws and patterns to business systems.

3. SYSTEMACITY

3.1. General view

The concept of systemacity follows from the systemic approach.

Systemacity is a property that consists in coordinating all interacting objects, including the environment.

Such interaction must be fully balanced.

An object will be made a system if and only if it meets the following system requirements.

1. The system must meet its **purpose**.
2. The system must be **viable**.
3. The system **should not negatively affect** nearby objects and the environment.
4. When building a system, it is necessary to take into account the **patterns of its development**.

3.2. Purpose of the system

The **purpose of the system** is described by the ***main function of the system***, satisfying a certain ***need***.

3.3. Viability

The **viability** of the system is determined by its **operability** and **competitiveness**.

The system will be **viable** if it is **operable** and **competitive**.

Operability is the ability to keep a piece of equipment, a system or a whole industrial installation in a safe and reliable functioning condition, according to pre-defined operational requirements (**Operability –** material from Wikipedia).

In other words, **operability** is the qualitative functioning of the system, i.e., the qualitative performance of the *main function of the system*.

In addition to the high-quality functioning of the system (including *reliability* and *durability*), *ergonomic parameters* can also be attributed to the operability parameters (characterize the compliance of the product with the properties of the human body).

Operability is determined by the presence of the necessary ***elements*** with the required quality, the presence, and quality of the necessary **connections** between the elements, and the organization of the necessary **flows** with the required quality.

The competitiveness of a product is the ability of a product to be attractive compared to other products of a similar type and purpose, due to a better correspondence between its quality and consumer assessments.

The competitiveness of a particular system is determined by comparison with a competing system. Competition depends on:

– on the quantity and quality of the functions performed;
– the cost of this system;
– the timeliness of its appearance on the market.

In addition to technical functions, **aesthetic** and **psychological** ones should also be taken into account.

One of the main *aesthetic parameters* is the *design of the product and packaging*, including the color scheme.

The *psychological parameters* include *prestige*, *attractiveness*, *accessibility*, etc.

3.4. Do not negatively affect the environment

Failure to take into account negative influences can not only adversely affect the performance of the system but also adversely affect the surrounding systems, the supersystem, and the external environment.

3.5. Accounting for the patterns of system development

Systemicity also takes into account the laws of the **historical development of the object under study**. This is the last requirement of the systemicity. It is taken into account when predicting the development of the object of study by taking into account the identified trends in the historical and logical development of this object and taking into account the general laws of system development. As a result, a general trend in the development of the object under study and a conceptual representation of its next generations are obtained.

Thus, systemicity has components: the purpose of the system, consisting of purpose, need, and function; viability, consisting of efficiency and competitiveness; no negative impact on the environment; and taking into account the patterns of development. This represents the structure of the law of increasing the degree of consistency.

4. THE STRUCTURE OF LAWS AND PATTERNS OF DEVELOPMENT OF BUSINESS SYSTEMS

The system of laws and patterns is divided into *unconditional* and *non-conditional*. The unconditional will be called **laws**, and the non-conditional – **patterns**.

Unconditional – these are those, the non-observance of which leads to the inoperability of the system. Unconditional – these are patterns that are realized only under certain conditions, and under other conditions may not be realized.

The development of any objects of the material world, nature, various areas of knowledge, activity, and thinking occurs according to its own specific laws.

Laws are objective in nature, expressing the real relations of things, as well as their reflection in the mind.

The laws and patterns of development of systems can be:

1. General – these are *universal laws* that are valid for any system, regardless of its nature, due to the unity of the material world. The most common of them are the **laws of dialectics** and the **pattern of S-shaped development**;

2. Laws and patterns of development of systems inherent in all *anthropogenic systems*;

The most general of the **laws of dialectics** are the **law of the transformation of quantity into quality**, the **law of the unity and conflict of opposites**, and the law **of the negation of the negation**.

The ***laws and patterns of systems development***, inherent in all *anthropogenic systems*, determine the requirements for construction and system development. They have two groups: the **laws of building systems** (determining the ***performance of the system***) and the **laws of evolution of systems** designed to create a **new workable system**.

The **laws of building systems** (determining the ***system performance***).

The **laws of building systems** include: *the law of conformity*, the *law of completeness and redundancy of the system*, the *law of conduction of flows*, and *the law of minimum coordination*.

Patterns of system evolution:

– **pattern of changing degree of ideality**;

– **pattern of changing degree of controllability and dynamicity**;

– **pattern of coordination – discoordination**;

– **pattern of transition to supersystem and subsystem**;

– **pattern of transition to micro-level and macrolevel**;

– **pattern of convolution – deployment**;

– **pattern of balanced – unbalanced system development**.

In addition, the system includes ***patterns of development of needs*** and ***patterns of changes in functions***, which will not be considered in this paper. They can be found in [5].

5. GENERAL LAWS AND PATTERNS

5.1. Dialectic laws

5.1.1. Law of the transition from quantitative to qualitative

The **law of the transition from quantitative to qualitative** changes reveal the general mechanism of development.

In the process of development, quantitative changes in the system occur continuously. When a certain limit is reached, qualitative changes are made. The new quality accelerates the growth rate.

In this case, quantitative changes are made gradually (evolutionary), and qualitative changes – are in leaps and bounds (revolutionary). The nature and duration of the jump can be varied – long and short, stormy and relatively calm, with and without an explosion, etc.

Example. Shopping centers

First, trading shops appeared in various directions, food, clothing, shoes, haberdashery, etc. Further, the shops united into shopping centers, then into malls, which contained not only shops, but also cinemas, training halls, coffee, game rooms, etc.

Example. labor cooperation

Labor cooperation, that is, the union of disparate producers, is a qualitatively new form of production. Quantitative changes here turn into a new quality. In turn, this new quality, i.e., the cooperation of labor, creates a higher productivity of labor than can be developed by isolated workers. Thanks to the cooperation of labor, the productive power of each individual worker, whose labor is part of the whole, is also increased. This means that qualitative changes cause new quantitative changes.

5.1.2. Law of the unity and conflict of opposites

The **law of unity and conflict of opposites** is that everything that exists consists of opposing principles, which, being one in nature, are in struggle and contradict each other (example: day and night, hot and cold, black and white, winter and summer, youth and old age, etc.).

The law characterizes one of the basic concepts of TRIZ – **contradiction**.

Example. Business systems develop in the most intense competition; therefore, the identification and resolution of contradictions is required constantly and in the shortest possible time.

5.1.3. Law of the negation of the negation

The essence of the **law of the negation of the negation** is that the process of progressive development occurs in three stages:

– ***initial state of the system;***

– ***negation of this state*** and transition to another state;

– ***negation of this state*** (negation of negation) and return to the original state, but, as a rule, at a higher level with the application of new principles of action, elements, materials, technologies, etc.

The development process takes place with relative repetition, as if along the steps traversed – in a spiral.

Example. Trading places

Initially, trade was carried out in shops and small shops. Then there were markets where they sold products and things. Those. shops and markets have become markets.

Then specialized stores reappeared and finally they were merged into shopping centers and malls.

5.2. Pattern of S-shaped development

At first, the system develops slowly (stage I), upon reaching a certain level, development accelerates (stage II), and after reaching a certain higher level, the growth rate decreases and, ultimately, the growth of the system parameter stops (stage III). This is a stage of stagnation that can continue for a very long time. Sometimes the parameters begin to decrease (stage IV) – the system dies (this is shown by the dotted line on the graph).

Such curves are often called **S-shaped** or **logistic**.

Example. Company development

• stage I – the birth of the company (the emergence of an idea up to the production and testing of a prototype);

• stage II – industrial production of the system and completion of the system in accordance with market requirements;

• stage III – minor refinement of the system, as a rule, the main parameters of the system no longer change, there are cosmetic changes, optimization of parameters and refinement of manufacturing technology, no significant changes in appearance or packaging. At this stage, there is a significant expansion of the sales market and the transition to mass production;

• stage IV – deterioration of certain system parameters, which can be caused by several factors:

– following the fashion, the influence of the economic, social or political situation, religious restrictions, etc.;

– physical and/or moral aging of the system.

As a rule, in section IV the system ceases to exist or is disposed of.

6. LAWS AND PATTERNS OF SYSTEMS DEVELOPMENT

6.1. Laws of building systems

6.1.1. Law of Conformity

This law speaks of the need to comply with the structure of the main function of the system.

Example. Company

The purpose of the company is to fulfill its main function to make a profit. Why can it produce and sell a product or service.

6.1.2. Law of completeness

Необходимым условием принципиальной работоспособности системы является обеспечение ее предназначения и наличие основных работоспособных частей системы.

A necessary condition for the fundamental operability of the system is to ensure its purpose and the presence of the main operable parts of the system.

Completeness and redundancy can be ***functional*** and ***structural***.

Functional completeness

Functional completeness should ensure the *general goal* and *main function of the system*, and perform all the *basic* and *auxiliary functions*, that is, fulfill one of the requirements of consistency – **purpose**.

Example. Trade area

The main goal of a trading company is to get the maximum profit from trading.

The main function is to create the most efficient activity of a trading company for maximum profit.

There are a lot of main and auxiliary functions in this area. This is how to ensure effective sales, marketing campaigns and marketing research, advertising and its effectiveness, identifying problem areas on the trading floor, determining the most effective store layout and product placement, monitoring staff work, etc.

It is necessary to determine the functional completeness – that is, whether all functions are taken into account and are effectively performed.

Structural completeness

Structural completeness should provide another requirement of systematicity – **performance** (part of the **viability**). This is ensured by the presence of the necessary **elements** (parts) and **connections** of the system, i.e., ensuring the **composition** and **structure of the system**.

Structural completeness can also be considered as the **law of structural completeness of the system**.

Elements can be:

– ***substantial;***

– ***energy;***

– ***informational.***

The **main parts** (**elements**) **of the system** are:

– **Working unit**;

– **Source and conversion of substance, energy, and information**;

– **Interactions**;

– **Control system**.

Example. R&D company

The working unit is the developers.

Source – terms of reference.

Connections – Connections between individual developers.

The management system is the management of the company.

6.1.3. The law of conduction of flows

Creating the right flows ensures the required **functionality** and **system performance**. The **absence** of at least **one vital flow** makes the system **inoperable**.

Example. R&D company

The company must ensure the passage of the necessary information flows.

6.1.4. Law of minimum system coordination

Example. R&D company

The company must be at least minimally consistent with its structure, connections and flows.

6.2. System evolution patterns

6.2.1. Pattern of changes degree of ideality

Conventionally, there are four possible degrees of system ideality:

1. Appear in the right place at the right time.
2. Self-service.
3. Ideal system – function.
4. Function becomes unnecessary.

Example. The Ideal store.

1. The right product appears at the right time, in the right place, under the right conditions.
2. Products appear without a seller – on their own.
3. An ideal store without salespeople and cashiers. There should not be an ideal store at all, but the sale is carried out.

All these are online stores and fully automated stores without sellers and cashiers.

4.You do not need to buy anything – everything is done on a 3D printer at home, and vegetables, berries and some fruits are grown in automated smart home gardens using aquaponics and hydroponics.

6.2.2. Pattern of changes in the degree of control and dynamic systems

Transition from central control to distributed and self-organizing control (network or network-central control).

The key principle of network-centrism: Solve problems as local as possible and as global as required. Decisions in a network-centric system are formed by coordinating individual decisions of subsystems, each of which works for its own purpose and performs its own tasks. This system has strategic, tactical and operational levels.

Example. Merrill Lynch Company

Merrill Lynch is the world's largest financial services company with a network of over 500 linked brokerage houses. Each of them has direct access to the database and to all the features of the central office. They also have the opportunity to use the results of the company's research centers, as well as direct access to global financial markets. Each financial broker operating at Merrill Linch's affiliate provides a very high level of individual competitiveness.

Example. Visa Co.

An American multinational company providing payment transaction services. It carries out transactions worth trillions of US dollars a year. It is a membership organization, an alliance of tens of thousands of financial institutions. Each company – a member of this organization owns only that part of "Visa", which was created by itself, forming a portfolio of cardholders. Visa doesn't own its members, they own it.

Transition to digital control.

Example. Digital control

Today, most companies have switched to digital control. There are already shops without sellers and cashiers and cash desks, they have completely switched to digital control.

Digital control is of particular importance in a network-centric control system.

6.2.3. Pattern of coordination – discoordination

The coordination – discoordination pattern includes two patterns.

1. Coordination – discoordination pattern.
2. Discoordination pattern.

The structure of coordination – discoordination pattern is shown (Figure 5.58). It is described below

1. Objects of coordination – discoordination.

1.1. Needs.
1.2. Functions.
1.3. Principle of action.
1.4. System.
1.4.1. Structure:
– elements;
– connection;
– shape;
– substance.
1.4.2. Parameters.
1.4.3. Flows.
1.5. Supersystem.
1.6. Environment.
1.7. Fields.
1.7.1 Energy.
1.7.2. Information.
– data;
– knowledge.

2. Ways of coordination – discoordination.
2.1. In time.
2.2. In space.
2.3. By condition.
2.4. Static (permanent).
2.5. Dynamic (variable).
Example. Slim waist.

Women want to be seen with slim waists. However, not every woman has a slender waist at any age.

A corset was invented for molding a figure into an "hourglass" silhouette. A corset pulls the body around the waist and gives the impression that a woman has a smaller waist and an hourglass figure. However, the internal organs are compressed in a tight corset, and this adversely affects woman health.

How can this problem be solved?

One of the solutions – the corset is made of an elastic corset mesh using light elastic regiline bones. This is structural coordination.

