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Collection of scientific papers "**TRIZ-Based Forecasting Methods"** is intended for TRIZ specialists, engineers, inventors, and specialists in innovation and forecasting as well as for trainers in the field of these disciplines. The collection includes latest developments of TRIZ specialists in the field of forecasting the evolution of systems - both in engineering and non-engineering spheres. Current collection of published papers includes articles related to the theory and practice of TRIZ methods application in the field of forecasting. The collection includes not only the articles written in 2010, but also those written in previous years.

The articles are published in authors' version.

Compiled by: M.S.Rubin, A.V.Kudryavtsev, S.S.Litvin, V.M.Petrov
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INTRODUCTION

"TRIZ Developers Summit" is a non-governmental organization created to the initiative of researchers working in the field of TRIZ. The main goal of TRIZ Summit is to organize the interaction of developers and researchers contributing to the development of TRIZ as a science. The activity of TRIZ Developers Summit involves annual scientific research seminars on TRIZ, which are held for the sixths time, starting from 2005. The activity of Non-Governmental Invention Laboratory and scientific seminars on TRIZ development, which took place in Baku and Petrozavodsk under the guidance of G.S.Altshuller, served as an "ancestor" for TRIZ Summit.

Usually both experienced and young researchers in the field of TRIZ are invited to participate in the work of TRIZ Summit conferences. Collections of scientific papers, which are included in the library of TRIZ Summit, were published since 2007. The present collection is the third issue of this library. It is published on the occasion of TRIZ Developers Summit 2010 (TDS-2010) and is devoted to studies conducted in the field of developing TRIZ-based forecasting methodology.

The present collection of papers is published both in Russian and in English. The collection contains both materials intentionally prepared for TRIZ Summit 2010 and materials written during previous years and devoted to TRIZ-based forecasting. Full texts of articles included in the English version of collection only in the form of abstracts are published in the Collection of papers for TRIZ Summit 2010 in Russian.

Compiled by: M.S. Rubin, A.V.Kudryavtsev, S.S.Litvin, V.M.Petrov

July 2010.

SECTION I.
PAPERS AND ABSTRACTS FOR TRIZ SUMMIT 2010

A.V.Efimov

Forecasting on the Basis of Unified System "Trends-Standards-Techniques"

Abstract

The present paper contains examples of practical application of Unified System "Trends - Standards - techniques" developed by the author and intended for forecasting the evolution of engineering systems (ES).
Besides, the author also analyzes two major stages of forecasting - namely, forecasting of new requirements to ES and development of a portrait for forecasted new ES meeting these requirements.
The authors shows that at the second stage forecasting is reduced to solving of inventive problem on improvement of existing system to the level of new requirements.
Key words:
Trends of ES evolution, Standards for inventive problem solving, Techniques for engineering contradiction resolving

Introduction

Major approaches to TRIZ-based forecasting of evolution of engineering systems (ES), as well as examples of such forecasting are described well enough by many authors [1, 2, 3, 4, 5].

It is truly indicated in these publications that studying and extrapolating existing tendencies of ES evolution to the future are insufficient for effective forecasting. It is necessary to identify contradictions, which in the future can hinder further ES evolution plus analyze tendencies in the evolution of requirements, which would be imposed to ES under consideration. An image of improved ES, for which forecasted contradiction will be resolved, actually represents a forecast of ES evolution. The present article represents an attempt to illustrate main stages of ES evolution forecasting involving the use of unified system of "Trends - Standards - Techniques" (US TST) proposed by the author earlier [6].

Major kinds of forecasts and forecast depth in TRIZ

The simplest forecast for the evolution of requirements to ES can be produced by extrapolating a parameter, which characterizes this ES to the fullest extent possible - see Fig. 1a. As a rule, this kind of forecast is not labor consuming and does not need application of TRIZ tools, but it is characterized by shortest term of and lowest reliability. In this case, TRIZ (including US TST) can be used at the second stage of forecasting - when solving an inventive problem on improving existing ES to the level of forecasted values of parameters.

The most sophisticated forecast involves (see Fig. 1e) extrapolation of several lines of supersystem evolution - namely, identification of contradictions between these lines, formulation of requirements to parameters of new ES, which would enable to resolve identified contradictions, and, finally, working out a portrait of new ES, which meets formulated requirements. As a rule, such kind of forecast ensures the longest term and reliability for the forecast, though it is characterized by high labor consumption.

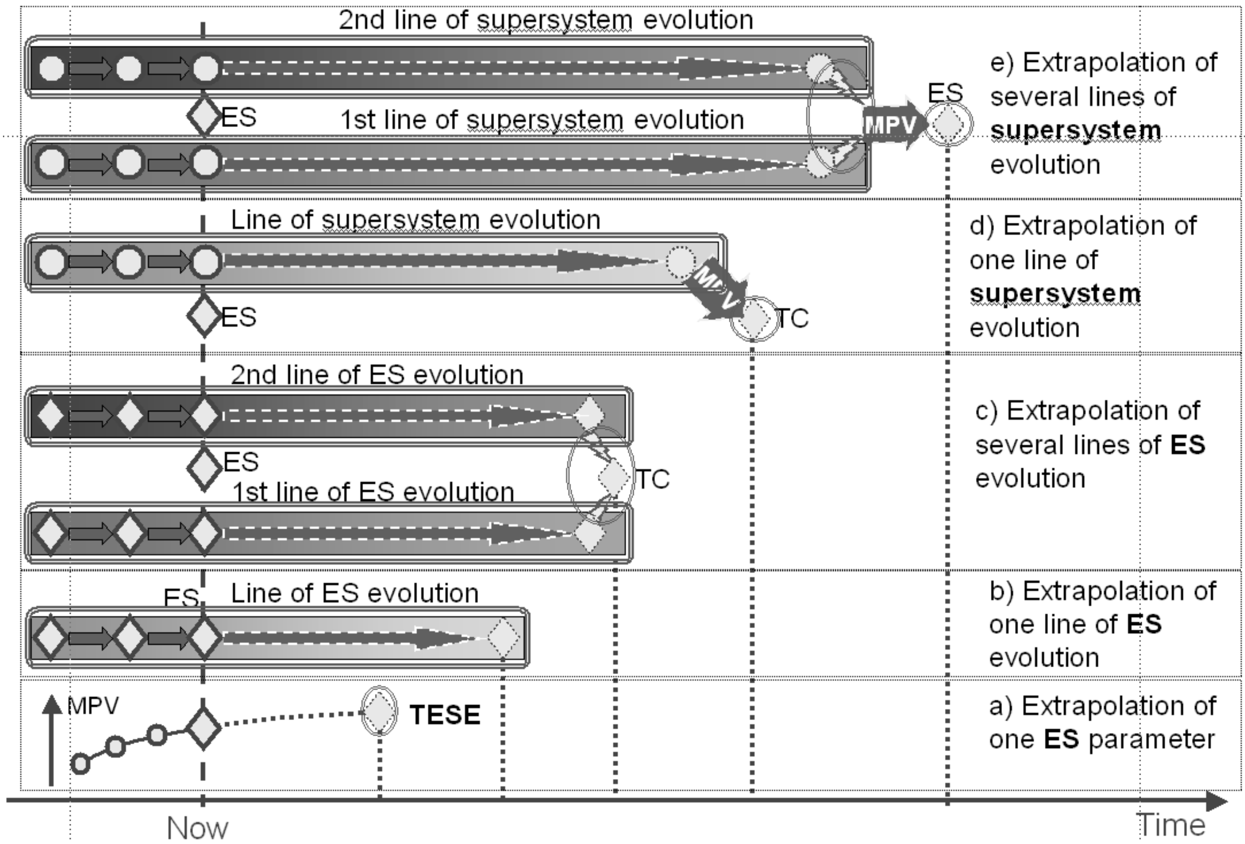

Fig. 1. Main kinds of forecasts in TRIZ and forecast term

Besides, intermediate kinds of forecasts can be also used, which involve extrapolation of one or several evolutionary lines of ES under consideration or one evolutionary line of the supersystem (Fig. 1 b-d).

Fields for US TST application for different kinds of forecasts

US TST tools can be used in forecasting both directly in the form of evolutionary lines when forecasting requirements to ES (they are enclosed in double-line rectangular frames in Fig. 1) and in the form of tools for inventive problem solving with the aim to improve ES under consideration to a level of forecasted new requirements (they are enclosed in double-line closed ovals).

In addition, as was indicated in [6], introduction of Standards for inventive problem solving and Techniques for engineering contradiction resolving into existing system of Trends upgrades the efficiency of Trends application for solving inventive problems.

Besides, the proposed functional input into unified system "Trends - Standards - Techniques" makes the application of this complex tool intuitively understandable and allows using it without complex algorithms.

Example of practical forecast using unified system "Trends - Standards - Techniques"

Foe the sake of simplicity and briefness, all types of forecasts indicated in Fig.1 are illustrated by one example. Not all the steps (described below to ensure completeness of methodology) were used in the real project. That's why, from the practical standpoint, some examples may appear to be obvious enough.

Initial problem

It is required to forecast evolution for blood separation systems.

Extrapolation of one ES parameter

Since to accomplish project goals, it was important for researchers to know how such parameter of blood separation systems as "blood separation efficiency" varies, then, having data about variation of this parameter in the past, it was not difficult to forecast what values of "blood separation efficiency" would be achieved by certain time point in the future, if current tendency of this parameter variation would remain constant (Fig. 1a). In a certain sense, such determination of "blood separation efficiency" value represents a simplest forecast. Such a forecast doesn't require special TRIZ tools.

TRIZ, and in particular TESE or US TST, may be necessary, if its required to forecast, how ES should change to reach a specified level of "blood separation efficiency". To find an answer, one should solve the following inventive problem - "How the blood separation efficiency of ES under consideration could be raised to the specified level?" In the example given below, US TST was used for this purpose.

The logic of application of this tool in a given example was as follows:

Increasing the blood separation efficiency represents a particular case of a problem of upgrading ES functionality. Therefore, we should address an appropriate section of US TST (section 3 in Fig. 2).

Problems to be solved (input)	Tool used	Description of tool (explanation)
3. Upgrading functionality (possibly, with concurrent certain growth in consumption of resources)	**3. Transition to the supersystem (means)**	**System efficiency can be upgraded via integration with other systems**
3.1. Increasing the level of function performance (productivity, accuracy, reliability, fastness of operation, ...)	3.1. Increasing the degree of ES completeness	System that can be broken down into four standard units - namely, source of energy, energy converter (transmission), operating/working member, and control system (some of these units could be missing, while their functions are performed by supersystem elements) - gradually transfer in the course of their evolution to self-performance of functions of these units - Expulsion of human involvement from ES

Fig. 2. Selection of required tool from US TST

However, functionality should be upgraded not by increasing the number of performed useful functions, but by enhancing the current function performance. That's why we should select subsection 3.1.

As a result, for this example we get the following recommendation - to increase the blood separation efficiency of the system, one should reduce the number of steps performed manually.

Extrapolation of one evolutionary line for ES

The same conclusion (as the one derived in the previous section) could be drawn directly after studying the evolution of ES under consideration along the line "Degree of human involvement expulsion from ES" used in US TST. Such an analysis shows that nowadays only the performance of small part of steps (that are not most labor consuming) is automated (Fig. 3). Based on this conclusion, for this forecast (as well as for the previous forecast) one can create a "portrait" of forecasted future ES.

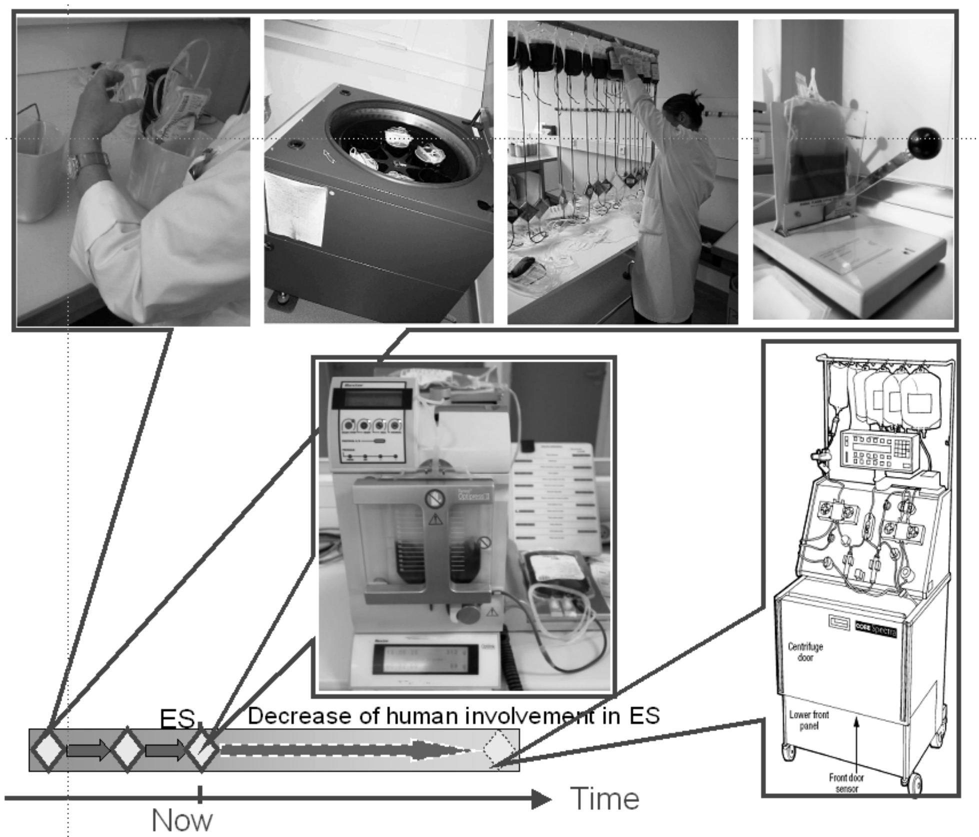

Fig. 3. Extrapolation of one evolutionary line for ES

Extrapolation of several evolutionary lines for ES

To produce more reliable forecast, a researcher needs to take into consideration not one evolutionary line, but several most significant lines of ES evolution. In our example, in addition to line "Degree of human involvement expulsion from ES", the line of ES ideality increase turned out to be very important from the marketing standpoint (due to reduction of costs).