6.2.4. Pattern of transition to a supersystem or subsystem

Systems are combined into a supersystem, forming a new system.

The combination of systems into a supersystem can take place in two ways:
– Integration into a new more complex system with one function (monofunctional system);
– Transition of the system from multifunctional to multifunctional.

Systems are combined into a supersystem, forming a new, more complex system.

Example. Company

Initially, the company was a country startup and was developing a new product. Further, the technological department was attached, and then the plant for the production of this product. The company has gone super-system.

Transition of the system from multifunctional to multifunctional.

Example. Company

Initially, the company produced only one product. Then she began to produce various products and provide services for these products.

Trend of combining elements

Initially, there is one – **mono-system**. Then combine two original systems to obtain **bi-system**. Combine three or more systems to form **poly-system** at the following stage. The next stage of development is when the bi- and/or poly-system form a new combined system (mono-system), which performs all the functions of its constituent systems. This operation is called **convolution**.

The creation of a supersystem by combining into a bi- and polysystem may include the following types of elements.

1. Homogeneous

1.1. Identical;

1.2. Homogeneous components with shifted parameters.

2. Heterogeneous

2.1. Alternative (competing);

2.2. Opposing – inverse (components with opposite parameters or functions);

2.3. Additional.

Example. The shops

1. Merged the same stores and got a big store.

2. Merged stores of different companies that sell the same type of products (with shifted characteristics).

3. Merged stores that sell products that perform the same functions in different ways (alternative).

4. Merged stores selling products that perform inverse functions, such as heating or cooling appliances.

5. Merged stores selling products for cleaning the apartment, broom, dustpan, rags, sponges, etc. (*additional*).

6.2.5. Pattern of the transition to the micro-level and to the macro-level

Transition to the macro-level

In the process of evolution, many systems constantly increase certain parameters.

Example. Shopping centers

Today, the largest shopping centers are located in various countries, including hundreds of shops and restaurants, dozens of cinema halls, sports facilities, swimming pools, medical facilities, etc.

6.2.6. Pattern of convolution – deployment systems

The pattern of convolution – deployment includes two patterns.

1. Pattern of convolution;

2. Pattern of deployment.

Example. Company

Many companies curtail some functions and transfer them to a supersystem – outsourcing. For example, cloud technologies are used, etc.

6.2.7. Pattern of unbalanced – balanced development of systems

Example. Company

Any company and its work must be balanced. Otherwise, she will be ruined.

FINDINGS

The purpose of this work is to show that the TRIZ methodology and, in particular, the laws and patterns of systems development can be used in business.

The system of laws and regularities developed by the author was used as an analogue.

In this paper, the structure of laws and patterns of development of business systems was presented. This system will allow to present the future development of specific business systems most effectively and in the shortest possible time.

Currently, this system has been tested for some types of business systems.

The author would like to draw attention to this very topical topic and continue the study of laws and patterns for other types of business systems.

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Development of evolution strategies using TRIZ

SUMMARY

The notion of «strategy» is a key notion in management theory. Strategy is a kind of behavior style, which preconditions quite definite and relatively stable line of behavior of the object of strategy application at a fairly long historical interval. That's why approaches and methods for strategy development, which are practically applicable, are so necessary and needed by the enterprises of any branch of industry and sphere of activity.

Methods for strategic planning are known, which are based on system analysis and modeling of interaction between the analyzed object and external environment in time. The main disadvantage of these methods consists in the fact that they are not adapted to registering of quality changes in the analyzed system. In order to take into account, the fundamental changes in the system, it is proposed to use TRIZ tools in strategic planning, in particular, direct and reverse use of TRIZ Model. The method of strategic planning presupposes twofold approach: one way of planning implies the direction from solving the problems and resolving the contradictions within the system, while another way presupposes following the direction from ways of realization of the already formulated future image of the system under discussion. Both approaches mutually enrich each other in the iterative process of strategic planning.

The article contains a review of existing methods of planning implying the identification of their strong and weak sides, comparison of these methods using a nine-screen model (system operator). The authors of this work describe the method and algorithm for forming strategic plans and quote practical examples for using this method and algorithm.

INTRODUCTION

Worldly known consultant and guru of management Izhak Adizes, answering the question concerning the order of variation (mission, strategy, structure), comes to the following conclusion [1]: «Mission is something base of what we have to change. Strategy is the method for performing this function. Discussion of strategy will lead to a large number of changes in structure. While planning the strategy we could draw up more than one hundred of preliminary variants. A step back, a step forward, from function to form and vice versa: structure based on strategy and strategy based on structure».

No doubt, these elements are strongly interconnected and it is impossible to consider them separately. However, it is strategy which constitutes that very line of action, or it would be better to say – the plan, which preconditions quite definite and relatively stable line of behavior of the strategy object at a fairly long historical interval – is a touchstone of all changes in the company.

Strategy enables to emphasize priorities, plan and distribute resources and – which is the most important thing – to form the vector leading to the final result, to which the company is moving during its evolution.

For a fairly long time TRIZ was developing as an exclusively «iron-oriented» methodology, which was accessible only to engineers, however, global processes and needs introduced their corrections to world experience of TRIZ application and, as of today, in our opinion, nobody doubts that TRIZ found its extensive and effective application in the sphere of business problem solving.

One of such problems is the development of strategies of evolution and in this direction TRIZ is able to prove its universality and instrumentality, which will be demonstrated by the authors on practical examples, which are quoted below.

Thus, it is possible to formulate the main goal of the authors' work – creating a method for strategic planning, which enables to work with qualitative changes in the system in focus.

RESEARCH OF EXISTING METHODS FOR STRATEGIC PLANNING

The main motivations, which encouraged the authors to create the new methodology for strategic planning using TRIZ, are as follows:

- Existing popular methods for strategic planning don't presuppose any qualitative changes in the object of strategizing;
- Recommendatory (or abstractly recommendatory) character of changes within the system, which are proposed as a result of using existing methods of strategic planning;
- Absence of clear algorithm for strategy forming, which preconditions very high requirements to the experience of strategy developer;
- The majority of methodologies are adapted exclusively to work with products and services.

The goals of the present work don't include complete analysis, detailed description and comparison of all existing methods for strategic planning. To make the comparison possible, several of them were analyzed: the ones, which, according to the opinion of the author are most widely spread in business milieu.

More or less objective comparison of methods for strategic planning seems to be a complicated task. The discipline of strategy relates to social and humanitarian sciences. It means that in order to compare the methods of strategic planning it is necessary to create or to select a homogeneous formalized space. Otherwise, the entire comparison will be reduced to listing pluses and minuses of methods, which are incompatible one with another and which bear a subjective character predetermined by the personal experience.

A multi-screen pattern of talented thinking, proposed by G.S.Altshuller [2], was selected as such homogeneous formalized space. This pattern is presented in Fig. 1.

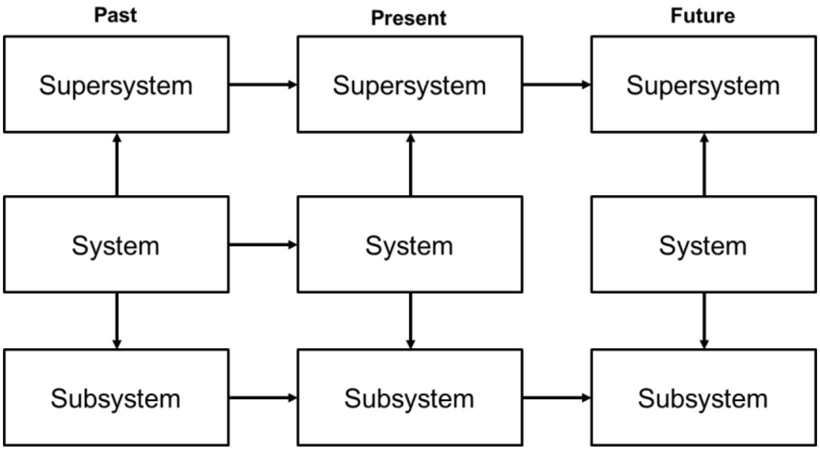


Figure 1

«The world, in which we live, has a very complicated structure. And if we want to know it better and to transform it, our mentality should reflect this world correctly. Complicated, dynamic and dialectically developing world should find in our mentality an analog in the form of its full model – complicated, dynamic, dialectically developing. » [2]

«Complete pattern» of thinking embraces all system levels, transitions between the levels and on the time axis. Therefore, this pattern (not without grounds) can be accepted as the most complete and even a reference model for comparing existing methods for strategic planning and the newly developed method.

GAP-analysis

This is one of the most widely known methods, which is extensively used in the companies, relating to various branches of business [4], IT, relating, logistics, etc. Born in the USA, behind the walls of Stanford, this method became popular in the whole world, first of all, due to its relative simplicity: it is necessary to understand, what the company wants and define, what the company has and then to concentrate on the research of the «gap» between two above-mentioned states (Fig. 2).

Figure 2

In a simplified form GAP-analysis can be reduced to the following:

1. Statement of goals of analysis.
2. Study of actual situation.
3. Analysis of goals planned at the very beginning.
4. Identification of deviations (gaps) between plan and fact.
5. Drawing up the plan of reaction.

An important issue in conducting GAP-analysis is the evaluation of adequacy of the desired result as well as deep immersion in the intricacies of business-processes and current market conditions. However, neither these things guarantee exact fulfillment of the future «plan».

The «complete diagram» of thinking shows that this method is responsible for a very modest part of it (it is color marked) (Fig. 3). The plan is the past of the system, fact is the present, there is no comprehensive target-oriented analysis of supersystems and subsystems. Moreover, there is no described methodology, with the aid of which one could formulate the plan of transition from the system «AS IS» (in the present) to the System «AS TO BE» (in future).

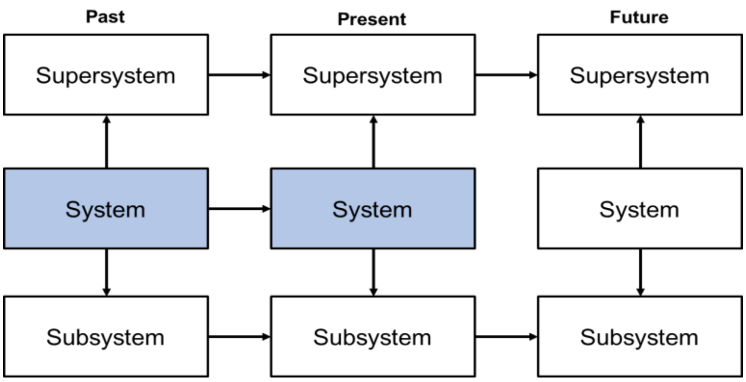


Figure 3

It leads to the following disadvantages:

• In most cases only the obvious factors are identified, which restrict the evolution and the non-obvious facts, which in fact can be of greater importance, are omitted;

• GAP-analysis enables to correct only the situation, associated with the occurred deviations;

• It is impossible to perform a qualitative jump in the system evolution;

• It is not clear how to work with conditions of presence of a large number of gaps, which influence one another;

• There are no tools, enabling to develop particular steps. Developing corresponding measures is in most cases reduced to brainstorming.

It is obvious that the relative simplicity of gap analysis on the one hand contributes to the growth of popularity of this approach, however, on the other hand leads to quite a number of disadvantages, which, in the opinion of the authors in many respects decrease the effectiveness of the approach.

SWOT-analysis

One more classical tool for forming strategic plans, the history of which dates back to 1960-ies [5]. One of the kinds of SWOT-analysis is OTSW-analysis, which was developed and is now being implemented by W. Quint and his followers [6].

The essence of this analysis or method is reduced to the following: «The method of SWOT unites strong and weak sides, opportunities and threats, as well as evaluates current and future potential of the enterprise. It constitutes a matrix, consisting of four parts, each of which signified a necessary sphere of activity to be studied». [7].

The obtained SWOT-matrix (Fig. 4) is used for formulating problems or possible strategic directions:

- What strong sides should be necessarily used in order to realize the potential (evolution)
- What potential can offer the basis for overcoming actual weak points (internal transformations)
- What strong sides should be used for eliminating threats (potential advantages)
- What weak sides should be eliminated in order to prevent threats (restrictions of evolution).

Figure 4

In the «complete pattern» of thinking SWOT-analysis covers the part, which is a little bigger than the one covered by GAP-analysis (Fig. 5). It happens because the analysis of strong and weak sides in this or that way is reduced to analysis of subsystems, while the analysis of opportunities and threats implies analysis of supersystems. In this case only the present time is meant, there is no methodology for describing the transition from the system «AS IS» to the system «AS TO BE», however, this is a touchstone in the issues of strategic planning.

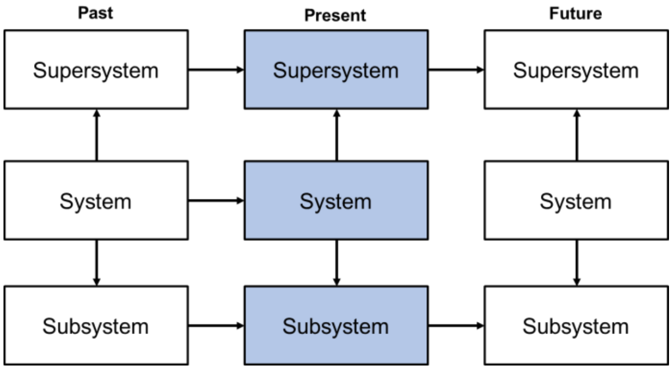


Figure 5

In spite of a great number of pluses, such as all-purposeless, forming a «new» vision of business, absence of need for special knowledge, in our opinion, the method cannot fully meet the needs of strategizing because of a number of fundamental disadvantages. To such disadvantages we can relate the following:

- Temporal dynamics is missing, which is well seen, when the method is superimposed over the «complete pattern» of thinking;
- Non-regulatory nature of obtained conclusions;
- Utterly strong influence of subjectivity of the analyst;
- Problems stated in the course of analysis are solved using the brainstorming methods;
- Features or disadvantages are not distinctly formulated and are not associated with a definite object;
- There are no criteria for prompt evaluation of quality of proposed solutions.