Concurrent consideration of both above-named lines allowed the author to formulate a contradiction, which is still non-obvious at the present evolutionary stage of ES in question. This contradiction is formulated as follows: "Motors, pumps, sensors and the like should be introduced to the system with the aim to transfer those functions to them that are currently performed by humans, and at the same time they shouldn't be introduced to the system because it would lead to the growth of ES cost".

After one formulates a forecasted contradiction as a requirement to ES, subsequent forecasting would involve solving of inventive problem. To do this, such a tool was selected from US TST, which is directly intended for resolving the formulated contradiction - "To reduce consumption of resources without impairing functionality" - see Fig. 4.

Problems to be solved (input)	**Tool used**	**Description of tool (explanation)**
1. Reduction of costs without impairing functionality		
...	...	...
1.2. Reduction in amounts of consumed resources - namely, funds, mass, volume and dimensions by more rational use of resources	1.2.a. Employment of field for performing the sideline function	If it is needed to introduce a field into a system, one should first of all utilize already available fields, the carriers of which are substances already present in a system.

Fig. 4. Use of US TST for inventive problem solving

As a result of using US TST recommendation, a proposal involving the employment of centrifugal force field (already available in the centrifuge) turned out to be the optimal solution (instead of solution involving creation of pressure field by means of special pumps).

Extrapolation of evolutionary line for the supersystem

It was not actually a blood separation system that served as an object to be improved in the real project described here as an example, but its subsystem - namely, a set for collection and storage of blood and its components - see Fig. 5. Thus, the analysis of separation system evolutionary line (described above) was an analysis of the supersystem for the real object. That's why a conclusion on necessity of reducing the number of manually performed steps (formulated for the supersystem) allowed to formulate new (and non-obvious, as of today) requirements to system under consideration - "A system for collection and storage of blood must ensure ease and quickness of blood feeding into automated blood separation system" - see Fig. 5.

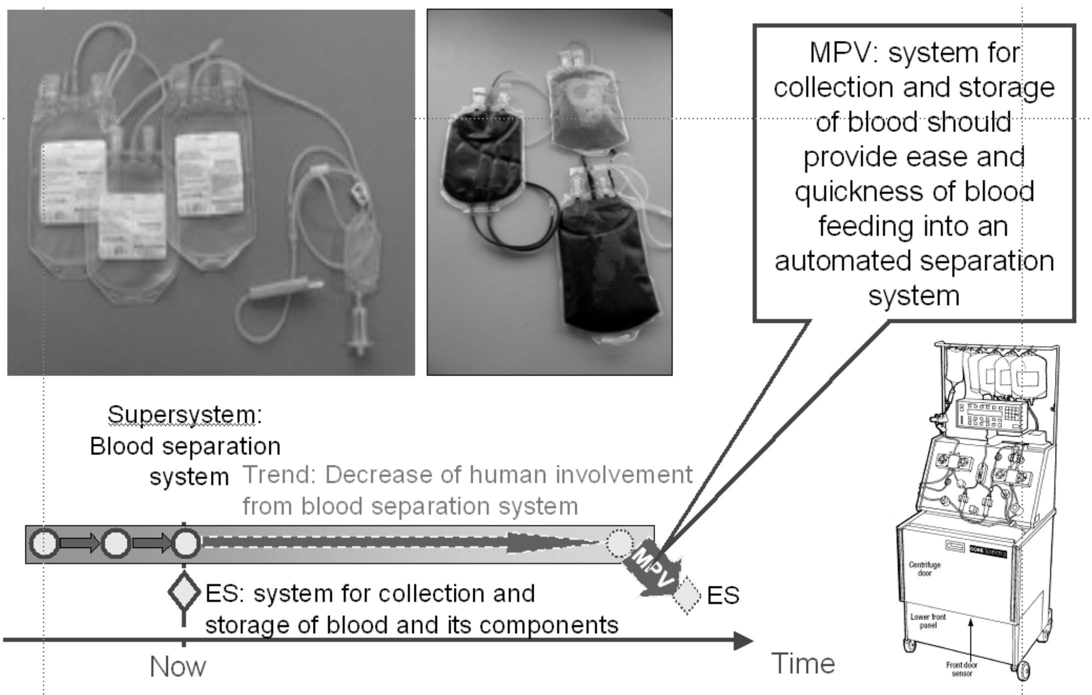

Fig. 5. Forecast of ES evolution by the method of supersystem evolutionary line extrapolation

After new requirements to a future system are identified, a necessity to solve inventive problem arises again because it is needed to create a portrait of forecasted ES that meets these requirements.

At first, key disadvantages impeding existing system for collection and storage of blood to meet formulated requirements were identified. Excessively high flexibility of system configuration (in other words, variability of system configuration) turned out to be the main key disadvantage. It wouldn't allow to insert such a system into separation station with one move of hand. Instead, it would be required to hang each bag (one by one) and unfold each tube (avoiding twisting of tubes) concurrently checking from what bag it goes and to what unit the other end of the tube is connected.

To eliminate the identified disadvantage, let's solve an inventive problem - again employing appropriate tool from US TST (see Fig. 6).

Problems to be solved (input)	**Tool used**	**Description of tool (explanation)**
3.1. Increasing the level of function performance (productivity, accuracy, reliability, fastness of operation, ...)	3.1. Increasing the degree of ES completeness	System that can be broken down into four standard units - namely, source of energy, energy converter (transmission), operating/working member, and control system (some of these units could be missing, while their functions are performed by supersystem elements) - gradually transfer in the course of their evolution to self-performance of functions of these units - Expulsion of human involvement from ES
...	...	...
3.1.4. Enhancing strength, rigidity, stability	3.1.4. Degrading the dynamicity of a system	In the process of evolution, the flexibility and dynamicity of systems and their components are degraded, admissible variations in their size get more stringent, plus their rigidity standardization and unification grow.

Fig. 6. Use of US TST for inventive problem solving

Creation of portrait for forecasted system based on obtained "prompt" is shown in Fig.7. By analogy with solving of similar problem for reel-to-reel movie projectors and tape recorders, the project team offered a "cassette" approach for the system for collection and storage of blood.

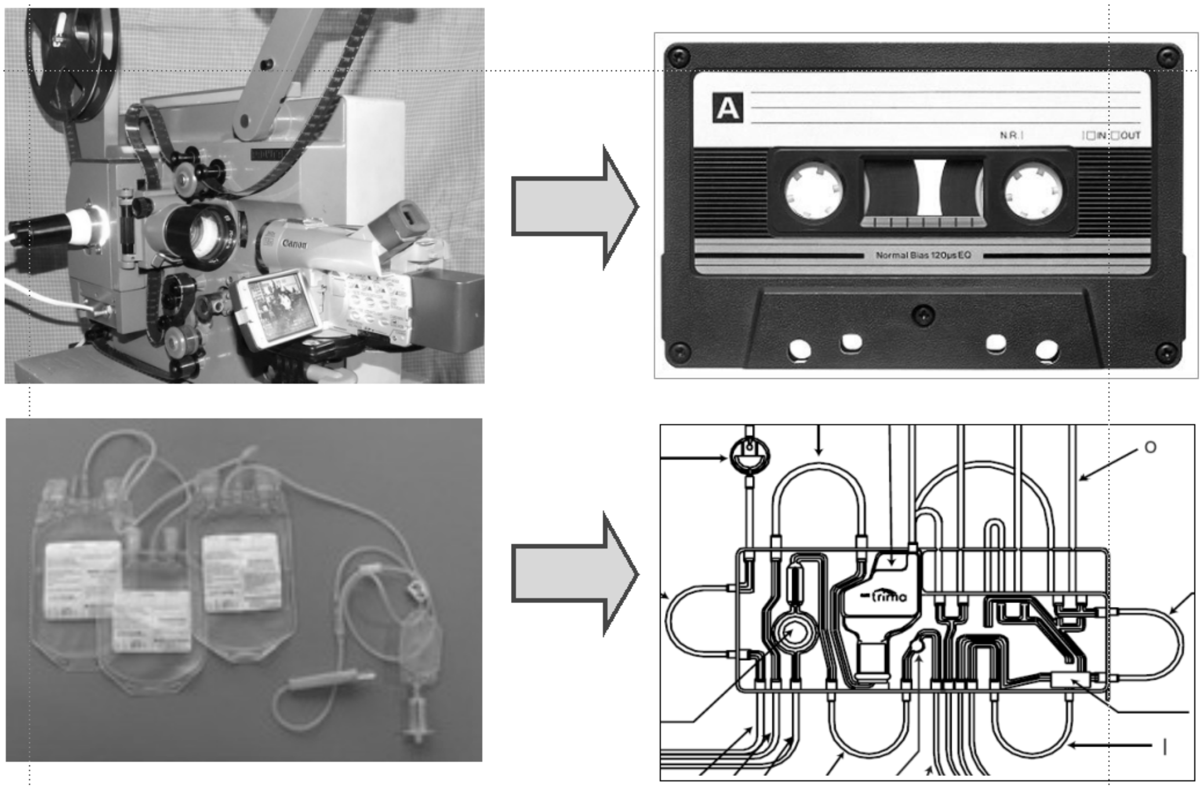

Fig. 7. Transition to cassette-based approach as implementation of principle of ES dynamicity degrading

Extrapolation of several evolutionary lines for supersystem

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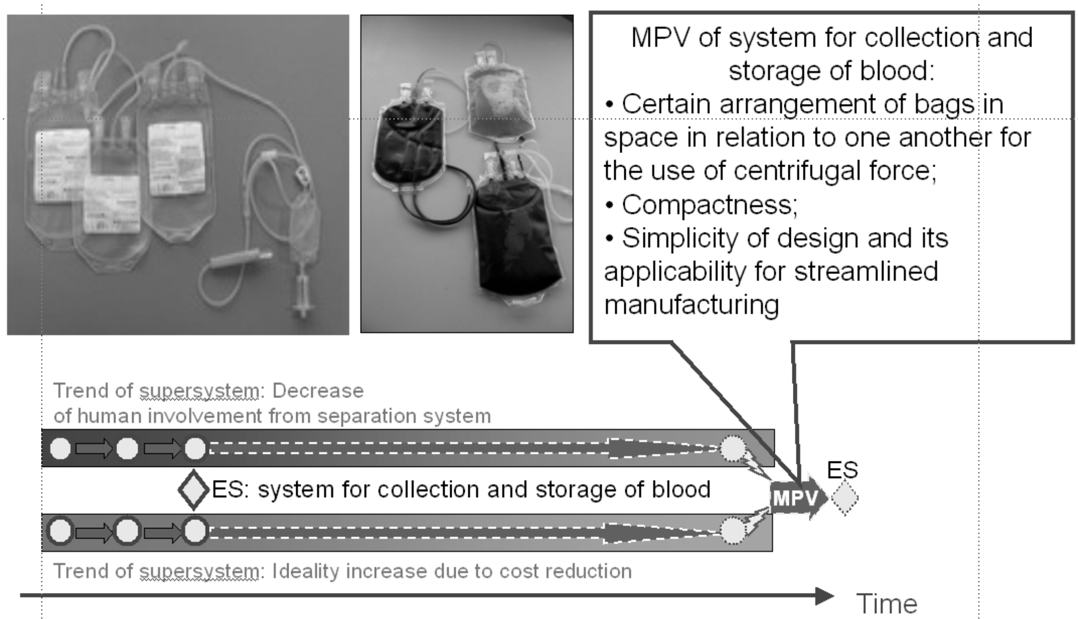

Fig. 8. Analysis of supersystem evolutionary lines with the aim to identify requirements to the system

To illustrate this principle, the author will use results of forecast presented above and derived using the method of extrapolation of several evolutionary lines for blood separation system, because this system represents the supersystem for the blood collection and storage system under consideration.

Problems to be solved (input)	Tool used	Description of tool (explanation)
1. Reduction of costs without impairing functionality		
1.1. Reduction in amounts of consumed resources for ES production - namely, funds, mass, volume dimensions, and time by reducing the number of components in a system.	1.1. Upgrading of trimming degree	The number of ES components is reduced. In the process of evolution the components are usually trimmed in the following order: transmission - Energy Source - Control system - Operating (working) member. The number of technological process steps is reduced.
...	...	...
1.1.2. How the performance of useful functions of those components that are planned to be trimmed could be provided?	... 1.1.2.b. Self-service	... The number of supersystem elements can be reduced if an object would start self-servicing itself performing auxiliary and repairing steps (functions).
...	...	...
1.2. Reduction in amounts of consumed resources - namely, funds, mass, volume and dimensions by more rational use of resources	1.2.a. Employment of field for performing the sideline function	If it is needed to introduce a field into a system, one should first of all utilize already available fields, the carriers of which are substances already present in a system.
...	...	...
1.2.1. Specific features of more rational use of resources for volume and dimensions reduction.	1.2.1. Nested doll	a) One object is placed inside another object, which, in its turn, is placed inside the third one, and so forth. b) One object passes through cavity in another object.

Fig. 9. Solving new inventive problem by means of US TST

It has been already shown above that a requirement to employ centrifugal force of the separator to perform the second function - for pumping fluids being separated - was formulated as a portrait for this supersystem.

This requirement for the supersystem determines a set of requirements (MPV) for the blood storage system under consideration - see Fig.8.

In its turn, the identified requirements determine conditions of new inventive problem. To solve this problem, the author again used the solving tools of US TST - see Fig.9.

Certain features of forecasted ES portrait obtained as a result of problem solving by means of US TST are shown in Fig. 10

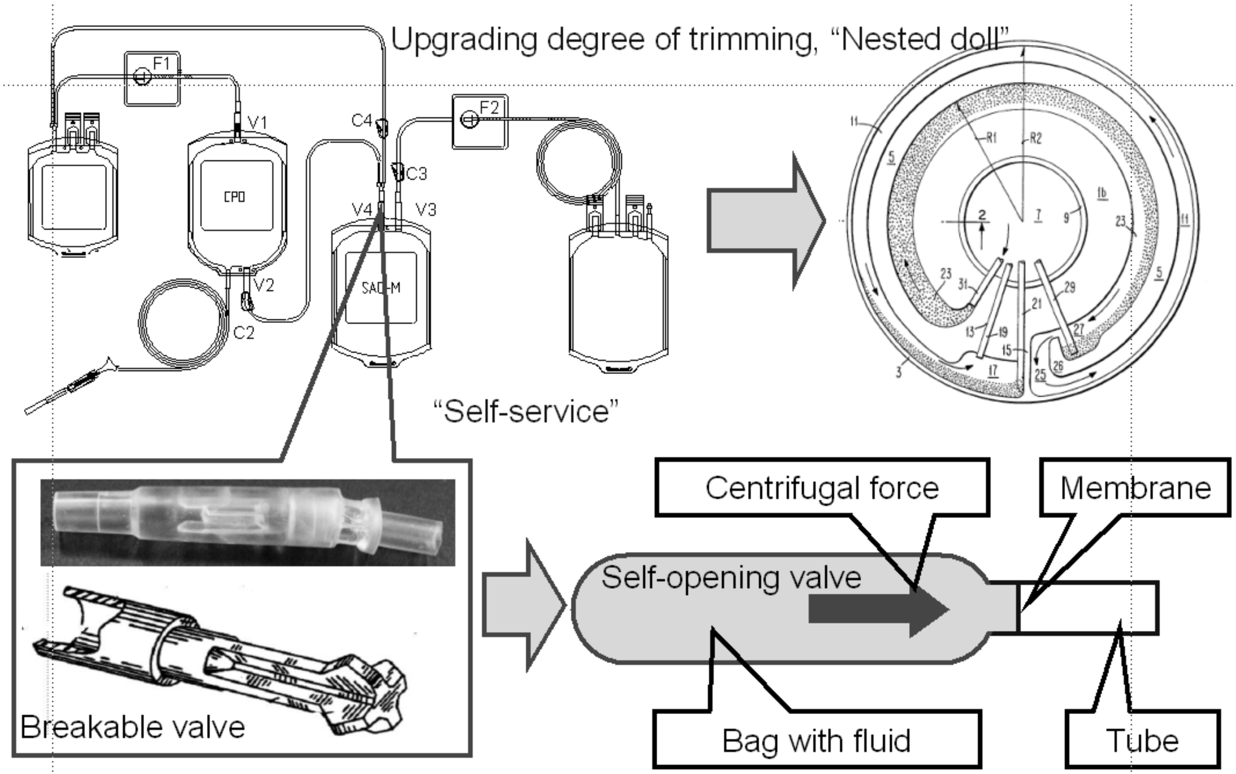

Fig. 10. Portrait of forecasted ES obtained through the use of US TST

Conclusions

Thus, the proposed US TST (as well as the TESE system, on which US TST is based) enable researchers to solve a wide range of problems related to forecasting ES evolution. Inclusion of Standards and Techniques in the TESE system would significantly enhance possibilities offered by this tool, while presence of functional input into the system allows using its tools without complex algorithms.

List of References

1. G.Altshuller, M.Rubin. What Would Happen after the Final Victory? Eight Thoughts about Nature and Engineering. http://temm.ru/ru/section.php?docId=3470

2. S.Litvin, V.Gerasimov. Long-term Forecasting of Engineering System Evolution Based on TRIZ and VEA. 1988. Manuscript stored at Chelyabinsk Regional Scientific Library.
http://www.metodolog.ru/node/306

3. M.Rubin. TRIZ-based Forecasting Methods. Petrozavodsk, 1999.
http://www.trizminsk.org/e/216002.htm

4. V.Petrov. Forecasting of Engineering System Evolution.
http://www.trizland.ru/trizba/pdf-books/zrts-19-prognoz.pdf

5. V.Petrov. Regularities in Development of Needs.
http://www.trizland.ru/trizba/pdf-books/zrts-04-potrebnosti.pdf

6. A.Efimov. Proposals of Development of Unified System "Trends-Standards-Techniques". Scientific and Practical Conference TRIZ-Fest 2009. Collection of Papers for the Conference. Saint Petersburg. 2009. Pp.60-66. http://www.metodolog.ru/node/293

7. V.Petrov. Trend - Anti-Trend. Scientific and Practical Conference TRIZ-Fest 2006. Collection of Papers for the Conference. Saint Petersburg. 2006. Pp. 212-218. http://www.matriz.ru/file.php/id/f5452/name/06-works-05.pdf

V.Petrov

Forecasting Methodology

Abstract

Forecasting methodology includes express and in-depth forecasting. Express forecasting is conducted using systems of standards for solving inventive problems and Trends of Systems Evolution.

In-depth forecast starts with S-curve analysis of system under study and analysis according to Trends of Systems Evolution. Then a forecast of needs evolution is worked out, a function model is synthesized, according to which the search for and analysis of technological information would be carried out. As a result, regularities of evolution for system under study, as well as alternative and inverse systems are identified. Generalizing these regularities and using Trends of system evolution, researchers derive the general tendency of evolution of system under study. Besides, in this process generated contradictions are identified and resolved, thus refining the forecast of evolution. Forecast verification is carried out at the final stage.

Key words:

TRIZ, forecasting, express forecasting, in-depth forecasting, needs, functional approach, trends of system evolution, verification.

(Full text of this article is given in the collection of papers in Russian)

V.Petrov

System of trends for engineering evolution as forecasting tool

Abstract

Improved and detailed system of trends for engineering evolution, which was developed by the author earlier, is described in the article. Express and in-depth forecasting can be carried out through the use of this system.

The system of trends includes levels of trends of evolution of needs, functions and engineering systems. Trends of engineering system evolution consist of two groups of trends - Trends of engineering organization and evolution.

A group of trends of engineering evolution includes trend of increasing ideality, trend of increasing controllability and dynamization, trend of transition to the supersystem and subsystem, trends of coordination and discoordination, trimming and deployment.

The trend of increasing controllability and dynamization includes subtrends - namely, subtrend of increasing degree of Su-Field completeness, subtrend of changes of relatedness, subtrend of increasing energy and information concentration, and subtrend of transition to the micro-level.

Changes in relatedness are implemented through the following regularities: increase of segmentation degree, transition to capillary and porous materials, and increase in degree of hollowness.

The trend of increasing energy and information concentration is implemented by means of regularities of increasing specific concentration and transition to more controllable fields. The last regularity is implemented via mechanisms of substitution of type of field and MONO-BI-POLY transition of field.

After forecasting is conducted, a researcher carries out coordination-discoordination and trimming-deployment as applied to each of the trends, identifying and resolving contradictions in this process. Verification of forecast is conducted at the last stage.

***Key words**:*

TRIZ, trends of systems evolution, trends of needs evolution, system of generalized models, forecasting, express forecasting, in-depth forecasting, functional approach, verification.

(Full text of this article is given in the collection of papers in Russian)

M.Rubin

ASI-Forecasting

Abstract

TRIZ-based methodology for social-and-engineering forecasting intended for creation of software forecasting complex (ASI-Forecasting) has been developed and tested in practice. Software complex is intended for use in all spheres of human activity. Individual software products have been developed, which are intended for creation and functioning of ASI- Forecasting complex: ARIZ-2010 (or ASI-2010[1]*), software programs for forecasting, application of standards, Development of Creative Personality (DCP), and statement of inventive problems.*

1. Goals.

Forecasting itself is an important, though poorly developed from the methodological standpoint field of knowledge, which is located at the boundary of different disciplines. Methodological difficulties inherent to forecasting are doubled, when we speak about forecasting based on TRIZ methods. TRIZ methods allow to create not only quantitative, but also qualitative forecasts taking into account changes in the principle of system action. However, application of these approaches in practice is associated with a large amount of analytical work and necessity to be highly qualified in the field of application of these forecasting methods.

Methodological problems inherent to practical application of TRIZ-based forecasting should be solved via creation of software complex intended for social-and-engineering forecasting. It will allow to make requirements to qualification of researchers in the field of TRIZ and forecasting less stringent, as well as to systematize and simplify the process of working out a system of forecasts.

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[1] ASI – algorithm for system improvement – development of ARIZ for solving not only engineering, but also inventive problems from other areas: business, economy, biology, information systems, etc.

2. What Kind of Forecasting is Discussed here?

It is necessary to specify the very notion of forecasting: what particular forecasting and what methods shall be discussed below. First of all, phylogenesis of socio-engineering, socio-cultural, information, and socio-economic systems will be analyzed as objects for forecasting[2]. The evolution of such systems is hard to describe in formal mathematical terms, the models of their evolution may quickly change, shortage of information required for describing them is always observed, and a multi-aspect approach taking into account the evolution of different superstems and subsystems is needed for forecasting the evolution of these systems.

It is necessary to distinguish socio-engineering forecasting from planning and inventive activity, which are also directed at creation of something new in the future. Planning is different from socio-engineering forecasting by several essential features:

- Planning implies presence of a certain subject, in the interests of which a plan to achieve a certain goal is prepared;
- Planning implies distribution of available resources, possibility to monitor them and control them; and
- Planning involves much greater certainty and amount of information concerning an object of planning and its environment than in the case with forecasting.

Forecasting is not aimed at realization of interests of a particular subject, it does not imply presence of controlled resources that are necessary for the forecast to come true. When planning something, we know what resources we have at our disposal and we only distribute them among needed areas at required time. When working on forecast, it becomes clear for us how the situation is going to develop in this or that sphere of human activity and how we could use it

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[2] For the sake of simplicity, hereinafter this complex of systems will be called socio-engineering systems.

or take it into account in the interests of a certain subject. Naturally, forecasting data could be used for planning purposes.

Forecasting models often imply invariability of certain features and relations. For example, thus appeared forecasts saying that it is impossible to create a flight vehicle that is heavier than air[3]. In reality, qualitative changes take place in systems with time, which could be forecasted exactly by resolving emerging contradiction (in other words, forecasted contradictions).

The following question often arises in the course of using TRIZ methods in socio-engineering forecasting: in what way is it different from inventive problem solving. From the standpoint of TRIZ, inventive problem solving consists in resolving contradictory requirements to one or another system. These requirements emerge during forecasting as part of forecasted processes, phenomena and identified tendencies.

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[3] Everyone heard an assertion of one specialist: "Everything that could be invented, has been already invented". This was said by Charles Dewell, specialist of the American Patent Office, in 1899, when there were neither computers, nor atomic bomb, nor Japanese animated cartoons.

"It is impossible to create a flight vehicle that is heavier than air!", - said Lord Kelvin in 1895.

"Humans will never be able to tame nuclear energy" - said R.Milligan, Winner of Nobel prize in the field of physics, 1920.

"Who might need a computer at home?", - asked Ken Olsen, CEO "DEC" in 1977.

"Such a device as telephone has too many disadvantages to be looked upon as means of communication. Therefore, I think that this invention has no value at all". This is a quotation from the discussion, which took place at Western Union. However, participants of discussion could be understood: the conversation took place in 1876.

"Nobody could ever find it necessary to have a computer at home", — said the founder and the President of Digital Equipment Corp. Ken Olson in 1977. And this is quite understandable. At that time it was still considered (and numerous articles on this topic could be found in the "Popular Mechanics" Magazine), that in future computers would weigh no greater than a ton and a half.

"640 KB should be enough for everybody". You wouldn't believe that, but Bill Gates said that back in 1981. http://www.lifemedia.ru/marketingovye_issledovanija.html

	Invention	Forecasting
Distinctions	Particular system or its part is changed	Generalized system is changed (phylogenesis)
	Changes have specific character	Changes may have general character or may refer only to one characteristics of the object (not to the system on the whole). Directions for changes and examples illustrating possible changes are given.
	Formulation of an invention does not change with time passing	Formulation of a forecast may change with time passing in the course of forecast monitoring. Variants of factors, upon which forecasts depend (scenario approach) could be given
	There is a subject (or an image of the subject), in the interests of which an invention is made	Is characterized by maximal objectivity, irrespective of the interests of a particular Client
	Analysis of supersystems is not necessary (only minimal-degree analysis is conducted)	Analysis of supersystem evolution is mandatory (if possible, it should be extended)
	Novelty is mandatory	Novelty is not mandatory
	Is made based on the existing requirements to an object	Could be formulated based on identified trends (not necessarily based on an object itself)
	Requirements should refer to specific components	Requirements may refer to generalized components (model components) of generalized system.
	Implementability is to be proved	Directions for actions are indicated, which can provide implementation of forecast.
Common features	It is necessary to conduct component-structural, function and resource analysis	
	It is necessary to analyze and resolve identified contradictions, formulate IFR	
	An invention could be made based on forecast	A forecast may include one or another invention

Table 1. Comparison of inventions and forecasts: common features and distinctions[4].

[4] This comparison was carried out jointly with Yu.I.Fedosov.

Invention represents a solution for existing identified contradictions, while forecasting consists in resolving contradictions formulated based on identified tendencies. An invention is a specific found solution for an inventive problem, while forecast requires constant refining and monitoring because source information needed for forecasting gets refined in the course of time. An invention could serve as a part of forecast, while forecast may not require solving an inventive problem at the invention level.

Socio-engineering forecasting uses a set of forecasting methods and methods for inventive problem solving, which are generated not only in the field of engineering system evolution, but also in other fields of human activity: information, social, economic, political and other systems. Socio-engineering forecasting is based on methods for inventive problem solving in non-engineering fields and experience of their practical use.