PEST-analysis

PEST-analysis is a tool intended for defining the strategy of the company for the distant future. [8]. The method exists both in classic form, when four factors of the macro-environment are taken into account: Politics – political environment of the company, Economics – economic environment of the company, Socio – Culture – social-and-cultural environment, Technologies – technological environment of the company, and in other variations, when additional spheres of human activity are added to the analysis (ecology, juridical milieu, etc.)

PEST methodology is in many respects analogous to SWOT-analysis and consists in:

- Compiling a matrix filling in the corresponding cells;
- Working out the company strategy, which, in the opinion of its compiler, will fully meet the company’s needs.

Work with PEST-analysis can be reduced to the following steps:

1. Identifying topical factors.
2. Describing the identified factors for nearest 3-5 years.
3. Selecting only such factors, which could influence business.
4. Developing the measures, which will enable to reduce the negative influence of identified factors.

The opportunities of PEST-analysis are shown in Figure 6 by color-marking corresponding sections of «complete pattern» of thinking. In contrast to SWOT-analysis we see losses in the depth of analysis. The main emphasis in this type of analysis is made on factors, which influence the object of strategizing, i.e., in terms of TRIZ – analysis of supersystems.

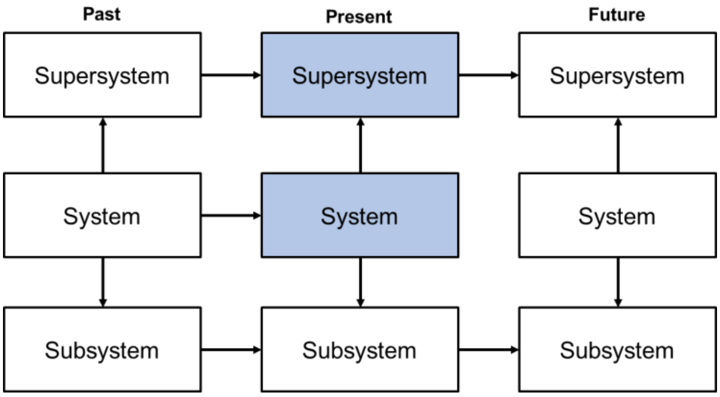


Figure 6

It leads to the following disadvantages of PEST-analysis:

• Non-regulatory character of obtained conclusions;

• Influence of the subjectivity of the analyst;

• Developing the measures on reducing the degree of influence of these factors is carried out via brainstorming.

Situational analysis of McKincey

Figure 7 presents the pattern of situational analysis. The authors of this analysis propose to «take into account the difference in the levels of indefiniteness of external forces, which exert influence upon the given branch of industry, influence of these levels upon its structure and the specific features of interaction inside the branches» [9]. It is also implied that with time the level of indefiniteness can change – become higher or lower.

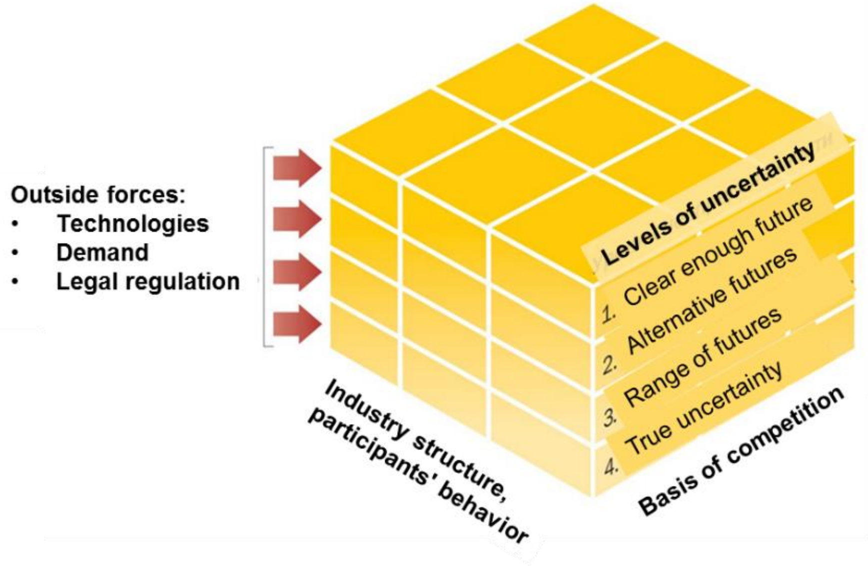


Figure 7

This analysis is the closest method to the method of strategic planning developed by the authors (in terms of embracing the full pattern of thinking) (Fig. 8).

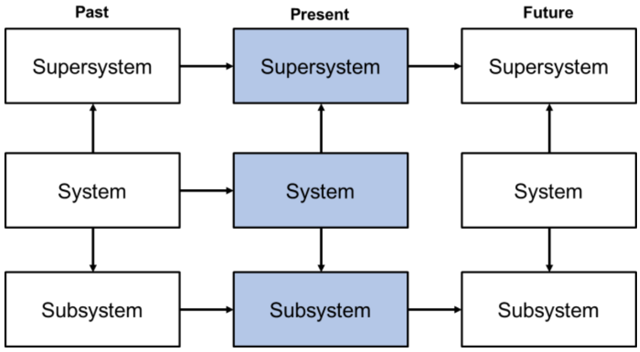


Figure 8

However, as it is seen from Figure 8, transition from the present state of the system, subsystem and supersystem to the future image is not methodologically grounded. This transition takes place as a result of brainstorming and the experience of the strategy developer, which might be insufficient for developing high-quality changes in the object of strategizing.

Summing up the above, the authors come to conclusions that the majority of disadvantages of the analyzed methods, applied in strategic planning, could be reduced to the following:

1. Indefiniteness of algorithms and methodologies for conducting analytical procedures.
2. Key role of experience of strategy developer.
3. Developing particular steps based on the results of analysis is not backed up by tools.
4. The methods don't take into account qualitative changes of the system.

The TRIZ-based method of evolution strategy, developed by the authors is intended for elimination of these disadvantages and enhancement of strategizing effectiveness.

METHOD FOR STRATEGIC PLANNING BASED ON DIRECT AND REVERSE USE OF TRIZ MODEL.

The strategy development method proposed by the authors is based on TRIZ model, presented in Fig. 9.

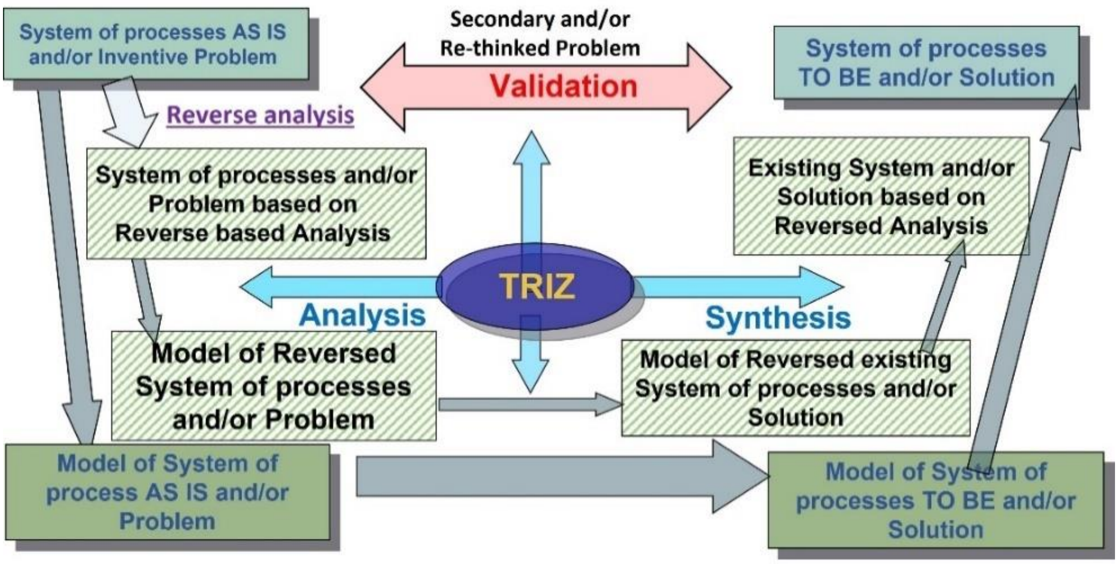
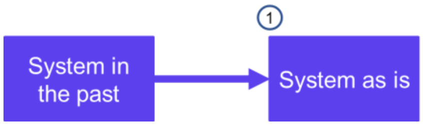


Figure 9

TRIZ model is a schematic presentation of a gradual transition from the problem to the TRIZ-model of the problem, after that – to TRIZ-model of solving and then to the solution itself; from system to TRIZ-model of the system, then to TRIZ-model of the new system and further, to real modification of the system. All mentioned transitions are instrumental, each of them implies formalized procedures, enabling to develop all-purpose algorithm of strategic planning.

Step 1. Select the object and horizon of planning.

As it is seen in figure 9, everything begins with choosing the object of analysis – system «AS IS» or Problem. This is an important step, since all subsequent steps depend upon it. For example, strategy of development can be prepared for a branch, enterprise, section of the enterprise or for an individual direction in the activity of the given enterprise. At this step it is necessary to clearly define the boundaries of the strategizing object.

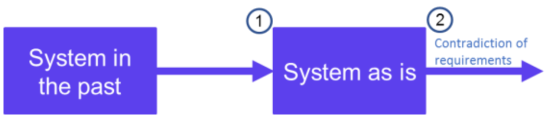


As a particular example of an object taken from the professional activity of the authors one can quote the direction in TRIZ in the aluminum division and in downstream division. These directions have distinct boundaries and structure.

Also, it is important to define the horizon of planning, since it will directly precondition drawing up further plans. Algorithm operates, also with modifications in supersystems, therefore the higher the horizon of planning, the more radical could be the influence of changes in supersystems and the higher is the need for transformations of the selected object.

Step 2. Describe the system «AS IS», what key problems are now contained in it? Formulate requirements contradictions based on key problem situations.

At this step it is necessary to describe the composition of the selected system in its present state. This is what takes place in the present. There are no ideal systems, already now there are key problems in the system, which hinder or restrict its evolution. If this is true, these problems may hide the contradictions, which are necessary to detect and to formulate according to TRIZ methodology.



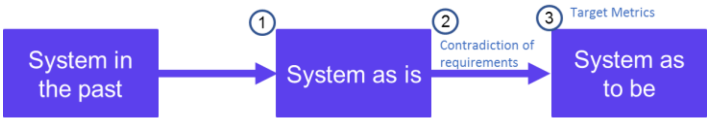
Getting back to the real example from Step 1, one of the key problems of TRIZ direction in the aluminum division and downstream division is the insufficient involvement of enterprise employees in TRIZ projects. At this step the problem was formulated in this particular wording. However, at the next steps it was refined and the contradiction was formulated.

The sources of information on key problems could be different documents (protocols, normative and constating documents) associated with the object, participants of the processes, which occurred in the selected site.

It is very important to note here that not all of the problems have contradictions in their basis, but as a rule, key problems, which restrict system evolution are based on such contradictions, the resolution of which could be a driver of growth in mid-term and long-term perspectives.

Step 3. Define target metrics of the object in keeping with the selected horizon of planning and specify the wording of requirements in identified contradictions of requirements.

If at the preceding step the wording of key problems can be of free form, at this step it is necessary to pass over to from the free form of formulating problems to contradiction of requirements worded in the following form: If (to do something), then Requirement 1 is achieved, however in this case Requirement 2 is not achieved. This transition is not always trivial and accessible at the first iteration. Deeper analysis of the problem situation with the aid TRIZ analytical tools might be required, for example, with the aid of cause/effect analysis.



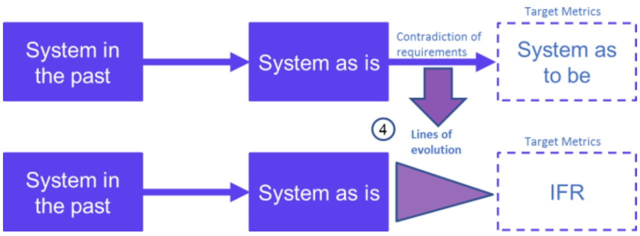
Based on the example offered by the authors, the problem «insufficient involvement of employees of the enterprises in TRIZ-projects» formed the basis for the following contradiction of requirements: «If the employee of the enterprise actively takes part in TRIZ-project, TRIZ is quickly incorporated into the processes of the company, but in this case the employee has no time for fulfilling his routine operational tasks. If the employee of the enterprise does not take part in TRIZ project, he fully fulfills his routine operational tasks, but in this case TRIZ gets incorporated into the company processes fairly slowly or even is not incorporated at all.».

Based on this example it is seen that the wording «insufficient involvement of enterprises' employees into TRIZ projects» contains a much smaller volume of information than the presented wording of requirements contradictions, which proves that certain analytical work has been done.

If the horizon of planning is 1-2 years, it could be possible not to perform subsequent steps. It would be better to concentrate on elimination of contradictions using the techniques of resolving contradictions. Obtained solutions and measures for realization of these solutions will form the basis for the future short-term plan.

Step 4. Using TRIZ tools intended for working with contradictions (contradiction of attribute, principles, IFR) formulate the lines of evolution of system «AS IS».

At this step deeper developmental work on these problems starts. Transition from contradiction of requirements to contradiction of attribute requires a deeper understanding of processes occurring inside the system «AS IS». Formulated contradiction of attribute offer an opportunity to pass over to IFR. At bottom, when a contradiction of attribute is formulated, transition to IFR is a mechanical operation of using already known models of IFR, resource IFR. For example, using a software complex Compinno-TRIZ, one can formulate IFR through single mouse click.



In the example, offered by the authors, the following contradiction of requirements was formulated at step 3: *«If the employee of the enterprise actively takes part in TRIZ-project, TRIZ is quickly incorporated into the processes of the company, however in this case the employee has no* *time for fulfilling his routine operational tasks. If the employee of the enterprise does not take part in TRIZ project, he fully fulfills his routine operational tasks, however in this case TRIZ gets incorporated into the company processes fairly slowly or even is not incorporated at all».*

As a system element the employee of the subdivision was selected, in which TRIZ is being implemented, while the parameter under analysis was labor hours. In this case contradiction of attribute could be formulated in the following way: *«Employee of the subdivision should spend labor hours on fulfillment of TRIZ project in order that TRIZ should be quickly implemented into the company's processes and should spend labor hours on fulfillment of his routine operational tasks in order to fulfill them fully.».*

Also, depending upon the selected contradiction of requirements, IFR and resource IFR will have the following wordings:

IFR1: *Employee of the subdivision with the attribute* ***Labor hours are spent on fulfillment of TRIZ-project*** *HIMSELF (HERSELF) allows to maintain operational activity.*

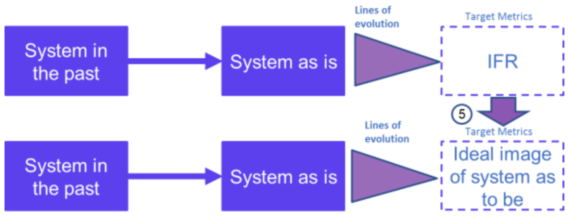
Resource IFR1: *X-resource (from the resources of system) in place of element Employee of the subdivision, retaining the attribute Labor hours are spent on fulfillment of TRIZ-project, should HIMSELF (HERSELF), during operational time within the limits of the operational zone provide for an opportunity to meet the Requirement maintains operational activity.*

IFR2: *Employee with the attribute Labor hours is spent on fulfillment of his (her) operational routine tasks HIMSELF (HERSELF) enables TRIZ to be quickly implemented into the process of the company.*

Resource IFR2: *X-resource (from the system resources) in place of the element Employee of the subdivision, retaining his (her) attribute Labor hours are wasted on fulfilling his routine operational tasks, should HIMSELF (HERSELF) during the operative time and within the limits of the operational zone provide for an opportunity to meet Requirement TRIZ is quickly implemented into the processes of the company.*

Step 5. Formulate the ideal image of the system «AS TO BE»

Based on the wordings obtained at step 4 and target metrics defined at step 3, the ideal image of the system «AS TO BE» is formed at the present step.



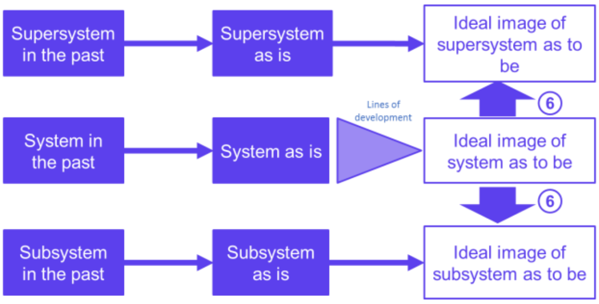
As a continuation of our once-through example let us quote several wordings of an ideal image of the system «AS TO BE»:

- The work on TRIZ-projects is an inseparable part of performing production functions;
- Development of skills and habits of an employee in the field of TRIZ is affected in the minimum volume necessary for participation in TRIZ-project;
- TRIZ-projects are an effective method to improve the material situation, build the career and get the recognition of colleagues and relatives.

This list is not exhaustive and is quoted here for the purpose of demonstrating the step.

Step 6. Formulate ideal images of subsystems and supersystems «AS TO BE»

This step is analogous to step 5, only in this case the images of subsystem and supersystem «AS TO BE» are formulated.

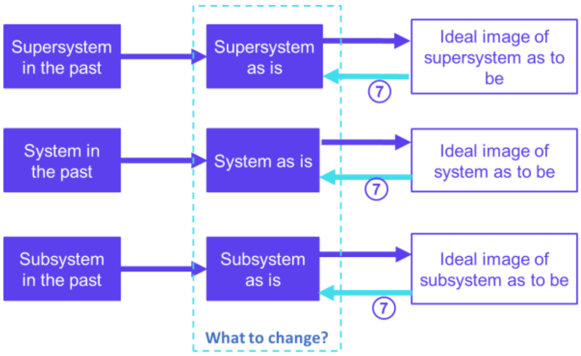


Here the authors will offer be only general comments and definitions, because this information is confidential. In discussing the system of TRIZ evolution it is implied that its supersystem will be understood as either the enterprise, the company as a whole, or particular subdivisions, in which the implementation takes place. In its turn, subsystems could be treated as subdivisions, which directly take place in implementation and development of TRIZ at the enterprise.

Step 7. Formulate, WHAT should be changed in subsystems, system and supersystems «AS IS», in order to approach the images obtained at step 6.

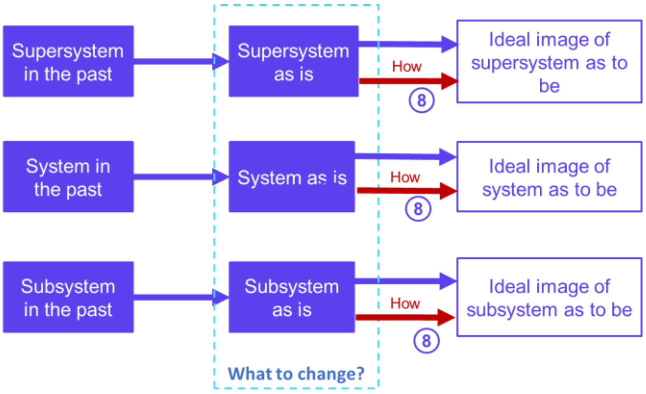
This step implies the comparison of two states of the system, subsystem and supersystem: «AS IS» and «AS TO BE».

For example, system «AS IS»: The work on TRIZ projects is an excessive load for the enterprise on the whole and for the employees in particular. System «AS TO BE»: The work on TRIZ projects is an inseparable part of performing productive functions. Comparing these two wordings and using the results of step 4, it is formulated what in particular should be changed in the system, subsystems and supersystems. This step is a linking chain between the current state of the system and the image, which was formed at the preceding steps. It has to be noted here that this is the work performed as part of preceding steps implying the identification of key contradictions existing within the system and the resolution of these contradictions, which allows to carry out qualitative transformations of the system, supersystem and subsystem.



Step 8. Formulate ***HOW*** *to change what was defined at step 7. The total sum and sequence of obtained points will be a strategic plan.*

Having defined at the preceding step, what in particular should be changed, the measures are formulated at this step, which will contribute to these changes. The total set of these measures will form the basis of the future strategic plan. After postulating the terms for realization of the above-mentioned measures as well as the persons responsible for this realization, the user of the algorithm gets a ready strategic program, directed at the resolution of system contradictions, which hinder qualitative transformation of selected system.



Due to the reasons of confidentiality the items of obtained strategic program of TRIZ direction development formulated by the authors are not quoted here.

If we use the reference pattern intended for comparing methods and approaches of strategizing accepted at the beginning of the article, the pattern of the proposed algorithm will take the following form:

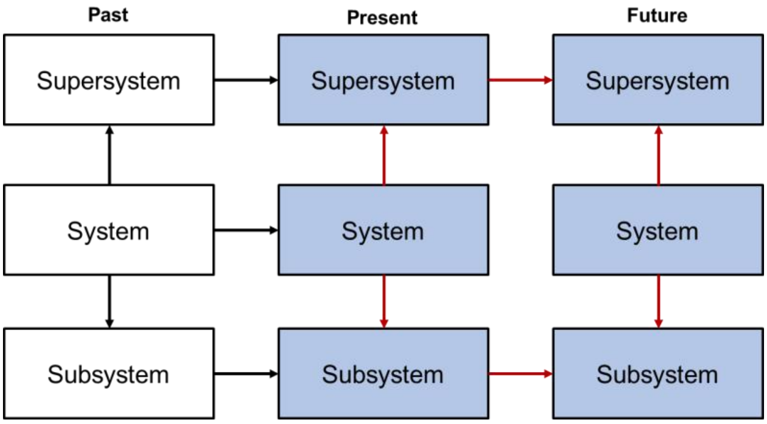


Figure 10

Figure 10 shows that the quoted algorithm embraces the analysis of systems, subsystems and supersystems and enables (with the aid of TRIZ tools) to pass over from the system «AS IS» to the image of the systems «AS TO BE». Based on the obtained results, it becomes possible to name particular measures concerning transformation of system «AS IS» into the system «AS TO BE». It offers an opportunity not to be restricted only by quantitative improvements, but also to attain qualitatively new transformations of the system.

CONCLUSION

Practical experience of the authors and the research conducted by the authors of a number of popular methods for strategic planning showed that:

- They possess a number of advantages, simplicity of use being the key advantage;
- They possess a number of key disadvantages, -- incorrectness of obtained measures, great role of brainstorming with all characteristic restrictions, absence of tools used for formulating qualitative transformations of the system.

In order to compare so different methodologies of strategic planning, a multi-screen pattern of talented thinking was selected. It enabled to visualize and evaluate the completeness of embracing the objects of analysis in the analyzed methodologies and the instrumental aspects of transition between the objects.

The authors quoted a detailed algorithm for strategic planning based on TRIZ model illustrated with examples of using it, where it was allowed by the considerations of confidentiality allowed that. Subsequent works on this topic could be associated with the verification of the given algorithm for forming strategic plans in any branches of industry followed by refining it and specialization of steps, taking into account specific features of the given branch.

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A. Trantin

Application of TRIZ tools and using the software complex Compinno-TRIZ for statement and solving organizational problems and problems of state management

SUMMARY

TRIZ is currently developing in many new branches of modern life as a methodology of strong and system-based thinking. The present article describes the experience of the author concerning the implementation of the approaches ARIZ-2010-U in solving the organizational problems of different companies and bodies of local administration. Application of TRIZ in the work with problems and contradictions, existing in municipal management, in the opinion of the author is a theme, which is insufficiently developed by modern community of TRIZ practitioners. This publication will demonstrate actual examples, proving the effectiveness of using the software complex Compinno-TRIZ for solving the problems of municipal management. Also, the author will show examples of using the method of dissonance of characteristics for identifying potential contradictions; the method for adapting the Problem Landscape to topics of problems of local management will be proposed and also next steps for developing TRIZ themes in municipal management will be described in short. The novelty of the work is defined in forming a complex approach to solving problems by the specialists, who are working in various spheres of municipal management.

Key words: *problem landscape, Compinno-TRIZ, contradictions in the field of local management.*

INTRODUCTION

Municipal management as an individual institution basically (in the form, in which it is known by the majority of us) develops in Russia since the beginning of 1990-ies. The foundations laid down in the constitution of the Russian Federation [1], found their subsequent development in the Federal Law, for example, in the Federal Law dated October 6, 2003 No. 131-FZ (version dated July 14, 2022) «On general principles of organization of local management in the Russian Federation». However, even the existence of a document, disclosing the essence of local management, large number of normative subsidiary laws and explanations of legal cases did not make the practical application of these laws much easier. On the contrary, they generated additional problems, which are not solved until now. This assertion is easily proved with the aid of a simple experiment: addressing the search system with the search pattern «municipal management» the user gets 5 million results (Fig. 1), while the search pattern «problems of development of municipal management» yields 18 million results (Fig. 2). The difference between two groups of results constitutes 3.6 times, which decidedly testifies to the vital character of the present palette of topics, also with the further application of TRIZ tools.

In the present article the authors will propose a complex step-by-step approach to issues of local management implying the use of TRIZ achievements (here and hereinafter local management, LM and municipal management, MM, will be used as synonyms). Also, individual cases related to LM will be analyzed, which are associated with such subject of the Russian Federation as Krasnodar Region. These cases were studied jointly with the Deputy Heads of the administrations of the above-mentioned subject as part of the course of MPA, jointly realized by Kuban State University and High school of State Management of Lomonosov State University of Moscow.