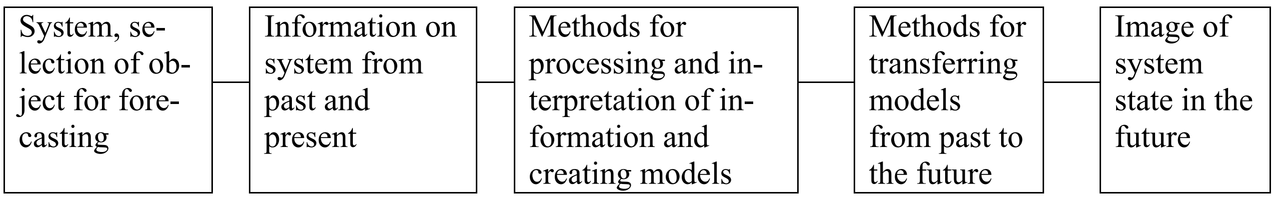
Socio-engineering forecasting is closely related not only to inventive activity and planning, but also with designing of systems.

3. Forecasting models.

There are a great number of methods and techniques for forecasting – dozens or even hundreds of different methods, systems, and techniques. Numerous publications create an impression that classifications of these methods are even more numerous than methods for forecasting themselves. It is easier to find the way in such a huge set of methods, if one identifies the underlying logic of forecasting, thus determining, which function is performed by this or that particular method in the forecasting system. For this purpose we will try to identify main methods and models of forecasting.

3.1. The basic principle of forecasting: processes and events that have already taken place would lead to one or another process or event with one or another degree of probability.

This simple wording contains quite a number of uncertainties in it: what systems should be monitored and taken into account, what parameters of these systems are important, what is the accuracy of information on these systems and parameters, how did they change in time, how they should be interpreted, what model should be used, how the identified tendencies could be transferred to the future, and so forth. Irrespective of the fact, whether qualitative or quantitative methods are used, objective data or estimates of experts, mathematical methods or other methods for forecasting – the general approach remains one and the same: based on information from the past we construct the possible state of the system in the future.



This forecasting model helps to determine, which particular function is performed by one or another method in the general system of forming socio-engineering forecasts. Let us give several examples.

The Delphi method is often called forecasting method, while in reality this is a method for averaging the collective opinion of experts, which is sometimes also used for "forecasting". Linear or non-linear approximation – this is also not forecasting, but a set of methods for processing information, for which an assumption is made concerning the correctness of projecting the identified mathematical regularities to the future.

TRIZ methods aimed at identification and resolving of contradictions could be classified with (according to proposed approach) to the creation of system evolution model (key contradictions) and generation of an image of the future system, considering that the future of the system corresponds to this or that option of this contradiction resolving (see item 3.7).

3.2. It is possible to analyze not a system as a whole as an object for forecasting, but only its main component, in other words, a "nucleus" of the system. The goal of forecasting could enable to simplify the model of analyzed system and to neglect its secondary (non-essential) features. This makes the forecasting process much more easier. Examples are Pareto rule and ABC-method, which could rather be looked upon as methods for simplifying a system model than as independent forecasting methods.

3.3. Not an entire system could be taken for forecasting, but only its main characteristics and parameters (or only those characteristics and parameters that are needed for forecasting); only their values would be forecasted in this case. A forecast of velocity of transport vehicle means motion, not a transport system as a whole may serves as an example.

3.4. A forecast of system evolution could be produced through forecast of other systems or factors that exert significant influence on the evolution of systems under analysis. In particular, supersystems and subsystems could be chosen as such systems. Trends and regularities of evolution of systems of analyzed class can serve as influencing factors. Examples of such methods: leading indicators method, correlation-and-regression analysis, application of trends and regularities of engineering systems evolution, etc.

3.5. A forecast for system evolution could be produced via forecasting the evolution of "similar", analogous systems. Analog modeling, transfer of method for implementing a function from one system to another, and others serve as examples of this approach.

3.6. Information and evolution models of systems or parameters, which are dependent upon an object under analysis, can be used for forecasting the system evolution. For example, in order to analyze a degree of popularity of one or another software product, one can use such a parameter as the number of search requests for this product in search engines in the Internet.

3.7. The evolution of a system is constrained by certain contradictions that are either exist at present or are predictable for the future. Resolving of these contradictions exactly determines the future of evolving system. Example: method for resolving central antagonistic contradictions of evolution, etc. [1, 7, 3].

3.8. General systematic principle of forecasting. All forecasts (produced according to one and the same scenario, but according to different models and based on different methods) should not contradict each other. Resolving of these contradictions represents a part of forecasting system. Example: method of system-based multi-level forecasting. [7].

The above-named methods and forecasting models are used in "ASI-Forecasting" forecasting methodology.

4. ASI-2010 automation system and creation of ASI-Forecasting software complex.

Algorithm for system improvement (ASI-2010) represents the next step in the development of ARIZ as applied for solving inventive problems in non-engineering fields [10]. The work is currently in progress on creating a software product of the same name[5]. It is convenient to create a software complex of TRIZ-based forecasting methods as a component of ASI-2010 automated system, since it is based on a possibility to resolve contradictions and solve inventive problems in different areas of human activity (not only in engineering). The majority of methods for analysis, which are employed for forecasting, could also be used for the analysis of problem situations, plus statement and selection of inventive problems.

A portal for forecasting development of software products [14], which is created nowadays, may serve as a prototype of ASI-Forecasting software pack-

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[5] http://www.triz-summit.ru/file.php/id/f4628/name/состояние-АСС-12-2009.pdf (jointly with A.Kirdin)

age. This portal is created based on forecasting methodology, which is described in this article.

5. Requirements to ASI-Forecasting software complex

Let's indicate main requirements to software package of TRIZ-based forecasting methods (ASI-Forecasting):

- possibility to work jointly with the ASI-2010 package for solving problems identified in the course of inventive problems forecasting

- opportunity to conduct forecasting for systems taken from fairly different fields of human activity (not only engineering)

- block (unit) structure of the software package should provide an opportunity for changing it and adding new methods and algorithms.

- the software package should be flexible and should possess a property of adjusting itself to different types of forecasting problems and different kinds of users.

- a system of forecasts should be produced in the ACI-Forecasting software package, these forecasts being interrelated by a common classification index and parameters that characterize objects and changes in objects.

6. Content of ACI-Forecasting Software Package

The authors identified nine basic units of the ACI-Forecasting software package.

1. Goals, tasks, and criteria of forecasting. It is necessary to formulate aspects of system consideration, geographical scale, and object of forecasting.

2. Model of forecasting object. It is necessary to identify and formulate components of forecasting object, to describe their relationships, functions and parameters. It is necessary to determine the minimal generalized model of an object. For phylogenetic objects, it is necessary to take into account their peculiarities and analysis of representatives of this object belonging to lower rank - e.g., for transport, automobile transport, for automobile transport, passenger transport and freight transport, and so forth. Wordings for the model and functions of phylogenetic objects require special methodologies.

3. Supersystems. Factors influencing an object of forecasting. Besides a brief component-and-structural and function analysis of supersystems, initial analysis of system evolution history (of object and its supersystems) and key inventions. Application of trends (regularities) of evolution specific for a given field.

4. Subsystems and dependent factors. Parameters depending upon an object of forecasting, indirect characteristics associated with an object of forecasting. Identification of cause-effect relationships. The evolution of forecasting object depends upon subsystem (resource) factors. Preliminary formulation of contradictions contained in requirements.

5. Gathering and analysis of information about an object (within the frames of its model), about supersystems (factors influencing the object of forecasting) and subsystems. Reviews and articles about forecasts. Constructing a chronological Table of main events and diagrams of parameters variation. Formulation of search requests, ideal image of information sought-for: what it would influence in the course of analysis, how it should look like, and where it can be located. Use of search analytical programs.

6. Historical trends. Constructing a time-dependence diagram for identified parameters and components. Identification of regularities of evolution, involving the use of mathematical, expert and other methods (e.g., morphological analysis). Identification of stage of system evolution. Repeated analysis from step 1 to step 6. Compiling a plan of work for forecasting, taking into account the formulated problems and available resources and information material. Correcting the plan.

7. Future trends. Substantiation for a method and depth of transfer of identified historical trends to the future and models (method) for such transfer. Identification of contradictions associated with these trends.

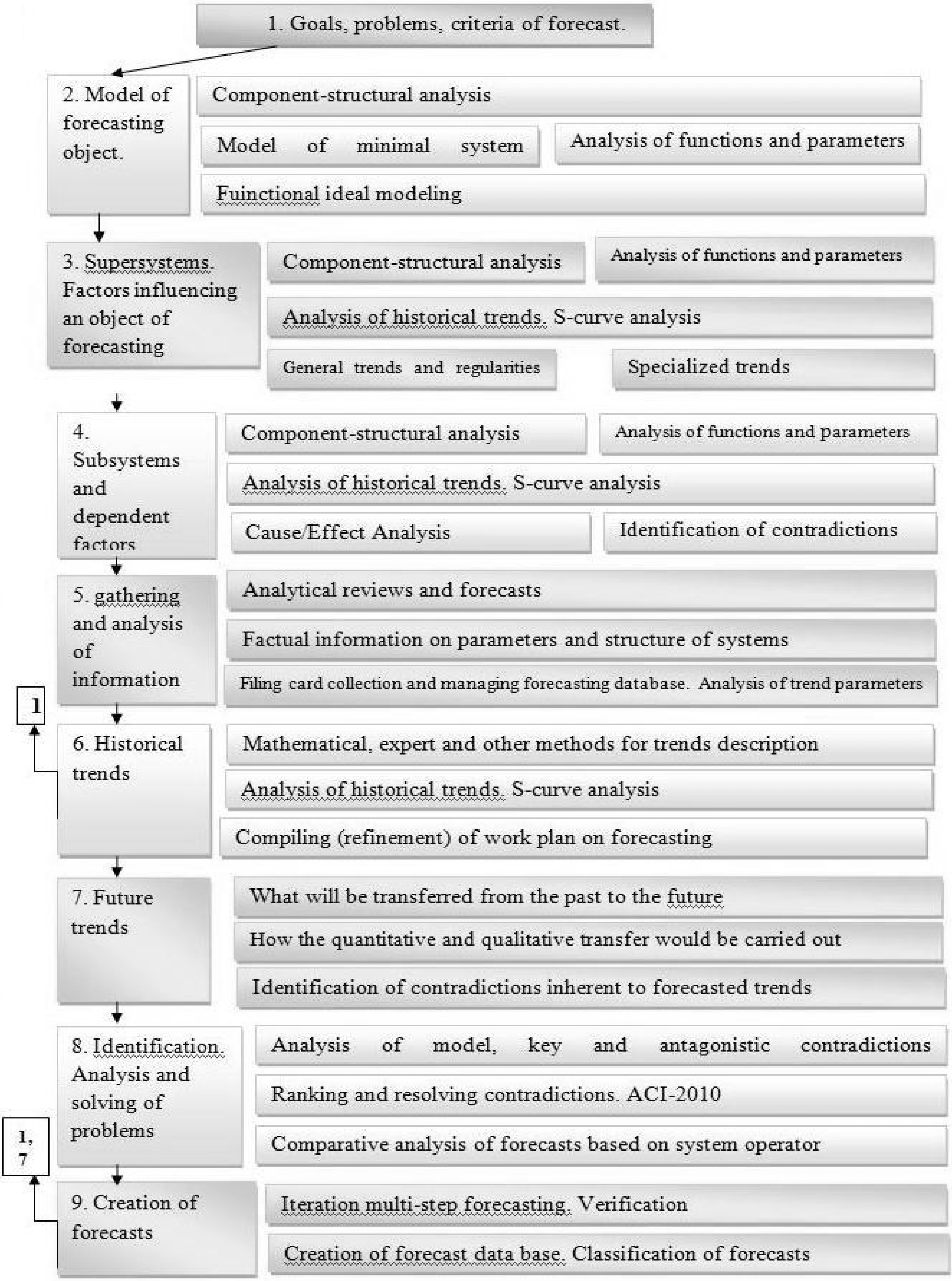

Figure 1. Structure of the methodology of ACI-Forecasting Complex

8. Identification, analysis and resolving of contradictions. Formulation and analysis of contradictions inherent to model (i.e., inherent to model structure), key contradictions (according to rules of system trimming) and antagonistic contradictions (solutions lead to still more difficult problems). Function-ideal forecasting. Ranking and resolving of contradictions, ASI-2010 and other tools.

9. Creation of system of forecasts. Constructing a system and general picture of forecast. Comparative analysis of forecasts "by horizontal line" (in time), "by vertical line" (subsystem-system-supersystem) and in different aspects (a forecast in terms of one aspect leads to a forecast in terms of another aspect). If the conducted study has been performed correctly, the forecast "by horizontal line" should coincide with that "by vertical line". Besides, one forecast should supplement, refine or expand another forecast.

A system of mutually interconnected forecasts is formed based on the above-described procedure for iteration multi-step forecasting. A base of forecasts being formed could be used in the preparation of other forecasts. Checking the system of forecasts (verification, information search). If necessary, refinement of forecast starting with step 7 or 1.

A structure of ASI-Forecasting complex is presented in Figure. It can be seen from it that the same methodological procedures could be applied at different stages of forecasting. The same procedures could also be used for solving inventive problems that are not associated with forecasting, which makes the software complex more universal.