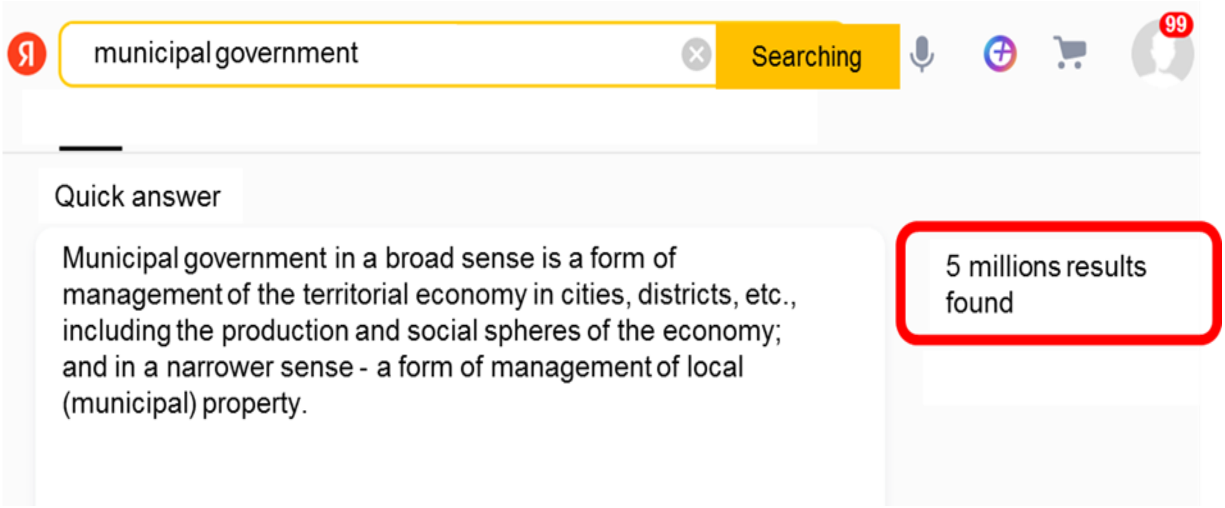


Fig. 1

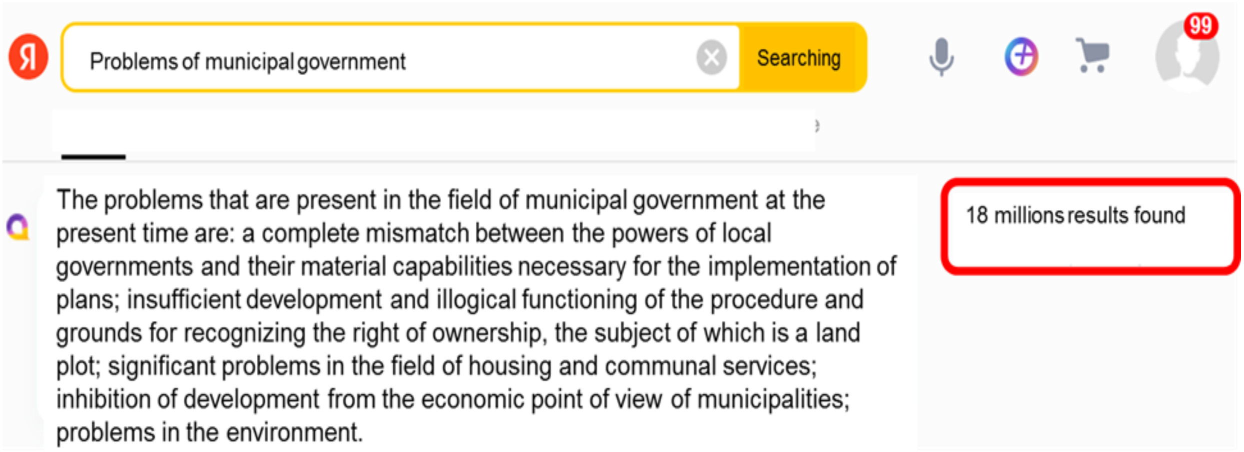


Fig. 2

REFERENCE

As part of preparation for the work on using TRIZ for solving problems, existing in municipal management, the author analyzed the materials of different conferences, collections of articles and other sources, in which these problems were tackled.

On the whole, if we consider the problems of municipal management as problems of organizational character, one can solve these problems by using already existing general approaches, which were developed during the period of applying TRIZ to problems of this kind. But the specific character of the object under analysis – municipal management – imposes serious restrictions on general approaches, while the municipal management in itself exists within very strict frames, which are delineated (or attempts are made to delineate them) imperatively within juridical norms.

Therefore, as of today, the author never found a universal methodological manual or a reference book, like such ones for the spheres of IT, programming or business on the whole, dealing with application of TRIZ to solving problems of municipal management. Separate cases find their reflection in articles by different authors and are dedicated to the search for solutions of particular problems, which in some cases are only indirectly associated with the topics of municipal management, though, can be decidedly also used for solving similar problems in municipal management.

MAIN PART

Initial data, existing and obvious problems and contradictions, search for dissonance of characteristics

In the opinion of the author, in order to identify the tasks of municipal autonomous management, which could be solved with the aid of TRIZ, it is possible to use three main methods:

- ✓ Analysis of general problems, which are characteristic absolutely of all subjects of municipal autonomous management with the following decomposition of problems up to the corresponding level and transition to possible contradictions;
- ✓ Analysis of obvious contradictions, which exist within the system of municipal autonomous management with the following decomposition of problems up to the corresponding level;
- ✓ Analysis of dissonance of characteristics.

If we consider the problems, which exist in the municipal autonomous management and hinder its development on the whole (and without any search for dissonances), it is possible to single out several such categories. The first big group of problems is associated with the fact that until the present day there is no correct description of objects of municipal autonomous management, criteria of evaluation, which could be identically understood by all participants of the process for carrying out local autonomous management. Until now there are problematic issues, which should reflect effectiveness of municipal institutions, but more often than not confusion is encountered instead of the ways to solve the problem.

Another big set of problems is associated with the lack of highly-qualified specialists. And first of all, it takes place because people, without getting sufficient money remuneration for their work have to leave their regions for bigger cities.

The third big problem could be formulated as the discrepancy between financial resources, which the authorities have and a set of problems, which have to be solved using these financial means.

All above-mentioned problems can be decomposed to particular problems of a particular subject of municipal autonomous management.

The next source of tentative problems, which could be solved by corresponding subjects of municipal management are obvious and explicit contradictions of the entire system of municipal autonomous management.

- ✓ **Contradictions in the legal sphere.** Principle of people power ineffectively works in the sphere of municipal management. A situation is being formed, when the laws presuppose the existence of local autonomous management, while the real practice of a number of settlements actually does not presuppose anything of the kind. Federal law No. 131 did not entirely solve the problems in the sphere of local autonomous management and in a number of cases even aggravated the contradictions.
- ✓ **Contradiction** between the processes of **centralizing** of state power and decentralizing, which forms the basis of local autonomous management.

On the one hand, there is no such subject in the form of a civil society, which might become the foundation of a local autonomous management, while on the other hand there is an obvious tendency of the authorities to make local autonomous management the lower grade of the top-down command structure. In this case local autonomous management did not become a foundation, but was reduced to a hanger, which hangs on subsidies, received from the upper grades. ***This is a conceptual contradiction***.

- ✓ **Contradiction of import substitution**: Should it take place due to state resources and state regulation or based on market mechanisms?

It is obvious that the above problems and contradictions are system-based contradictions, which relate practically to all subjects, responsible for realization of autonomous management and naturally, it is clear that one separate district or another municipal body cannot manage solving these problems alone or on their system level. However, the decomposition of problems of upper level enables to formulate such problems, which are more obvious and quite solvable, and which later on can be ranked using Problem Landscape.

In order to visualize th search of problems using the analysis of dissonance of characteristics, the author used the data from the summary report of the Krasnodar Region «On the results of the monitoring of effectiveness characterizing the activity of the bodies of local autonomous management of municipal, city districts and municipal regions of Krasnodar Region in 2020». (https://admkrai.krasnodar.ru/content/1137/show/602748/)

In short, the information on all subjects of (LAM) Local Autonomous Management can be reduced to a table of dissonances between development levels in different directions (Fig. 3).

Municipal entities	Economic development	Social-cultural issues	Housing policy and communal services	Municipal government	Energy efficiency	Total grade	Spread of values
1	1	2	1	1	1	**1,2**	1
2	11	1	4	3	11	**6**	10
3	6	8	10	6	2	**6,4**	8
4	11	16	5	19	3	**10,8**	16
5	8	9	5	10	25	**11,4**	20
6	13	7	18	16	18	**14,4**	11
7	26	5	12	15	16	**14,8**	21
8	14	15	16	7	34	**17,2**	27
9	25	10	17	33	5	**18**	28
10	18	22	9	25	22	**19,2**	16
11	22	16	7	23	29	**19,4**	22
12	19	20	21	11	35	**21,2**	24
13	31	23	9	21	31	**23**	22
14	29	24	22	29	20	**24,8**	9

Fig. 3

In this section of the table one can see the most important markers or criteria, according to which the effectiveness of activity of these or those bodies of municipal autonomous management is reflected. One can argue about the sufficiency of these data, however, on the whole, it is reflected in different laws and regulations acts, therefore, in any case the local autonomous management encounters a situation, when they are evaluated based on these particular parameters. It is possible to draw a conclusion from the data of the table that there is one leading municipality in this country, 2-3 municipalities of mediocre importance and many municipalities that are lagging behind and trying to catch up with the others.

In this case it is noteworthy that there are dissonances between various characteristics within the limits of one municipal body. For example, the municipal body number 7 has a very low level of evolution according to such parameter as economic development, and at the same time a fairly high level according to such metric as socio-cultural sphere; the difference between them amounts to more than 20 units. Municipal body number 13 is in still worse situation according to the parameter *economic development*, however, at the same time it looks rather well in terms of such directions as strategic housing and public utilities. Identified dissonances in characteristics enable to direct the focus into particular weak places of this or that subject of municipal autonomous management, which helps to identify existing administrative contradictions, and afterwards, making our knowledge of a particular problem deeper, pass over to requirements contradictions and feature contradictions.

Adaptation of Problem Landscape

Problem Landscape was used by the author in his work on identifying priority in problems to be solved. This Landscape is adapted to requirements of production company and reflects specific character of a particular business (Fig. 4).

Scale of the problem \ Efficiency potential	Less than 1 mil.	1-5 mil.	5-20 mil.	more than 20 mil.
World				
Country				
Technical				
Industry				
Company				
Division				
Plant				
Workshop				
Sector				

Fig. 4

Taking into account that these criteria of scale are unsuitable for problems of municipal management, the authors developed a version of the landscape with specified criteria (Fig. 5.)

Scale of the problem \ Efficiency potential	Less than X mil.	X-Y mil.	Y-N mil.	More than N mil.
World				
Country				
Federal district				
Subject				
Area				
City				
Local Administration				
Department				
Group				

Fig. 5

Logics of work with the Problem Landscape is formulated in the following way: first of all such problems are selected for studying and solving, which are situated in the first quadrant (Fig. 6.). These are problems, which can be basically solved at the corresponding system level of the solver, for example, deputy head of municipal management of a particular district. And these are the problems the solving of which will bring the highest economic effect. Naturally, it is understandable that many problems, encountered by the municipal authorities are rather difficult to digitalize, but the author adheres to the idea that everything in the world can be digitalized. And even, for example, a conventional queue to the kindergarten can find its reflection in the money equivalent.

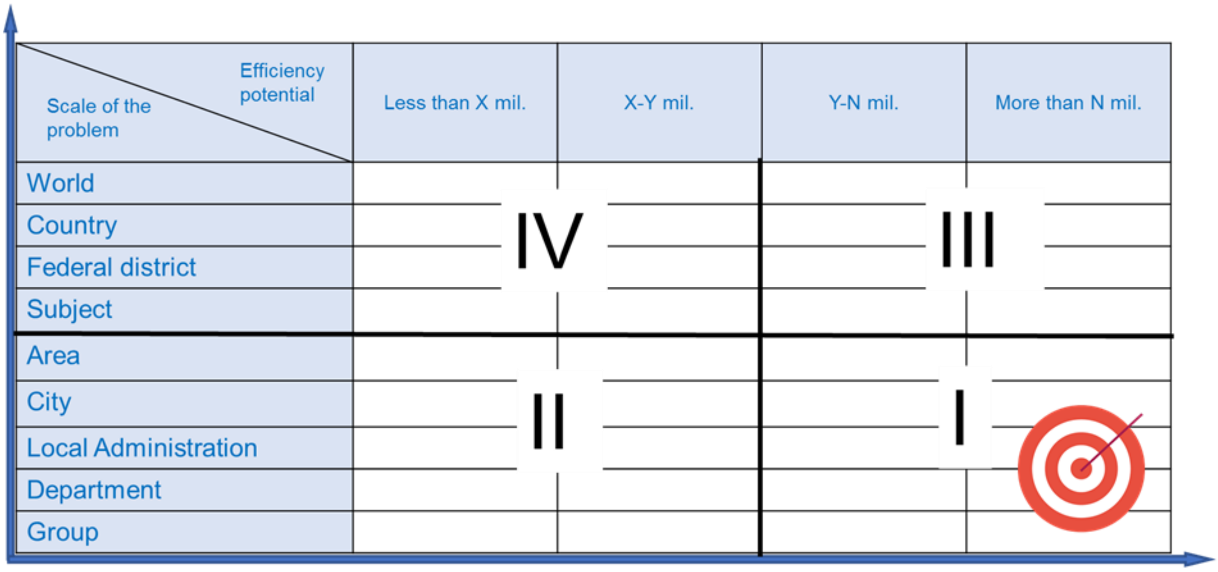


Fig. 6

Examples of decomposed problems of municipal management and approaches to solving them

As a platform for solving decomposed problems of municipal management, which were identified in the course of work with system contradictions and dissonances and reflected at the Problem Landscape, the author proposed to use software complex Compinno-TRIZ. In order to unify the demonstrated examples, the use of the software complex was restricted by modules «Description», «Contradictions», «Techniques» and «Ideas». However, this contracted feature branch was sufficient for obtainment of working solutions. Examples are also quoted in this form and in the form, in which they were solved by deputy heads of management of the subject, which was named earlier.

Example 1. Dumping site with SHW (solid household wastes).

Source problem: Unpermitted rumps of solid household wastes (SHW) regularly appear throughout the territory of state forest fund. Accumulation of solid wastes deteriorates good ecological situation and diminishes tourist attractiveness of the region. At the same time local management bodies have no powers to liquidate rumps of wastes throughout the territory of state forest fund. Fig.7 below shows the formulations, which were further on obtained automatically. (Here and below automatically translation into English via Microsoft Edge is used).

★ Contradiction of requirements - 1	IF **Allocate budget funds for clearing** THEN it is performed **requirement Eliminate unauthorized MSW landfill,** BUT NOT The requirement not **to violate budget legislation** is met.
★ Contradiction of requirements - 2	IF **you do not allocate budget funds for clearing**, then it is performed: **requirement Do not violate budget legislation,** BUT **The requirement to dismantle unauthorized MSW landfill** is NOT met.
Contradiction of attribute	ELEMENT budget **funds** must be **allocated** in order to **eliminate the unauthorized dump of MSW** and must be **unallocated** in order not to **violate budget legislation.**
Functional IFR	**The X-element itself** fulfills the requirement **to Dismantle the unauthorized MSW landfill.**
IFR	**budget funds** with the attribute of **unallocated** **itself** allows you **to eliminate an unauthorized dump of MSW.**
Resource IFR	**X-resource** (from system resources) in place of the **budget** item, keeping it characteristic **unallocated** , must **itself** during operational time within the operational zone provide the ability to comply with the requirement **to dismantle the unauthorized dump of MSW.**

Fig. 7

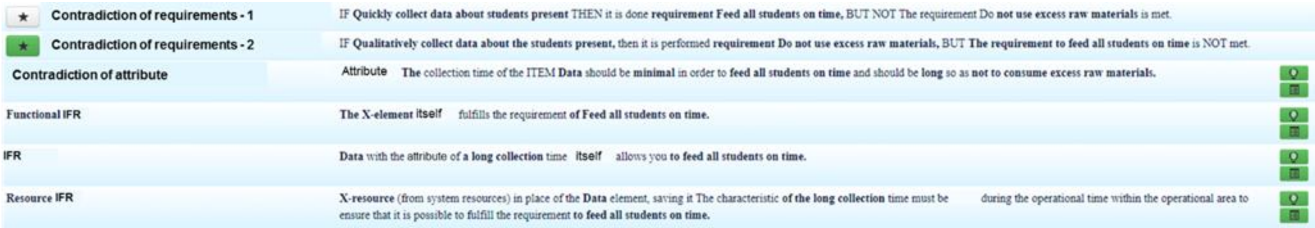
During the process of solving, it became possible to find a solution, which enables to minimize the risks of contamination of forest territories and excludes the violation of budget legislation.

Idea and solutions. Indicated sits are included with the pattern of arrangement (dislocation) of SHW throughout the territory of municipal district, which imposes obligations upon the regional operator consisting in collecting, transportation, processing, utilization detoxification and burial of solid household wastes.

The following techniques were used: 10. Principle of preliminary action, 24. Principle of an «intermediary», as well as work with IFR.

Example 2. Organization of hot meals

Source problem: In planning current number of products needed for organization of hot meals for schoolchildren the employees of school cafeterias committee spend more than 1.5 hours for collecting information about absent schoolchildren. The information is furnished by class masters in the form of paper notifications. There are mistakes and incorrect information may also occur, which leads to overspend of raw material and unreasonable payment for meals. It is necessary to reduce the time of collecting information regarding the absent schoolchildren and exclude incorrect information. The formulations, which were obtained automatically, can be seen below, in Fig. 8.



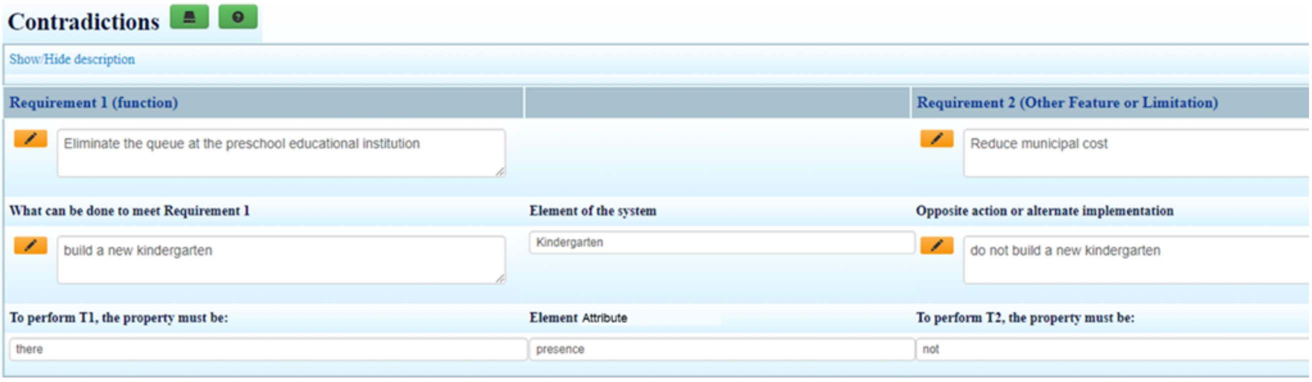
Contradiction of requirements - 1	IF Quickly collect data about students present THEN it is done requirement Feed all students on time, BUT NOT The requirement Do not use excess raw materials is met.
Contradiction of requirements - 2	IF Qualitatively collect data about the students present, then it is performed requirement Do not use excess raw materials, BUT The requirement to feed all students on time is NOT met.
Contradiction of attribute	Attribute The collection time of the ITEM Data should be minimal in order to feed all students on time and should be long so as not to consume excess raw materials.
Functional IFR	The X-element itself fulfills the requirement of Feed all students on time.
IFR	Data with the attribute of a long collection time itself allows you to feed all students on time.
Resource IFR	X-resource (from system resources) in place of the Data element, saving it The characteristic of the long collection time must be during the operational time within the operational area to ensure that it is possible to fulfill the requirement to feed all students on time.

Fig. 8

Idea of solution. Electronic google tables are compiled covering all classes of all schools of municipality. Only class masters have access to filling in the table with the data on absent schoolchildren. The access is affected through the personal google-account of class master through any accessible gadget. The time of access is standardized. Data in the tables is coordinated with the daily menu-requirement, and the formation of volumes of raw material in the assortment for preparing foods is affected automatically. The monthly reports on situation in schools, classes and categories of schoolchildren who get hot meals are also formed automatically.

Example 3. Kindergarten.

Source problem: Existing queues to kindergarten (pre-school educational institution – PEI) may be several years old. At the same time local administration has a strongly restricted budget for building new PEI. For an example of filling in the cells in a software complex is given in Fig. 9. Automatically obtained formulations are quoted below in Fig. 10. Example of work with Altshuller Matrix is given further in Fig. 11,12.



Contradictions

Show/Hide description

Requirement 1 (function)		Requirement 2 (Other Feature or Limitation)
Eliminate the queue at the preschool educational institution		Reduce municipal cost
What can be done to meet Requirement 1	Element of the system	Opposite action or alternate implementation
build a new kindergarten	Kindergarten	do not build a new kindergarten
To perform T1, the property must be:	Element Attribute	To perform T2, the property must be:
there	presence	not

Fig. 9

Contradiction of requirements - 1	IF **Build a new kindergarten** THEN it is done **requirement Eliminate the queue at the preschool educational institution,** BUT NOT The requirement to **reduce municipal expenditure** is met.
Contradiction of requirements - 2	IF **you do not build a new kindergarten**, then it is done **Requirement Reduce municipal spending,** BUT The requirement **to Eliminate the queue in the preschool educational institution** is NOT met.
Contradiction of attribute	Attribute **THE PRESENCE OF AN ELEMENT Kindergarten** must be **there** to **Eliminate the queue in the preschool and** must be **not** to **Reduce municipal costs.**
Functional IFR	**The x-element** itself fulfills the requirement **to Eliminate the queue in the preschool educational institution.**
IFR	**A kindergarten** with the attribute **is not the presence** itself allows you **to eliminate the queue in the preschool educational institution.**
Resource IFR	**X-resource** (from system resources) in place of the **Kindergarten** element, saving it characteristic **is not available**, must during the operational time within the operational zone provide the ability to comply with **the requirement to eliminate the queue in the preschool educational institution.**

Fig. 10

Altshuller's matrix

Selected Requirement Contradiction	
IF **Build a new kindergarten** THEN it is done **requirement Eliminate the queue at the preschool educational institution,** BUT NOT The requirement to **reduce municipal expenditure** is met.	
Altshuller's complete table	
What needs to be improved:	
What gets worse at the same time:	
Selected parameter pairs	
30. Harmful factors acting on the object	23. Loss of matter
09. Speed	19. Energy consumption of a moving object
33. Ease of use	36. Device Complexity

Fig. 11

Methods of resolving technical contradictions

Refresh

15. DYNAMISM a. The characteristics of the object or the external environment should change so as to be optimal at each stage of work b. Divide the object into parts that can move relative to each other c. If the object as a whole is stationary, make it mobile, moving	09. Speed - 19. Energy consumption of a moving object
26. COPYING a. Instead of an inaccessible, complex, expensive, inconvenient or fragile object, use its simplified and cheap copies b. Replace the object or system of objects with their optical copies (images). Use zooming (enlarge or shrink copies) c. If you are using visible optical copies, switch to infrared or ultraviolet copies	33. Ease of use - 36. The complexity of the device

Fig. 12

Idea for solving. Erecting additions to buildings of existing kindergartens; Use of a typical design of a PEI; Erecting kindergartens of typical design.

CONCLUSION

System-based approach, which is offered by TRIZ, can also be successfully used in work with problems of municipal management. Use of TRIZ for focal search and analysis of problems, use of tools for finding the solution proved their effectiveness.

The best results, in the opinion of the author, can be achieved, if TRIZ is used at all stages of work with a complex of problems and tasks, not exclusively in solving one problem, which the solver encounters.

Formation of a separate trend of TRIZ within the sphere of municipal management requires significant working-through, but already now it is obvious that this direction can be demanded for in the nearest perspective, taking into account these global processes, which take place in the world.

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Socio-informational system contradictions and evolution laws

SUMMARY

Our lives are becoming more and more dependent on digital products. We trust autopilot systems in plain and cars, doctors rely on healthcare systems to prescribe a treatment, money gave way to cryptocurrencies, and the list can go on. An organization stands behind every digital product with its social structure, culture, and values. The understanding that a technological system does not exist independently of social systems helps us better understand the principles of system evolution, system contradictions, and possible avenues for improvement.

This paper will explore socio-informational systems through the lenses of the Theory of Innovative Problem-Solving (TRIZ). We will explore the well-known software industry laws, their intersection with TRIZ laws, and the contradictions.

Keywords: *Socio-Informational, Contradictions, Evolution Laws*

INTRODUCTION

The term socio-technical system was originally coined by Emery and Trist (1960) in the book describing the project undertaken by Tavistock Institute in the British coal mining industry. They created the socio-technical system term to describe systems that involve a complex interaction between humans, machines, and the environment. This interaction is true of most enterprise systems. [1] Eric designated three levels of socio-technical systems even though they are interrelated [2]:

- Primary work systems – systems are carrying out a set of activities involved in identifiable and bounded subsystems of the whole organization – such as a line department or service unit.
- The whole organization system – is a combination of all subsystems of an entire company producing the value.
- Macrosocial systems include systems in communities and industrial sectors and institutions operating at the overall level of society.

In this paper, we will focus on the primary work system level; moreover, we will devote our analysis to the specific class of technology systems, such as information systems. However, we may argue that our observations apply to the broader spectrum of technology systems.

Lehman studied information systems and discerned three types of programs with different characteristics: E-type, P-type, and S-type. [3]

- S-type systems have formally defined specifications with clear criteria of correct implementation matching results to the inputs. result
- P-type systems are more complicated; they are designed to solve real-world problems with defined rules. Even though the problem to be solved can be described, the acceptability of the solution depends on the environment/context in which it is executed. An example of such a program is a chess game algorithm.
- E-type systems are real-world systems that don’t have static rules, environment, or clear specifications; We are talking about software programs working within living business organizations involving people. Given the evolving nature of the software program's environment, correctness is vaguely defined. Examples of such programs are systems automating business processes.

In our paper, we will focus primarily on the E-type of information systems developed by the correspondent social construct of the primary working system.