7. Municipal transportation system. Example for making a social-engineering forecast.

Proposed methodology was worked out since 1979 in different works on forecasting the evolution of different systems: forecast of civilization evolution, science evolution, sports evolution, cities evolution, tidal energy industry evolution, software products evolution, and so forth. For example, already back in

1980-ies, the process of sports commercialization and appearance of fitness were predicted, as well as sales of drinking water in the shops. In 2010 the proposed methodology was tested for forecasting the evolution of software products [14] and information systems[6]. A research on forecasting the evolution of city transport system [7, 12] was selected as an illustration for implementation of the proposed forecasting system. Only brief results of this research are given in the present article. Ground, underground, water, air and pipeline transport were considered as municipal transport means. The model of the system consists of:

- Means of transport (carry people and/or cargoes)
- Roads (hold transport means, create a supporting point for acceleration and braking of means of transport)
- System of control over transport flows
- Devices for letting in and letting out of passengers and loading and unloading of cargo
- Energy supply system

An example of model contradiction: the greater is the number of roads, the more space is available for transport, but the smaller is the effective area of the city. An example of antagonistic contradiction: the better is the city transport system working, the lower is its capacity to manage the cargo flows because these flows from suburbs become more intensive. An example of a contradiction of trends: speeds of means of city transport become higher, while the speed of transport flows in the city is thereby decreased.

The evolution of municipal transport system mainly occurs due to efforts of development of transport system and road system. It does not give any significant effect and cannot produce such effect. The analysis of identified contradictions shows that the main directions for the development of city transport system are associated with the development of information technologies:

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[6] The work on forecasting the evolution of information systems is conducted

- Change in the structure of production and technologies for decreasing the transport-related mobility of the population (city without transport [5])
- Substitution of transportation of material objects with transportation of information (all-purpose engineering reduplicator [9])
- Development of automated system for controlling transport flows: transport without drivers, continuity of transport flows, combination of private and public transport [5], automated cargo delivery, real-time changes of road signs and even traffic rules, etc.

The work on forecasting the evolution of city transport system is in progress [12].

8. Scientific and Methodological Foundation of Social-Engineering Forecasts

The ASI-Forecasting software package should include a base of forecasts, offer an opportunity to introduce developed forecasts to this base and quick search for mutually interrelated forecasts [13]. For this purpose, each forecast should be related with the model for this forecast in the format "object – its parameter and forecast of direction for its change". To identify interrelations between objects, it is recommended to use a classification from web site glossary.ru (Fig.2). During forecast preparation, this classification enables to identify supersystems, subsystems and interrelated objects.

9. Conclusions.

1. Proposed system for socio-engineering forecasting allows to combine the possibilities offered by quantitative and qualitative methods of TRIZ-based forecasting.

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jointly with S.S.Sysoyev and S.V.Sysoyev.

2. Forecasting methodology proposed for the ASI-Forecasting software package was successfully tested at different times and by different authors as applied to different material and non-material objects.

3. ACI-2010 software products (which are under development at present), portal of software evolution forecasting, programs for formulation and selection of inventive problems, CPD (creative personality development), and other tools can be used for the creation of ACI-Forecasting software package.

4. ACI-Forecasting software package should be created as a constantly evolving product, involving the use of the best methodologies of different authors in the field of forecasting and TRIZ.

5. ACI-Forecasting software package should include a data base of interrelated social-and-engineering forecasts and this data base should be constantly supported.

10. List of References

1. G.S.Altshuller, M.S.Rubin. "What Will Happen after the Final Victory. Eight Thoughts about Nature and Engineering", 1987. www.temm.ru/ru/section.php?docId=3470

2. I. V. Bestuzhev-Lada, G. A. Namestnickova: Social Forecasting. A Course of Lectures.— M.: Pedagogical Society of Russia. 2002. — 392 pp.

3. S.S.Litvin, V.M.Gerassimov. Long-Term Forecasting of Engineering Systems Evolution based on VEA and TRIZ. 1988, Leningrad. www.triz-summit.ru/file.php/id/f4545/name/Прогноз-TRIZ-ФСА.pdf

4. M.S.Rubin. Sports – a Trap of the 20th Century, Baku, 1988, www.temm.ru/ru/section.php?docId=3419

5. M.S.Rubin. Ideal City. Baku,1989. www.temm.ru/ru/section.php?docId=4038

6. M.C.Rubin. Mankind at a Cross-Road, Petrozavodsk, 1992, www.temm.ru/ru/section.php?docId=3599

7. M.S.Rubin. TRIZ-Based Methods for Forecasting. “Journal of Forecasting Academy”, edited by I.V. Bestuzhev-Lada, “Nectar Nauki publishers”, No. 1, 1999, p. 19. www.temm.ru/ru/section.php?docId=3602

8. M.S.Rubin. Theory of Material Systems Evolution (TMSE). Saint Petersburg, 2002. www.temm.ru/ru/section.php?docId=3878

9. M.S.Rubin. On theory of design of innovation-technological systems, 2008, www.temm.ru/ru/section.php?docId=3935

10. M.S.Rubin. ARIZ of New Generation: Multi-Aspect Cycle for Elimination of Contradictions, Saint Petersburg, 2009. www.triz-summit.ru/file.php/id/f4365/name/АРИЗ-2010-Фест-РМС.doc

11. M.S.Rubin. Phylogenesis of Socio-Cultural Systems. Secrets of Evolution of Civilizations, Saint Petersburg, 2010, www.temm.ru/ru/section.php?docId=4472

12. M.S.Rubin. Forecast of City Transport Evolution, Saint Petersburg, 2010 www.temm.ru/ru/section.php?docId=4496

13. M.S.Rubin. Data Base of Socio-Engineering Forecasts, Saint Petersburg, 2010 www.temm.ru/ru/section.php?docId=4485

14. Rubin M.S., Odintsov I.O., Ponomaryova A.V., Zinenko O.I. Forecasting of TRIZ-Based Software Evolution. In the collection of publications: Methods of TRIZ-Based Forecasting. Collection of Scientific Papers. Library of TRIZ Developers Summit, Issue 3, SPb, 2010.

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TRIZ-Based Forecasting of Software Evolution

Abstract

Application of TRIZ methods for forecasting evolution of software is described and specific features of their application are taken into account. TRIZ tools are supplemented with trends of software evolution, system of use of standard and patterns as well as with other tools. Software products implementing these methodologies were developed.

1. Problem statement and review of approaches to this problem solving

Working out forecasts for software products evolution is an important direction of software (SW) industry. There is a huge spectrum of forecasting types, more than 100 of them could be named. The most popular are:

- Extrapolation (taking peculiarities of object evolution into account);
- Modeling (imitational, game, operational, network and other models);
- Polling of experts and population;
- Historical analogy;
- Forecasting scenarios; and
- Matrices of mutually influencing factors and methods based on graph plotting, etc.

Forecasting on the basis of TRIZ methods [1] is the most efficient approach for forecasting qualitative changes in SW evolution. When they are used in the field of programming, the following problems arise:

- TRIZ applicability in the area of SW forecasting; and
- Identification of specifics of TRIZ application for forecasting SW and information systems.

Besides solving these two problems, the goal of the conducted work was to create a prototype of software product (portal) for forecasting SW evolution through the use of TRIZ methods.

2. Main blocks of SW forecasting algorithm

Approaches described in [1] represent a basis in creation of SW forecasting methodology. A software product was created, which implements main approaches of TRIZ-based forecasting methodology involving adaptation to specifics of their use in the field of programming and information systems.

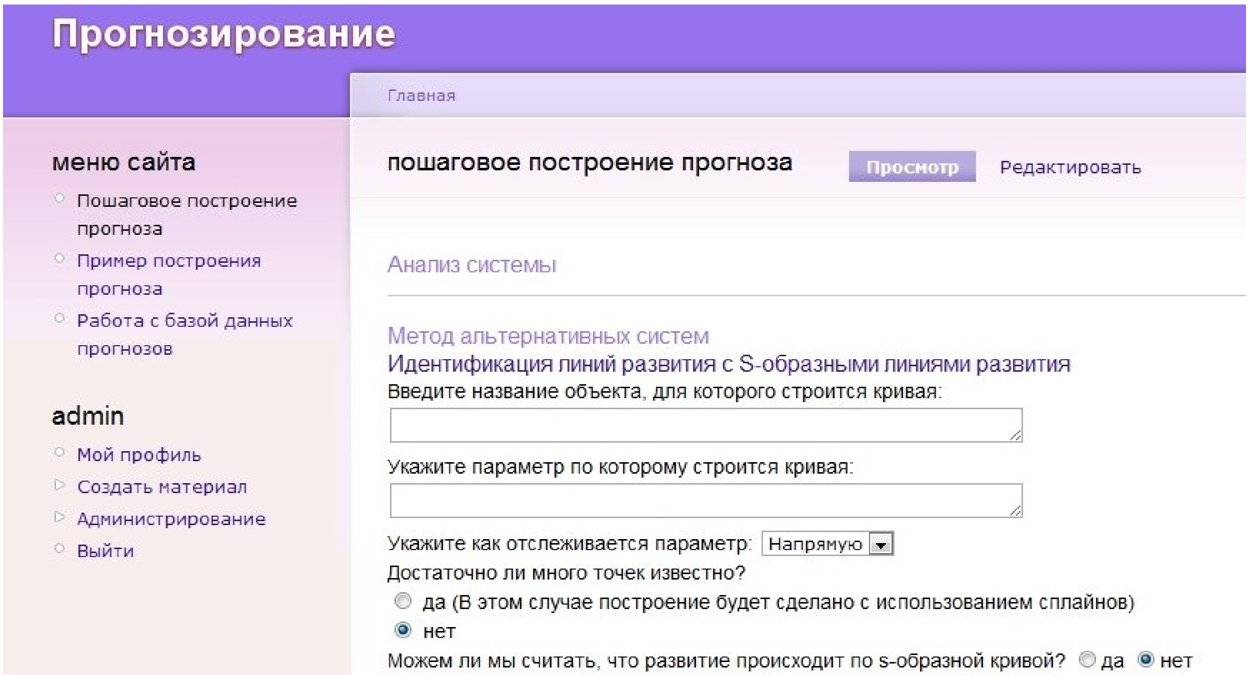

Figure 1. Example of user interface of SW forecasting portal

The following main blocks of SW forecasting algorithm (implemented at special portal "Forecasting") were used:

1. Object of forecasting
2. Goals of forecasting, terms and resources.
3. Functions, refinement of forecasting object.
4. Main parts (components, subsystems), of which an object subjected to forecasting is composed.

5. Collecting card file on selected object, reviews and forecasts.
6. Refinement of requirements imposed on the object, refinement of parameters that take part in object functioning, and refinement of system of functions.
7. Identification of minimal functioning system: of what parts (components) it should consist, what functions should be performed, what supersystem is important for consideration. Specification of subsystems, in which an object for forecasting is included.
8. Gathering of historical information, constructing a distribution of main factors from evolution history along the time axis.
9. Benchmarking of alternative systems aimed at identification of main characteristics.
10. Application of the alternative systems integration method.
11. Identification of evolution lines based on comparison with S-curve evolution lines. Determining the system evolution stage.
12. Formulation of intra-structural contradictions (contradictions between components of object for forecasting).
13. Formulation of forecast problems.
14. Application of general evolutionary trends and trends (regularities) that are specific for a given field and for a given object of evolution.
15. Formulation of forecast. If necessary, return to block 1.

Implementation of each block is associated with a number of methodologies for forecasting and solving of inventive problems. Integrating them into a single complex would create qualitatively new opportunities for forecasting software. Above-indicated blocks represent a simplified option of algorithm [1].

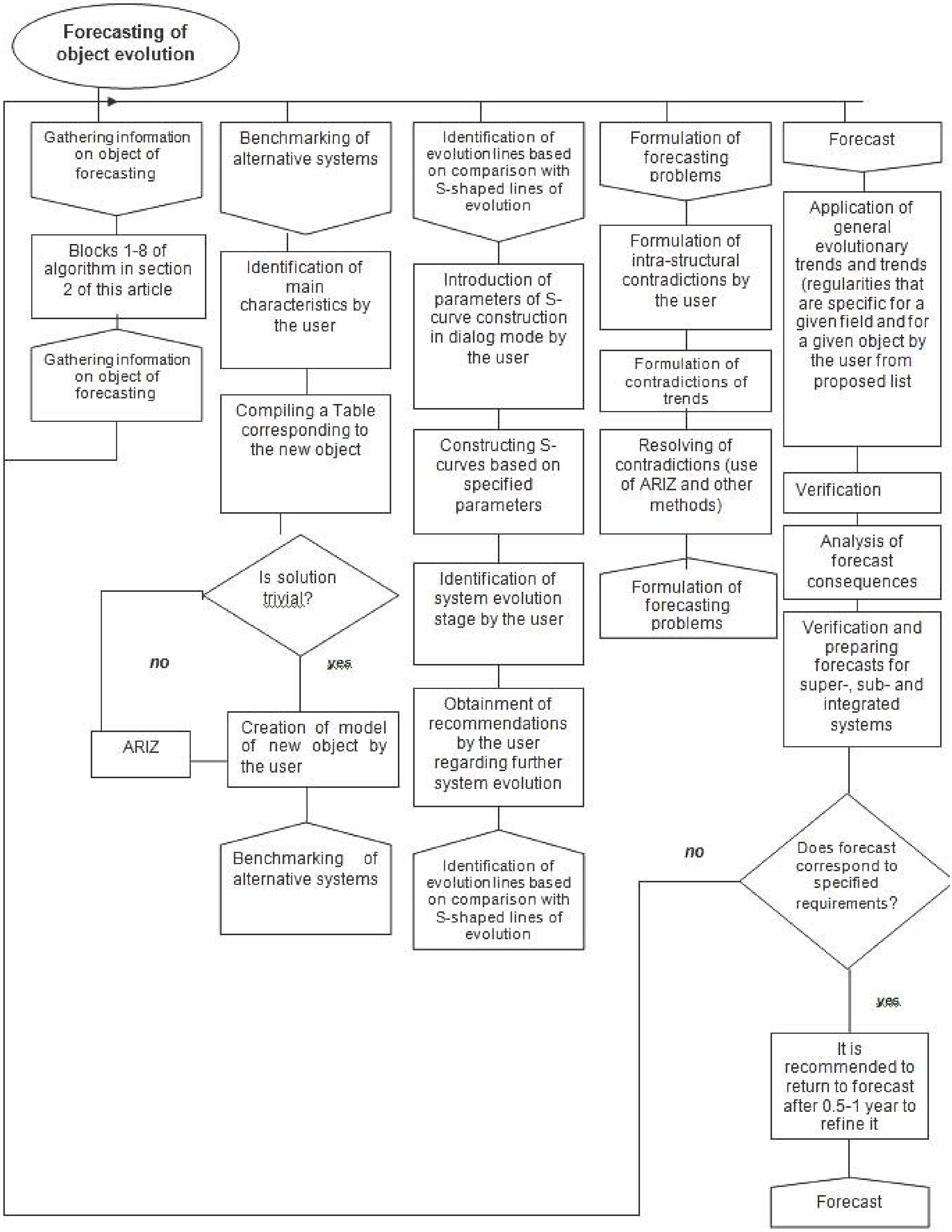

Figure 2. Architecture of software forecasting system being developed

3. Architecture of system under development

The program under development will represent a tool assisting to forecast the evolution of software products.

Main components:

- Database containing trends, objects (added to the database as a result of using the program for new forecasts) and forecasts proper.
- The program part responsible for interaction with the user and interface.
- The program part responsible for processing of user data (saving data in databases, construction of S-curves, etc.).

Software product created on the basis of this architecture is currently undergoing experimental testing, with its algorithm being refined and forecasts for evolution of different software types (namely, word processors, systems of support for highly productive calculations, grid, etc.).

4. Use of Logistic Curve in SW Forecasting

Methods for forecasting based on S-shaped evolutionary curves (also called logistic curves) are quite widely used in TRIZ. Software products and information on their evolution are characterized by two specific features:

- It is possible to find out a year of creation for all types of software; and
- Search requests for all types of SW are regularly made in search engines.

If we suppose that this or that SW evolves according to S-curve (this or that parameter characterizing this evolution), the starting point will be always known – the year of creation of this SW.

If the number of search request in one or another search engine (e.g., http://wordstat.yandex.ru/) is taken as an indirect parameter characterizing the degree of SW popularity, it is possible to identify one more point on the S-curve of search requests for one or another SW.

It is also possible to take into account that the logistic equation (S-shaped curve) can be described analytically (via formula)

$$P(t) = \frac{K P_0 e^{rt}}{K + P_0 \left(e^{rt} - 1\right)}$$

where: **r** is a parameter characterizing rate of growth (multiplication), **K** — capacitance of medium (i.e. maximal number of specimen in the population), $\mathbf{P_0}$ – initial number of specimen in the population, **P** – number of specimen in the population at point in time **t**.

Thus, restricted information enables us to we can construct a possible view of logistic curve for the evolution of different SW based on limited information and compare different SW types.

For example, let's assume that we would like to compare the evolution (popularity degree) of file formats for word processors: pdf, doc and docx.

File format of word processor	Year of creation (frequency of demonstrations - zero)	Number of demonstrations in February 2010 (thousands per month)
PDF	1991	742
DOC	1993	250
DOCX	2007	37

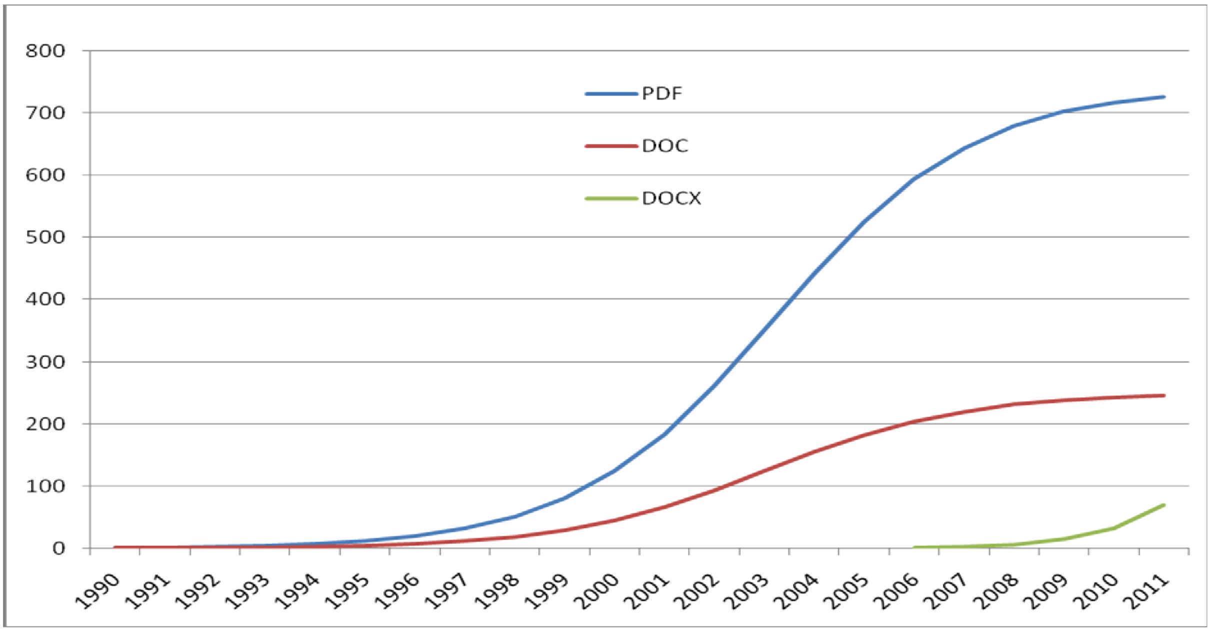

Figure 3. Constructing the curves of inquiries distribution for file formats.

This approach was implemented in the software product being developed and could $\frac{k*P_0 e^{r*t}}{k+P_0(e^{r*t}-1)}$ be used for forecasting not only SW, but also systems of other types.

5. Ele-Field analysis, Standards and Patterns used for forecasting SW Evolution

At the analytical stage of forecasting it is required to conduct component-structural and function analysis of SW, which have their own specific features as compared to the analysis of material (engineering) systems. In non-material systems (including SW) there are no substances, therefore, the term "Ele-Field" (meaning a combination of elements and fields of their interaction) was used in the course of creation of an elemental model of the system. Refinements were made in the rules for constructing an Ele-field, in the system of standards for inventive problem solving and in the algorithm for using standards (AIST-2010).

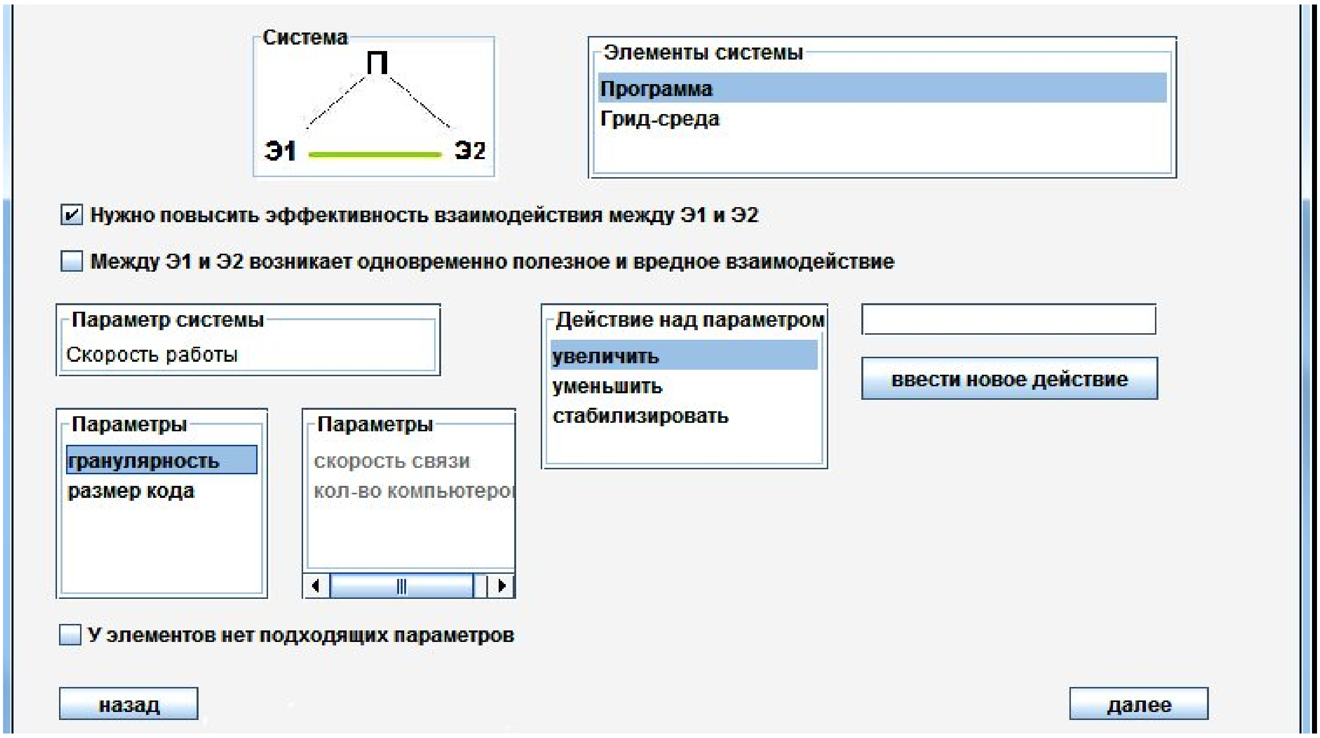

Figure 4. Example of user interface for developing SW based on standards and patterns

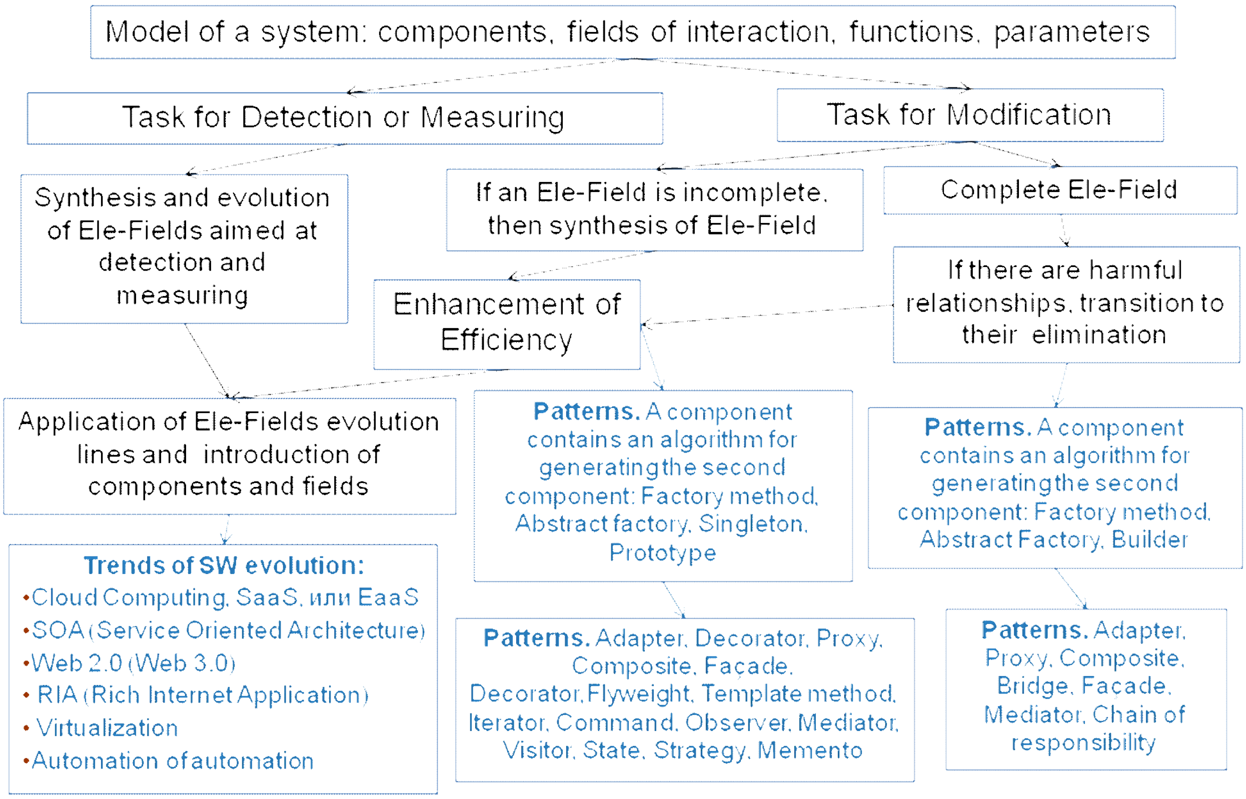

Figure 5. Structure of algorithm for using standards and patterns AIST-2010-P

An algorithm for combined application of standards and patterns (AIST-210-P) was developed and tested. Based on it, software for solving problems with the use of standards and patterns [8] was developed. An example of program interface is shown in Fig.4.

6. Trends of SW Evolution

To create a system for SW evolution forecasting, the authors analyzed existing trends in the field of information technologies and formulated basic provisions describing current tendencies in software products development.

1. SaaS (Software as Service), or, in the more general case, EaaS (Everything as a Service). Computer resources and capacities are provided for users as Internet service. Transfer of entire Software Product (SP) or its part to an external server and provision of access to users to SW through Internet browser.

2. SOA (Service Oriented Architecture). Service Oriented Architecture is a paradigm of arrangement and use of distributed information resources - such as: applications and data staying in the sphere of responsibility of different owners for the sake of obtaining desirable results by the user, which could represented by: end user or another application (OASIS). Multiple use of functional elements of IT, elimination of reduplication of functionality in SW, and unifications of typical operational processes.

3. Web 2.0. Methodology for designing systems, which are improved due to taking network interactions into account - the higher is the number of people who use them, the better they become (Tim O'Reighly) [9]. Use of a higher number of users for improving SW.