Socio-Informational System Definition

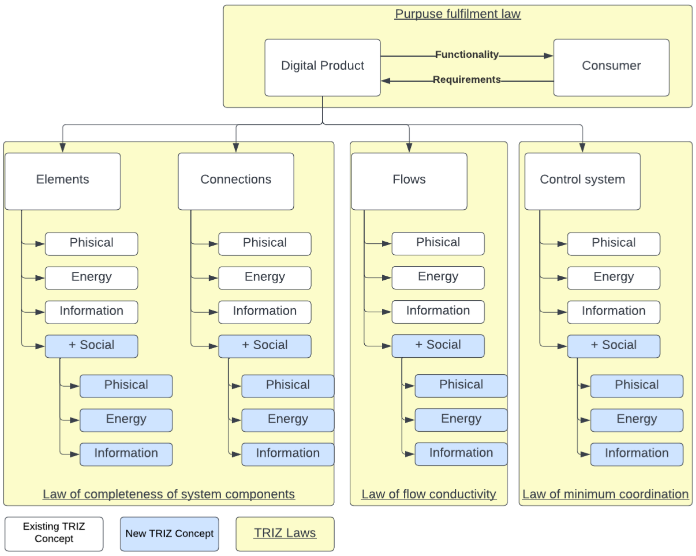

Figure 1. Structure of the socio-information system

Let's define the socio-informational system more precisely. Following the Lehman system classification, this is an E-type, real-world system. Systems that are intertwined with processes of real life, with business processes, with real people where there is not necessarily a specification of 100% correctness. Because the system's requirements are ever-changing, a consumer is not entirely sure what they want to have. Or even if they are sure today, tomorrow might not be the case. It's important to emphasize that that's not necessarily just because of uncertainty. That's because consumers exist in an environment that's subject to change since people's and business needs evolve. Therefore, the specification and requirements of our system are not stable.

Given that premise and the fact that digital products cannot automatically implement new requirements without people's involvement, we need to recognize additional structural elements. We call it "social," which defines a human organization as responsible for delivering new functionality and fulfilling the purpose of the system. Without human organization, no digital product can be created or abandoned after creation since it becomes misaligned with the changing environment that eventually breaks the purpose fulfillment law.

The socio system is an alive system; therefore, its construct is comprised of people and their relationship (network) that together defines the property of the socio system as a whole designed to live within the environment. [4] The social component is well recognized across fellows of the socio-technical system, and Badham articulated the following key characteristics of the socio-technical system, where the social component is named as a subsystem referring to people, work for context and organization.

- Systems should have interdependent parts.
- Systems should adapt to and pursue goals in external environments.
- Systems have an internal environment comprising separate but interdependent technical and social subsystems.
- Systems have equifinality. In other words, systems goals can be achieved by more than one means. This implies that there are design choices to be made during system development.
- System performance relies on the joint optimization of the technical and social subsystems. Focusing on one of these systems to the exclusion of the other is likely to lead to degraded system performance and utility. [5]

Another piece of evidence supporting the existence and importance of social elements is the Conway Law or mirroring hypothesis that was confirmed by Alan MacCormack. [6] "*Products tend to "mirror" the architectures of the organizations in which they are developed. This dynamic occurs because the organization's governance structures, problem-solving routines, and communication patterns constrain the space in which it searches for new solutions. Such a relationship is important, given that product architecture has been shown to be an important predictor of product performance*". Therefore, the social and information product architecture are intertwined and should be considered cohesive.

A social element should be treated as a system comprising elements (people), connections (social structures), flows, and a control system. Following the TRIZ definition of the system structure [7], the social system should have the following construct:

- Physical: teams' decomposition, distribution among physical locations and time zones.
- Energy: money, team engagement, motivation, wellness
- Information: knowledge about digital product architecture and element's structure

The efficiency of our entire socio-informational system depends on the structure and how the interactions/flows among structural elements are organized and coordinated in the physical, energy, and information realms. Moreover, the socio part of the socio-informational system should be aligned with technical architecture to be efficient.

Law of completeness of system components

Our social element should have the competencies and knowledge to produce the required technical changes in the informational product; if the person/team knows how the component works gone, then the whole socio-informational system's existence might be questioned. In the organizational management research field, we found that Youndt [8] introduced the term intellectual capital, which transients the notion of the competencies described above. He defined intellectual capital as "the sum of all knowledge firms utilizes for competitive advantage. The sum of all knowledge means that the concept of intellectual capital encompasses all assets available to a company. Different divisions of intellectual capital into components exist. [8] Claes take it forward and discern three types of intellectual capital: human capital, social capital, and organizational capital. [9] Human capital is individual knowledge; social capital is the social construct that provides an infrastructure for interaction/information flows, and organizational capital refers to processes and the external organizational network with customers and partners.

From the TRIZ perspective, we can say that the social subsystem should have people with their human capital (knowledge and skills); the way it transforms information could be referred to as a part of organizational capital (processes), connections that are social capital, and management system could also be referred to the organizational capital.

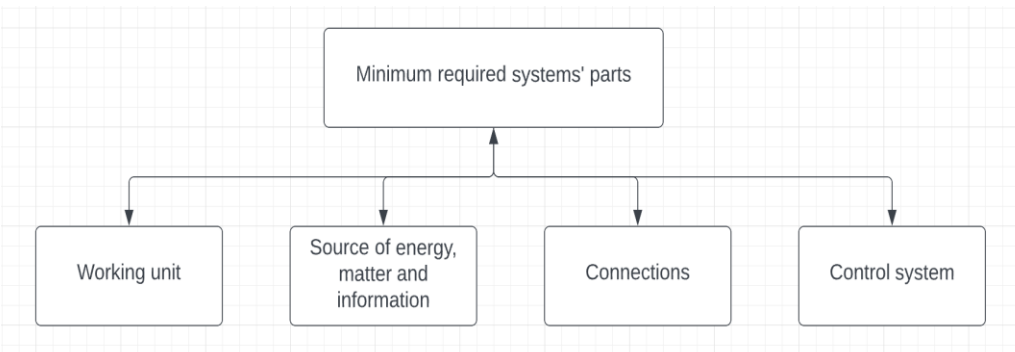

Figure 2. System Structure Law of flow conductivity and Law of minimum coordination

Since systems are comprised of multiple elements, in the case of the socio-informational system, we have socio-construct and associated with it informational system architecture. Both layers have communication and coordination mechanics that sometimes intertwine.

In alignment with TRIZ, the flow conductivity of the socio-system should have informational conductivity that represents the social and organizational capital and energy conductivity in the form of financial resource distribution to keep the system alive. Henry Mintzberg proposed five coordinating mechanisms between elements to ensure coordination: mutual adjustment, direct supervision, process standardization, output standardization, and skill standardization. As organizational work becomes more complicated, the favored means of coordination continuously shift from mutual adjustment to skills standardization and back to mutual adjustment. Depending on the environment and nature, various parts of the organization will grow – operational core, technostructure, mile line, support staff, and rarely strategic apex. [10] In the case of socio-informational, the operational core, support staff, and middle manager represent the largest structural elements of the systems. The design approach for the efficient operational core of the socio-informational system proposed by Manuel Pays and Matthew Skelton defines organizational constructs, communication, and coordination patterns that depend on the human cognitive load. [11]

We can see how the coordination mechanics evolve along with the organization's growth. The competitive environment in the technology business force companies to grow to adapt the product to the changing environment; therefore, the number of informational system components and a number of people grows, increasing social interactions and cognitive load to the efficiency ceiling when adding more people doesn't add more productivity. This is when organizational transformation happens since the system wants to survive.

Following mechanistic and organic organization structure classification, we proposed a simplified representation below. [12] In small organizations starting the development of an information system, we can observe organic forms with flat and cross-functional structures that don't need additional administrative organs or support. When the number of information system components grows, the socio structure changes doubling, tripling, switching to a hierarchical structure, and becoming more mechanics. Once it reaches the ceiling of efficiency, it tends to transform into an agile, organic structure again.

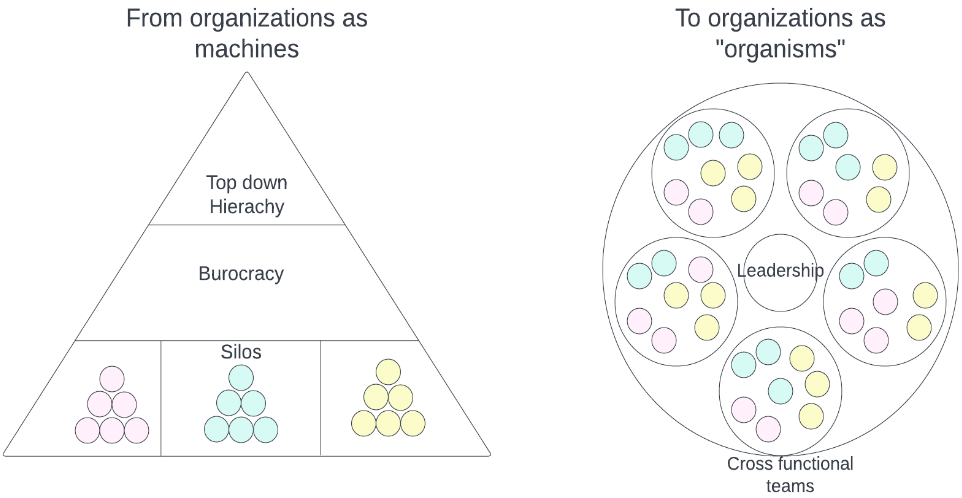

Figure 3. Schematic diagram of organizational paradigm evolution

Evolution of the socio-informational systems

Let’s take a look at the evolution of information system architecture and put it into the context of social construct producing digital/informational products of correspondent architecture.

The general pattern that the development of systems is in the direction of increasing degree of dynamicity is applicable to the socio-informational system.

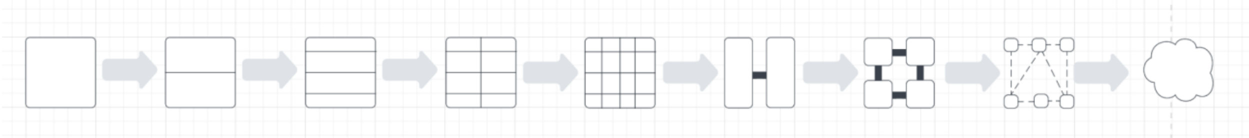

Figure 4. Transition from solid to agile state

Building a parallel with information system architecture, we can highlight trends from the monolith to multilayers, microservices, and serverless architecture. This trend of system granularization has one key driver – speed, the number of change implementations within a time frame. If a digital product got a market fit, then the company that satisfies the most users’ needs in the fastest manner without quality tradeoffs wins the market. So, we can generalize that information system architecture is driven by the competition pressure within a specific industry/field/domain. Michel Porter conceptualized these thoughts in the five factors defining the strategy for an organization, which applies to the socio-informational systems as an example of any organization creating value for its consumers. [21]

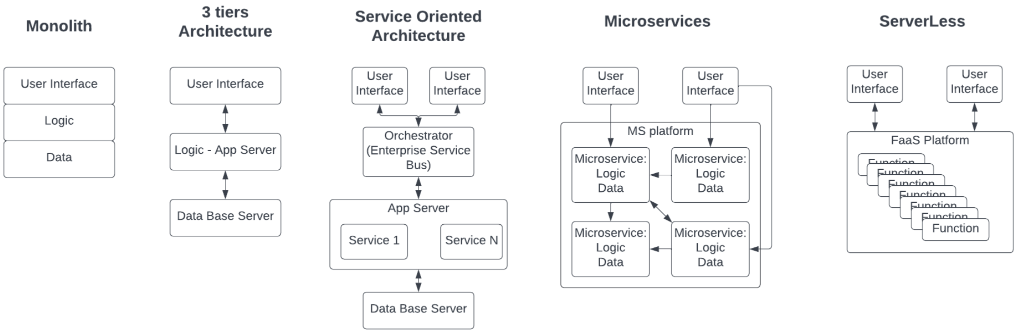

Figure 5. Information system architecture evolution

As we laid out earlier, product architecture defines the social construct of the organization producing it; therefore, we should also adhere to the trend of organization architecture evolution. Below we schematically outlined a typical organizational structure supporting various informational system architectures.

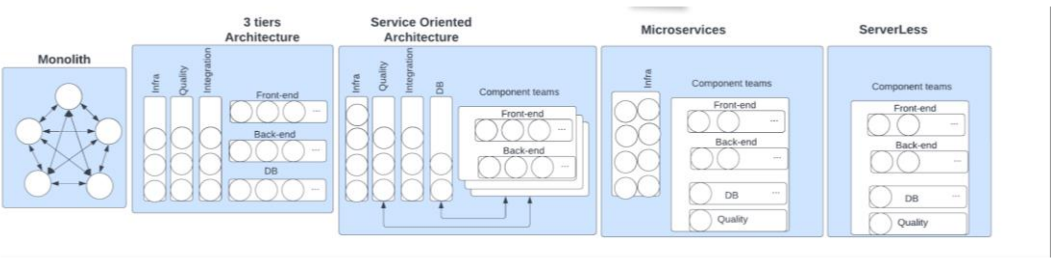

Figure 6. Team composition associated with information systems architecture

Let's consider the beginning of product development. Usually, a small team starts a development, and often the architecture gravitates toward a monolith pattern when all layers are tied together to some extent; If any part of the system changes, the whole system should be rebuilt and deployed. And everyone knows every element of the system to make a change.

Along with product success, the demand for features is growing; therefore, the pressure to extend the engineering teams increases. At the same time, the flat structure doesn’t provide efficient coordination and scaling. Team decomposition and designated ownership become inevitable. The borderline of the team decomposition has its origin in an architectural construct and often falls into the layered pattern like client-server when data and business logic are decoupled from the user interface. To accommodate such decomposition, the social structure often fell into a functional pattern, where we have teams responsible for the change implementation at the specific layer. Once we have several teams, the coordination layer comes into play to make sure the changes are integrated properly without defects.