4. RIA (Rich Internet Application). Application available through Internet, which is rich in functionality of traditional desktop applications that is not directly supported by browsers.

5. Cloud Computing. The use of cloud computing leads to reduction of expenditures on IT solutions. Companies that use cloud services will more and more often act as cloudy suppliers of applications to clients and partners [10]. Moreover, experimental studies devoted to rolling-out of clusters of virtual machines in the clouds are currently in progress. on placement of clusters of virtual machines in the clouds.

6. Complex analysis. Analytical tools are currently used in many areas, including optimization and simulation of business processes. The next step is to provide not only the information proper for the analysis, but also processes in order to understand more exactly, what could happen in the future [10].

7. "Green IT". The use of information technologies as an all-purpose method for upgrading the efficiency (including ecological efficiency) of different technologies (circulation of documents, transport, heating systems, decison-taking by managers, and so forth) [10, 12].

8. Changes of data-centers. The practice of data centers construction changes. If in the previous years companies planned their potential growth for a period of 15-20 years, nowadays this period is reduced to 5-7 years [http://www.securitylab.ru/news/386807.php].

9. Integration into social structures. Companies should pay attention to the use of social SW and social resources, as well as integration of such communities into their work [10].

10. Safety: monitoring of users activity. Specialists in the field of information safety encounter the necessity to identify harmful activity in the constant flow of discrete events. At the same time, departments dealing with safety encounter the growing demand for means of analysis of safety and reporting. Tools for analysis and monitoring enable companies and organizations to efficiently find and investigate into suspicious activities in real-time mode [10].

11. Flash memory for disks. This technology (SSD-memory devices) is not new, but already nowadays it finds new ways of use in corporative sector. While earlier such solutions were too expensive for companies (though they were characterized by higher operating efficiency than HDD-memory devices), against the background of price reduction, flash memory will start finding use more extensively [10].

12. Virtualization. Technologies in this field quite strongly influence the development of industry, but, according to forecasts made by Gartner, in 2010 new elements will become popular. For example, "live" migration including the "moving" of functioning virtual machine, while OS and SW continue functioning in such a way, as if they remained at the physical server [10]. "From virtual DPC to cloud computing, and then - to the use of "virtual clients" and further on -- to "virtual devices" (M.Lewis).

14. Mobile applications. According to the information from Gartner, by the end of 2010 1.2 billion people will use broad spectrum of opportunities offered by mobile applications. However, according to the opinion of experts, further

evolution of such technologies would require unification of the platform with fully featured personal computers. [10]. A boom of applied programs for hardware platforms iPhone and Intel Atom will be observed, as well as operational platforms Google Android and MeeGo [9,13].

15. Upgrading the automation level (automation of automation).

Any automation systems start with data level (obtainment, storage and provision of information). The next level – automation of process control, then comes automation of knowledge and experience, generation of ideas [14].

7. Using TRIZ Methods for Software Forecasting

To refine the methodology and set of tools used in SW forecasting methods, their classification was prepared (Table 1).

	Construction and recognition	**Transformation**	**Generation and retrieval**	**High-level combinations**	**Combinations at library level**
3. Applied SW	Recognition: Interfaces, Games, DB, ES	Scientific-and-engineering and economic calculations. Weather forecast based on MPI, OpenMP and Grid	Retrieval and synthesis: search systems, training and consultation systems	Complex systems: ACS of a hospital, corporative resources on the basis of services	Applied libraries: graphic users interfaces
2. Instrumental software	Word processors, music, video, smells. DBMS, KBMS	Transformers: compilers, filters …	Analyzers: generators of statistics, profilers	Types of environment: programming environment, expert systems shells, software environment for Grid	Tool libraries: primitives on matrices, processing of lines, TBB
1. OS Algorithms and hardware	Presentation of extended virtual machine instead of actual hardware	Rational management of resources: Processes, communication, memory, files.	Organization of safe activity of users and functioning of programs	Add-ins to OS: Intermediary software for Grid, for services, virtual OS.	Base libraries of OS: MPI, mathematical

Table 1. Classification of software systems.

Currently the work is in progress aimed at forecasting the evolution of word processors, as well as systems for supporting highly efficient computing and grid. The main function for word processors, as well as system components and supersystem elements, main requirements to parameters characterizing functioning of word processors and their components were refined. The following elements were identified as a minimal structure necessary for functioning of word processors: files and their format, word processor interface, software, engineering support. Benchmarking of alternative systems and other kinds of analysis necessary for forecasting were conducted. Applicability of proposed methodologies for SW evolution forecasting was demonstrated.

8. Conclusions.

1. Application of TRIZ for SW evolution forecasting enhances the efficiency of its development.

2. Specific features of SW make it necessary and possible to introduce certain changes and additions to TRIZ-based forecasting methods (application of Ele-fields, patterns, special evolutionary trends, terms of SW creation, which are observable in historic scale, etc.)

3. Developed software intended for implementation of TRIZ-based forecasting methods for the preparation of SW evolution forecasts may become a basis for all-purpose software product "ACI-Forecasting" [1] for working out forecasts in various fields of human activity.

4. A structure for the base for socio-engineering forecasting has been created as a part of software for working out forecasts and as a tool for information support when forecasting of evolution not only of SW, but also of other material and non-material objects.

5. Integration of SW intended for forecasting with other TRIZ-based software products: ARIZ-2010 (ACI-2010), system of standards and patterns, CPD (creative personality development), system of statement and selection of inventive problems is possible and necessary.

10. List of References

1. Rubin M.S. ACI-Forecasting. In the collection of papers: TRIZ-Based Methods for Forecasting. Collected papers. TRIZ Developers Summit Library, Issue 3, SPb, 2010.

2. Odintsov I.O. Professional Programming. System-Based Approach. – BHV-Petersburg publishers, 2004.

3. Odintsov I.O., Rubin M.S. Upgrading the Efficiency of Software Products Development Based on TRIZ Methods / Scientific conference "TRIZ-Fest-2009": Collected Papers of the Conference. SPb, 2009.

4. Odintsov I.O., Rubin M.S. Experience of Applying TRIZ Methods for Enhancement of SW Development Efficiency. Moscow, 2009, www.temm.ru/ru/section.php?docId=4419

5. M.S.Rubin. Approaches to Forecasting the Evolution of Word Processors, Theory of Evolution of Material and Models [Electronic resource] // http://www.temm.ru/ru/section.php?docId=4520 (as of 13.06.2010)

6. M.S.Rubin. Basis for Socio-Engineering Forecasts, Saint Petersburg, 2010 www.temm.ru/ru/section.php?docId=4485

7. A.V.Ponomareva. Forecasting the Evolution of Software Products Using TRIZ Methods. Saint Petersburg Technical University, diploma paper, Scientific Directors: Odintsov I.O., Rubin M.S., 2010.

8. Zinenko O.I. Systematizing and Analyzing Design Patterns Based on Standards of the Theory for Inventive Problem Solving. Saint Petersburg Technical University, diploma paper, Scientific Directors: Odintsov I.O., Rubin M.S., 2010.

9. V. Vassiliev, A.T.Vakhitov, O.N.Granichin. Modern State and Perspectives of Cloud Computing.

10. Gartner named ten key technologies, Security Lab [Electronic resource] // http://www.securitylab.ru/news/386807.php (as of May 12, 2010)

11. Trends in Grid Computing /IDC, 2005

12. Alexander Selzer. DPC will deliver heat for heating Helsinki, IT // News|22|141|December 15, 2009.

13. Forecasts for 2010: IDC, PC Magazine/RE [Electronic resource]// http://www.pcmag.ru/club/group/21/blog/691/ (as of 12.05.2010).

14. Trends of Internet and IT Evolution from Pavel Cherkashin, [Electronic resource] www.artishev.com/internet/trendy-razvitiya-interneta-i-it-ot-pavla-cherkashina.html.

15. Rubin M.S. New System of Standards for Inventive Problem Solving, 2009, http://www.temm.ru/ru/section.php?docId=4201 .

16. Rubin M.S. Algorithm for Using Standards for Inventive Problem Solving – AIST-2010, http://www.temm.ru/ru/section.php?docId=4423 .

A. Kashkarov

Improving the Operation Principle of Engineering System

Abstract

Proposed paper describes further development of methodology for modeling and analyzing substance and energy transformations taking place in any Engineering System (ES). Simplicity of graphical representation of processes occurring in each ES component allows to clearly demonstrate both the operation principles of ES and its disadvantages. This offers additional opportunities for formulating prognostic problems for ES improvement and determining the importance of changing the ES operation principle. A list of techniques for changing the operation principle is given in the article. These techniques can contribute to forecasting and improvement of ES. The techniques for changing the operation principles of ES are illustrated with well-known 40 inventive principles. The second part of the article is devoted to analysis of example involving the use of techniques for changing the operation principle as applied to actual problem.

Key words: *operation principle, forecast, model, flows, cause/effect structure, substance and energy transformations.*

(Full text of this article is given in the collection of papers in Russian)

B.Akselrod

Experience of Effective Technological Forecasting

Retrospective Analysis of an Actual Project

Abstract

The history of forecasting TRIZ-based projects is still too short to give us a number of real examples that would make it possible to look back and analyze their results. All the more, a rare opportunity to analyze such a case would be of great interest.

Certain errors of the project, which was conducted about 15 years ago quite successfully under the author's leadership and aimed at forecasting the evolution of toothbrushes, are analyzed in the article. This period allows to see, what forecast came true and what didn't. For the confidentiality reasons, the author uses only those concepts in his case studies, which have appeared to be disclosed to public as a result of commercial or patent activity of various companies.

Some specific problems of forecasting projects are analyzed. The author conducts an analysis of major reasons for errors in forecasting the evolution of engineering systems. The author also proposes approaches for preventing forecasting errors and emphasizes the importance of thorough work with patent information.

Key words: *technological forecasting, concept development, S-curves, error analysis, patent data.*

1. Gordian Knot of Problems Inherent to Forecasting Projects

A number of in-depth studies devoted to forecasting was published at different times - for example, [1-6], and others. Within the range of reference sources studied by the author, one can draw two conclusions: a) a large body of knowledge on evolution of systems and potential possibilities of forecasting this evolution has been accumulated, analyzed and developed, and b) the said knowledge are lacking the most important element necessary in practical activity – namely, instrumentality. By instrumentality the author means practicality of approaches, which allow formulating quite **reliable forecasts during an acceptable period of time** (with a special emphasis upon "reliability"), which would be different from obvious forecasts.

It was shown in [6] that many forecasting problems are rather complex, even when taken individually. When taken together, they form a Gordian knot, which one has often to cut in the real time mode. The author's experience shows that in this case a set of different methodological approaches, on the one hand, and experience as well as "art", on the other hand, serve as a sword (i.e. a tool). Though in this case methodologies represent a foundation, but according to author's estimate, under the conditions of usual lack of time, experience and "art" account for up to 80% of the obtained results. What is this estimate based on? There are many specialists, who know the methodology. However, there are only a few successful projects with non-obvious results verified in the course of time.

The goal of the present paper consists in developing the both parts of this complex tool. Recognizing the utmost importance of experience and "art", the author believes that methodological vision is required to improve them both, because it is difficult to swing a sword that doesn't have a handle.

One of the most serious problems inherent to forecasting projects, which was not identified in [6], consists in the necessity of "fan-shaped" information-and-analytical studies aimed at investigation into evolution of a system proper and a field, to which it belongs, as well as tendencies in a number of other fields. In this case these "other" fields include not only the ones, which are close to one under investigation, but also some others that could be quite far from it. The main Gordian knot turns out to be surrounded by additional ones. They are less complicated, but there are a lot of them. The volume of information-and-analytical work to be done becomes rather high. A possible solution, in author's opinion, consists in intensive application of modern approaches to work with information - especially patent information [8, 9, 10].

According to author's opinion, critical analysis of errors is exceptionally useful for training in any field. At the same time, though the majority of previously published works devoted to this issue were characterized by in-depth study and width of coverage, the author failed to find materials, in which the actually conducted forecasting studies were analyzed with sufficient degree of criticism.

For example, one of specific tools for forecasting projects – namely, analysis of system evolution by S-curve – often appears to be unreliable due to a number of problems. Sometimes they turn out to be so difficult to formalize, that any attempts to solve them strictly methodologically don't lead to reliable and consistent results. These problems are mainly associated with:

- Selection of parameters characterizing the evolution of a system,
- Determination of limit for system evolution,
- Selection of operation principle, for which the limit of evolution is to be determined, and
- Combining the results of analysis carried out for different parameters, etc.

Besides, evaluation of potential, volatility, segmentation and other characteristics of consumer's market is of great importance for correct forecasting. All this imposes additional requirements upon project results and can degrade their reliability.

Many of specific difficulties inherent to forecasting retain their significance and influence at presence, while other gradually become less significant. For instance, much more powerful information-and-analytical set of tools is available nowadays as compared to the situation 15 years ago; the methodologies have been developed further; and certain experience has been accumulated since then. Nevertheless, the main reasons for errors still remain in force. The goal of the present article is to decrease the probability of occurrence of similar errors.

The content of the present article represents a result of thorough analysis of a real project that was quite successful on the whole. The author tries to learn from his own mistakes and offers the others to learn from these mistakes as well.

Very few specialists in the field of innovative designing had an opportunity to acquire similar experience.

2. Subject Matter of Analysis. Goals and Objectives of Analyzed Project

The present article was written as a result of critical analysis of a particular forecasting project, which is 15 years old. 15 years is a significant part of several dozens of years that constituted a formal forecasting period according to project work specification.

So, in 1995 a project was carried out, which was aimed at forecasting the evolution of the engineering system "Toothbrush".

The following constraints were imposed on this project: all brushes having cleaning heads of ordinary type that are set into motion by means of electromechanical drive fell outside the scope of analysis. It was required to give both a short-term and long-term (for dozens of years) forecasts for the evolution of this system. The number of worked out forecasting concepts (as well as their quality) should have enabled the client to evaluate the degree of perspectiveness of this industrial direction on the whole.