If the product success continues, the demand for features grows even further; therefore, the number of engineers grows, and consequently, the necessity to avoid code conflicts arises again. The solution is to add another dimension to reduce the elements' size further. The service-oriented architecture is the pattern of meeting such a need that has layers and components known as services. The social construct accommodates an additional dimension known as a matrix. We have layers grouped by architectural components (services). The growing number of components quickly leads to repeated functionality implemented in different ways, which is not an efficient time investment that has no impact on the development speed. Such an adverse effect is mitigated by standardized, reusable frameworks and shared services solving everyday tasks and reducing the duplication of efforts. On the one hand, the frameworks add productivity gain; however, they require more time to onboard a newcomer and add additional cognitive load along the way. The importance of the integration team becomes even more important since the number of moving pieces to orchestrate grows.

If an organization continues to grow in the described above paradigm, then the growing number of people reaches its productivity saturation point, followed by diminishing returns. Often the bottleneck is the coordination and integration layer as well as the disbalance of skill distribution to produce the value without waiting time. To solve the integration and dependency problem, the microservices architecture comes into play and emphasizes every component's delivery and deployment independence. To enable such autonomy, automation comes to the forefront of focus with common frameworks automating routine and enabling engineering freedom. The social construct also evolves: the integration team loses its demand, and components are managed by flat independent teams where specialization is not as important as before, eliminating the skill disbalance, and the automation team increases its power.

Organizations require a strong engineering team to build such an automation platform, though the skill is scarce, so not all engineering organizations can accommodate the required demand. The invisible hand of the market solves such a problem, and we see a growing number of cloud providers as well as serverless architecture that alleviates the necessity of a significant automation team. Until such a configuration satisfies the appetite for the speed of value delivery, we will observe the continuation of the trend in the cloud and serverless architecture.

Mapping of TRIZ laws of evolution and information systems evolution laws

Let’s review the correspondence between TRIZ laws and laws of software system evolution to explore the overlap and gaps.

TRIZ articulated six laws [13]:

- Increasing degree of controllability and dynamicity
- Transition to a super system
- Transition to a macro or a micro level
- Coordination
- Convolution deployment
- Balanced development of the system

Leham articulated eight laws [14]:

- Continuing change
- Increasing complexity
- The fundamental law of program evolution
- Conservation of organizational stability
- Conservation of familiarity
- Continuing Growth [15]
- Declining Quality [15]
- Feedback system [15]

Law of increasing degree of controllability and dynamicity.

Such a law describes the combination of trends. The first one is the increasing control of elements along with the growing dynamicity of elements. Such trends reflect the increasing efficiency of managing feedback loops within the system. Often controllability improvement goes together with the reduction of human involvement in the functioning of technical systems. Below you can find the schematic representation of the trend reflecting the controllability improvement.

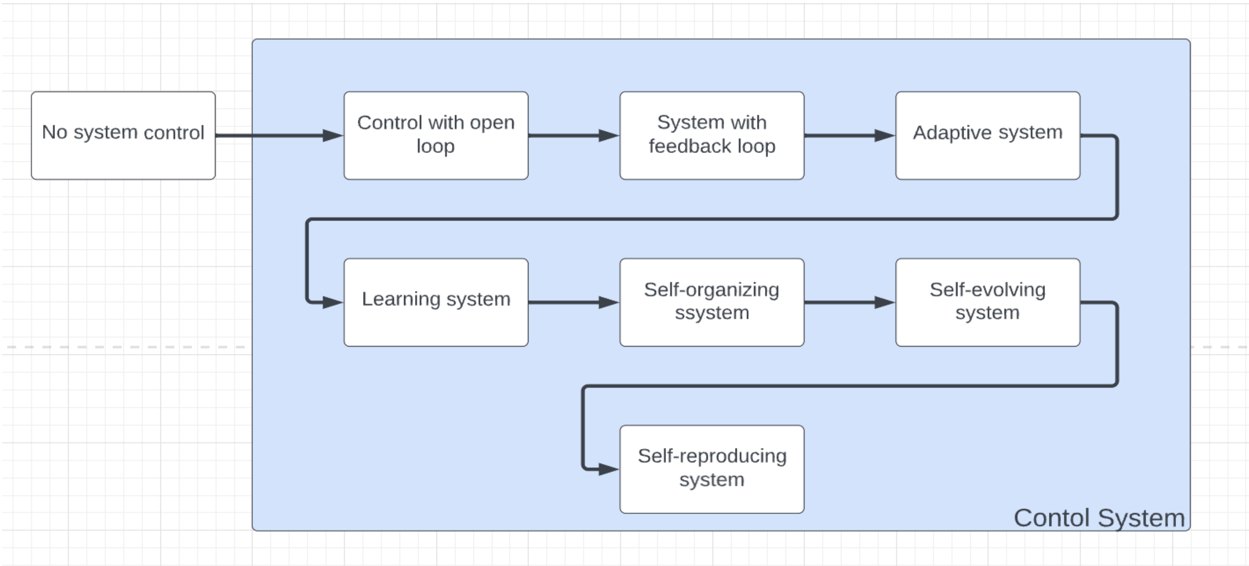

Figure 7. Transition from unmanageable system to manageable

Below, we outlined trends of increasing dynamicity among various dimensions such as time, space, or on condition.

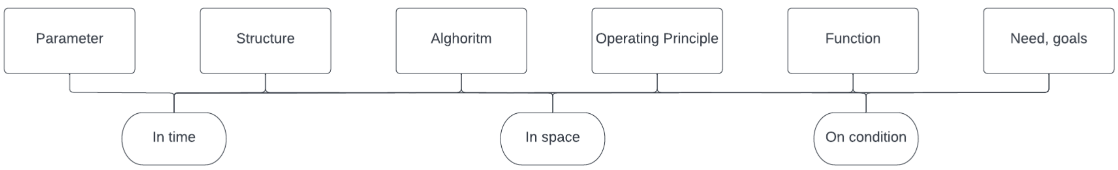

Figure 8. Flow of increasing dynamicity degree

Making a parallel between TRIZ and software evolution laws, we observe the fundamental accordance in the role of the feedback loop. [16] E-type evolution processes constitute multi-level, multi-loop, multi-agent feedback systems and must be treated as such to achieve significant improvement over any reasonable base. Even though the trend of controllability and dynamicity was not articulated formally still, we can observe it in the life cycle of the software product; when the first version is always limited and doesn't provide enough flexibility, then along with time a program becomes more sophisticated, more dynamic, and configurable. In some cases, like Tesla, some program elements become self-learning due to contemporary artificial intelligence technologies.

1. ransition to supersystem

The system combines with another system, creating a new, more complex system. [17]

In the software, we see such a trend embodied in the Increasing Complexity and Continuing Growth laws. Increasing complexity was articulated as an E-type system evolves; its complexity increases unless work is done to maintain or reduce it. Continuing Growth was articulated as an E-type system that must be continually adapted, or it becomes progressively less satisfactory.

Both laws have negative implications for the speed of development. An example might be cyclomatic complexity and its effect on engineering productivity [18]. Cyclomatic complexity is a software metric used to determine the complexity of a program. It is a count of the number of decisions in the source code. The higher the count, the more complex the code. Given the program's growing complexity and size, this metric also goes up, making it harder for engineers to implement a new change.

2. Transition to a macro or a micro level

According to TRIZ, systems tend to reduce in size their elements; at the same time, their selves often grow in size, power, efficiency, and other dimensions.

Looking at the evolution of information architecture, we can see the same trend. Components become increasingly granular until the lambda function in the cloud, where an engineer doesn't need to think about infrastructure, just define the function and deploy it to one of the cloud providers. Given the trend to reduce in size of the components of information systems, we observe the trend of the growing platforms to run such small apps in a number of functions provided, scale, availability, and other characteristics.

3. Coordination

According to TRIZ, coordination and harmonization of the internal elements of the systems require to minimize negative effects and make the system more efficient. The Lehman law of declining quality suggests that internal coordination and harmonization of elements – the quality of an E-Type system will appear to decline unless it is rigorously maintained and adapted to operational environment changes. Therefore, to avoid the quality erosion of the system, engineers undertake special techniques of various test automation.

Coordination can happen not only within the system but also between the system and the environment. This is exactly what we experience in information systems. According to the law of continuous change – E-Type of the system must be continuously adapted, or it becomes progressively less satisfactory. It is obvious that if demand from a customer is not addressed, then the customer will look for another solution.

Here is another both internal and external system coordination aspect specific to information systems known as "Conservation of Familiarity law". Leham suggests that as an E-type system evolves, all associated with it, developers, sales personnel, and users, for example, must maintain mastery of its content and behavior to achieve satisfactory evolution. Excessive growth diminishes that mastery. Hence the average incremental growth remains invariant as the system evolves.

The laws of continuous change and conservation of familiarity are laws affecting qualitative attributes of the information system but can be resolved outside the information system only since they are related to people and the socio realm. Therefore, if we produce an information system to make it efficient, it is not enough to consider only the architectural characteristics of the system; it is essential to design the social construction delivering, supporting, and evolving the information system. We assume that this observation will be relevant for other technical systems; therefore, we consider this a new element for the TRIZ system.

Given the definition of the socio-information system and empirical confirmation of Conway law, we believe it is expedient to consider an extension of the TRIZ apparatus with such a law for the scope of informational systems. And do empirical research on Conway law relevance for the broader category of technology systems.

4. Convolution deployment

Based on TRIZ, the Law of –convolution-deployment is such that any system during its development collapses or expands its functions and components.

Analogous law in software is the law of Continuing Growth that we attributed to the transition to the super system, though it is also applicable here since reflecting the notion that the system, if not appropriately evolved, losses its value for users and becomes obsolete. We can see a plethora of such cases in software. Sun Microsystems doesn't exist anymore, Yahoo lost the market of internet search, Microsoft closed its mobile department, and the list can go on.

5. Balanced development of the system

System elements' development is imbalanced, and the more complex system, the less balanced development is, TRIZ suggests. The third and fourth laws of E-Type of software systems evolution support TRIZ balanced development and suggest that there is an intrinsic system dynamic of socio-informational systems that enforce the balanced way of system evolution. Self-Regulation law says that E-type system evolution processes are self-regulating with the distribution of product and process measures close to normal; and Conservation of Organizational Stability says that the average effective global activity rate in an evolving E-type system is invariant over the product's lifetime. We could argue that these laws reflect the dynamics of growing information systems. When the stakes of success and failure go up, the social system tends to minimize large disruptive changes that could lead to instability of the informational system. Therefore, along with the growing number of engineers, the individual engineering productivity rate goes down, so the overall rate of change tends to be invariant to the number of people and defined by the informational system architecture. Changing both informational architectures as well as the architecture of a social system could yield a productivity change.

CONTRADICTIONS

As we saw above, social and technical systems are complementary, and one cannot exist without another. The information architecture might be brilliant, but its implementation will depend on the social structure that depends on the people's ability to produce the work. It is not possible to increase the number of people infinitely since they need to interact with each other. And people's capacity is limited by the number of social interactions one person can handle, known as the Dunbar number [19], and cognitive load limits [20] that restrict the ability to do the mental work that is the core of information system development. Without such limitations, any organization developing an information system, even a tightly-coupled monolith, might scale infinitely. Since we have people within the system, we cannot scale system development without addressing information architecture.

DISCUSSION FOR FURTHER RESEARCH

Exploring socio-informational systems beyond the primary work boundaries is expedient, specifically, at the whole organizational and macro-social levels. Such research might reveal laws, trends, and implications for our that established organizations and technology entrepreneurs can take into account to amplify positive effects and mitigate adviser effects.

Another consideration for further research is validating the hypothesis of whether a Conway law can be attributed to the broader category of technology systems, which will support its adoption beyond socio-information systems, as we proposed above.

We also consider validating the hypothesis that only joined and balanced changes in the informational and social systems could positively impact productivity. Whereas independent changes in an information system of a social system most likely result in a negative productivity trend.

CONCLUSION

Such research revealed the importance of new socio-considerations for analyzing and designing information systems and their delivery mechanics. That became even more actual with the growing dependency of humanity on the informational systems; therefore, we should find a way to properly balance and harmonize socio and informational systems together, minimizing adviser effects related to their evolutions. Quality degradation, growing complexity, conservation of familiarity, and implications of the team composition, these challenges related to the people aspect and without proper address could lead to an irreversible situation with mission-critical systems that empowers healthcare, self-driving algorithms, aviation, etc. We have also shown that socio-informational systems follow the TRIZ evolution laws that can inform the decision-making of people in charge to manage the end-to-end life cycle of such systems properly.

Even though the combination of socio systems and technology systems is the field with a solid research foundation, we believe there is great potential for further research on the combination of socio and informational systems across all levels of production, organizational as well as a macro social one. The authors intend to continue research in the mentioned area.

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"TRIZ Developers Summit" DECLARATION

Major TRIZ Components and Provisions

TRIZ is founded on the objective laws of technological evolution.

The major laws of technological evolution are systemic and can be applied for solving inventive problems of engineering and non-engineering systems, including non-material ones.

TRIZ ideology is based on the provision that systems evolve through emergence and resolution of contradictions. High level inventive solutions leading to the resolution of contradictions in system evolution constitute the knowledge base for disclosing the laws and trends of system evolution.

Developing TRIZ for its application in non-engineering fields relies on knowledge bases containing high level inventive solutions from various areas of human activity.

TRIZ relies on a model approach to problem statement, search for solutions, and elaboration of system evolution trends. At that, models based on Su-field and function analysis and ideal final result, as well as those describing the process of inventive problem stating and solving are used.

The inventive thinking includes systemic, evolutionary, and resource thinking. To create such thinking, attention should be paid to developing inventive imagination.

TRIZ is based on the approaches laid by G. Altshuller's works.

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