In terms of this principle client's goal, it was necessary to concentrate efforts on solutions and products that would have sufficient potentialities for market success. Besides a forecast for already existing sub-directions, of special interest was a forecast for products with supposedly

- significant improvement of the level of main function performance, and
- new functions, which are characterized by high consumer/customer value.

At the moment of project performance, a number of systems were offered at the market that employed different operation principle as compared to the conventional toothbrush, for example:

- electromechanical brushes,
- vibro- and ultrasonic brushes, and
- water jet devices for mouth cavity care.

Besides, a number of new directions and operation principles (as compared to a conventional toothbrush) existed at that moment at the level of at least patented solutions. For example:

- toothbrushes with ion-exchange resins and toothbrushes using electrophoresis-based methods for introducing medications into the mouth cavity;
- toothbrushes that combined teeth cleaning with effective massage;

- chewing toothbrushes;
- devices in the form of tray put on teeth capable of feeding a cleaning solution or other substance into the tray;
- devices intended for disinfecting toothbrushes during storage, and other systems.

3. Brief Review of Project Results

1. The main outcome for the client consisted in the following. It was explicitly and convincingly shown (and proved) that as applied to this old and already "ploughed" field of engineering solutions for non-mechanical toothbrushes, new solutions are to be expected in future, which would be able to

- revitalize the market in existing consumer niches of this product, and, moreover,
- create new consumer niches, and, jointly,
- bring the evolution of non-mechanical toothbrushes from the stage of stagnation to the new stage of evolutionary S-curve.

Certainty of this outcome was ensured by:

- analysis of biological grounds for teeth cleaning and compliance of existing toothbrushes to these biological grounds;
- analysis of explicit and latent expectations of consumers associated with that;
- analysis of evolutionary trends of the "toothbrush" system;
- conceptual design of new systems within the frames of existing directions;
- conceptual design of new directions and corresponding systems;
- prognostic* design of new systems for long-term future; and
- scientific substantiation of operational ability of proposed concepts.

Concurrently, the client has got a brief analysis of relationship between the performance of similar functions by two interacting systems – toothbrushes and toothpastes. A common approach to rational distribution of functions between them was worked out.

2. What did the contractor acquire in addition to payment?

The above-listed actual outcomes, which predominantly ensured the success of the project, in their turn, appeared as a result of a number of methodological and other innovations. Practical and theoretical experience was enriched quite significantly.

Main achievements of the contractor:

a) methodological, for instance:

- for the first time, statistics of patenting in terms of directions and subdirections was studied within the frames of particular project. Moreover, the notion of benchmarking appeared in practice of the contractor after the completion of this project because of this analysis of patenting statistics;
- for the first time, cause-effect chains were developed to microlevel processes (subsequently, it became a commonly accepted practice). This achievement served as a basis for new methodological developments, which took the form of a number of published materials;
- multi-criteria approach to working out the ratings for concepts perspectiveness was successfully used.

b) actual achievements in project results: a number of directions and concepts was generated and main goals of the project were attained (see above)

c) organizational achievements: a technology was developed for gradual improvement of synthetic outcomes in course of obtainment of information and analytical results and with contracting still higher number of external experts, and so forth.

d) business goal of the contractor was certainly attained.

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* Prognostic concepts are understood in the present article as concepts with supposed implementation in the very distant future - i.e. in 20-50 years

3. A lot could be said about success here, but errors are of much higher importance for a researcher. This article is devoted specifically to some errors.

Let us make it clear: the author didn't set a goal for himself to study all possible errors that might be done in forecasting projects. The goal of the present article consists in identifying some particular types of errors and illustrating them with specific examples from a "real" – moreover, successful - project.

Due to obvious and all-round success, at that time the project seemed to approach the ideal in terms of achieved results. However, with accumulation of experience and further development of methodologies not only the achievements became obvious, but certain errors as well. The time that have passed since then also gave an opportunity to see the actual evolution of products offered at the market. Besides, at present it is possible to conduct some kind of "verification" of concepts by analyzing patent information for the period that has passed since then.

So, let's switchover to identified errors.

They could be classified using different approaches, - for example:

- purely methodological errors – ones associated with insufficient development of particular methodological approaches or with faults in applying them;
- errors resulting from "perception stereotypes", "preconceived viewpoint", and insufficient engineering analysis;
- errors resulting from shortage of information;
- errors resulting from underestimation of market potential;
- errors resulting from overestimation of market demands; and
- psychological errors – ones associated with stereotypes as well as with effect of insufficient thoroughness in thinking without apparent reason for that [10].

Depending upon accepted classification of errors, one can systematize reasons for these errors and give recommendations for avoiding them. In the present article they are analyzed from the viewpoint of methodological faults, which are directly associated with "experience and art".

The final evaluation of perspectiveness of a direction or concept was carried out in a complex way, taking different factors into account and using several criteria. For example, evaluation of compliance with TESE (Trends of Engineering Systems Evolution) was conducted in such a way that different trends were analyzed concurrently, and the results of previous evolution of the system as well as supposed consumer demands and other circumstances were taken into consideration. Multi-criteria evaluations allowed to minimize errors in final conclusions. Therefore, as a rule, the errors were determined not by one reason, but by several reasons at once. In connection with this, certain examples (given below) concurrently illustrate several reasons for forecasting errors.

Practical work showed that multi-criteria approach for evaluations does not always protect against errors. Therefore, even with such "protective" approach, it is very important to enhance the reliability of estimate in terms of each of the criteria.

4. Analysis of Errors

4.1. FORECASTING ERRORS ASSOCIATED WITH INCORRECT USE OF THE S-CURVE ANALYSIS

Let us first assume the following:

1. By regularities of S-curve evolution the author means the modern view at trends of irregular evolution of systems, which, in addition to [1, 2], was reflected in a number of modern studies, e.g. [4, 5, 6] and others.

2. Nevertheless, the basic notions [1, 2] developed by the time of project performance are used in the analysis presented in this work, - this is done for the sake of simplicity and briefness of reasoning. In the author's opinion, these notions were quite sufficient (and are quite sufficient nowadays) for preventing errors, if the information and analytical work is organized properly.

4.1.1. WRONG TIMING OF BEGINNING AND DURATION OF STAGE 1 OF SYSTEM EVOLUTION

This is a very interesting and probably infrequent error encountered in forecasting projects.

If one manages to identify a system that stays at Stage 1 of its evolution, forecast for this system depends upon estimate of time required for transition to Stage 2.

When conducting the project, the author proposed a direction for modifying the toothpaste, and this direction implied the use of different effects generated by toothbrush. The goal was to confer such additional properties to toothpaste at the moment of teeth cleaning that were missing during toothpaste storage during its storage due to any reason. The author understood modification in this case as a qualitative change of physical and/or chemical properties of substances that were already available in the toothpaste - not, for example, simple addition of an accessory substance from the toothbrush.

The author was not aware of such ideas at the moment of project performance. Therefore, it was supposed that even Stage 1 had not yet started.

By the time of project performance, the author was not aware of such ideas that anybody has been working on. Therefore, it was supposed that even Stage 1 had not yet started.

Therefore, based on a set of various factors, it was anticipated that active development of this direction would take place in a distant future – in about 20 years. However, when working on this article, the author found out that developments, which refer to this direction, were underway already at the time of project performance. In particular, in 1997 a patent US5658148 with priority date of April 1995 (Fig.1) was published. By 2003 and later, a number of patents referring to this direction were published. Joint analysis of commercial and patent information shows that, for example, such companies as Oroscience Inc. (http://www.oroscience.com/home.html), Biolitec AG (www.biolitec.com) and CeramOptic GmbH (http://www.ceramoptec.de) are already orienting their business for products belonging to this direction. This fact confirms the truthfulness of the forecast on the whole. However, adhering to strictly critical position, the author thinks that incorrect timing for this forecast implementation was an error.

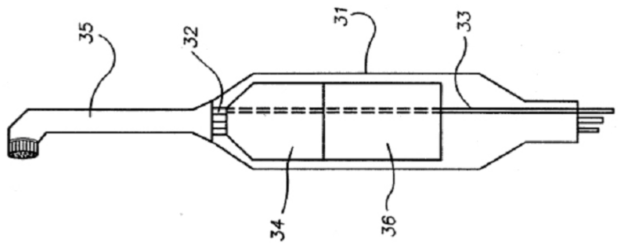

Fig. 1. Toothbrush for use at home with a semiconductor laser (32) for activating a special toothpaste according to patent US5658148 (1997)

The reason for this error in determining forecast implementation period consists in **insufficient investigation into background (prehistory) of some developments**, which, in one or another way, preceded the appearance of the concept under consideration. For example, if we had had an opportunity to conduct an in-depth investigation into patent solutions evolution, we would have discovered that some of them were coming nearer to the anticipated direction. Then the timing for forecast implementation would have been more exact.

Nowadays, such opportunities have appeared owing to commercial patent data bases with their advanced search and analysis service.

4.1.2. WRONG TIME ESTIMATE OF DURATION AND COMPLETION OF STAGE 2 OF SYSTEM EVOLUTION (OF ES LOCATION ON AN S-CURVE AT STAGE 2 OF ES EVOLUTION)

Diversity of optimization options for a system is one of the major distinctive features of Stage 2 of system evolution, especially after the system has passed the midpoint of this stage.

By the moment of project performance, a great number of engineering solutions has been accumulated in prior art, which were devoted to relatively minor improvements of operating head, bristles, their incline and mutual arrangement of bristles, etc., which slightly enhanced the efficiency of teeth cleaning, but were unable to provide significant gain in efficiency.

This set of solutions could be conventionally joined into a direction of design-related improvement of standard toothbrush. Some similar engineering solutions already existed not only in patents, but were also embodied in products offered at the market.

Our team assigned this direction to the period of system transition to Stage 3 of the S-curve. We decided that, due to insignificant differences in terms of main parameter – namely, teeth cleaning efficiency, – this direction could hardly have serious potentialities for expanding the market in the future. We decided not to waste time and efforts on serious work in this direction, considering it to be of little promise both from the engineering standpoint (in terms of teeth cleaning efficiency enhancement) and from the commercial standpoint.

Fifteen years have passed, and the said diversity of designs increased, is still present at the market and still sells quite successfully. The author's error lied in **underestimation of overall potential of the market and in underestimation of market segmentation.** As the time showed, with appropriate advertising the market appeared to be able to absorb all this diversity of minor improvements and continues absorbing them successfully till nowadays. Transition to Stage 3 turned out to shifted in time.

One of major methodological errors consists in underestimation of market potential. With the high level of the market and its ability to absorb a large number of optimization solutions, the transition of the system to Stage 3 is shifted forward.

However, this error was not of great importance. The Client was primarily interested in the perspectives of non-traditional directions.

4.1.3. WRONG ESTIMATE OF POTENTIAL (LIMIT) OF ENGINEERING SYSTEM EVOLUTION

On the outside, this error is expressed in a similar way as the previous one – namely, in a wrong forecast of system transition to Stage 3. However, its essence is different. As it is correctly indicated in [6], correct estimate of evolution limits is rather complex and very often objectively impossible. However, the solution could be sought for in the use of **qualitative estimates and qualitative relationships**.

Example: chewing toothbrushes. It was forecasted that highly effective disposable chewing toothbrushes (with external design that is close to that of chewing gums - Fig. 2) would enter the market quite quickly and widely. Since then similar toothbrushes were mentioned in newspapers and periodicals from time to time. However, this forecast did not come true for the market.

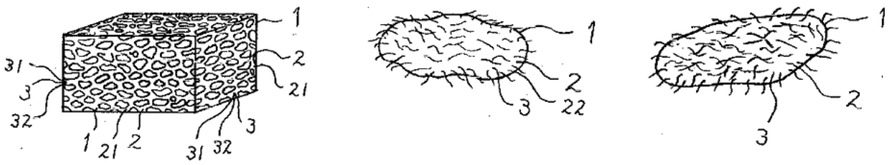

Fig.2. Chewing toothbrushes described in Japanese application JP2000072637 (2000) (2 – water-insoluble fibers or sponge, 3 – cleaning composition)

Besides, chewing gums with cleaning effect appeared and occupied a market segment. We forecasted the appearance of such products too, but they were beyond the scope of project goals and constraints.

What was the reason for this forecasting error? First of all, **evaluation of evolution limit was conducted without taking into account (to a sufficient extent) the biological constraints in combination with safety constraints** (factor of the supersystem of the next hierarchical level - human body). Excessive degree of optimism played its role here. The efficiency of such devices for solving a complex of problems was overestimated, and the influence of individual differences of people upon teeth cleaning efficiency was underestimated. So, a set of problems inherent to such toothbrushes was underestimated: it is probable that a combination of requirements to safety and hygiene lowered the actual evolution limit of efficiency of such toothbrushes.

Another reason for this error consisted in excessively intensive application of some selected TRIZ tools (See section 4.2.1) to the detriment of other tools.

That's why, a forecasted intensive penetration of these directions to the market did not come true during the time that has passed and possibly it won't come true at all.

General recommendations regarding a group of errors associated with wrong use of S-curves are as follows:

- to study materials on using S-curves of system evolution in innovative designing [1, 2, 4, 5, 6], and others.
- to give greater attention to completeness and depth of information and analytical studies.
- to use modern information and analytical set of tools – namely, data bases, especially commercial patent ones.
- to overcome own stereotypes.

4.2. ERRORS FROM LOCAL APPLICATION OF INDIVIDUAL METHODOLOGICAL APPROACHES

4.2.1. NON-CRITICAL TENDENCY FOR EMPLOYMENT OF RESOURCES

Example 1. The chewing brushes (Section 4.1.3) serve as a good illustration for this very reason superimposed upon TRIZ stereotypes. Probably, underestimation of their fundamental disadvantages served as a consequence of non-critical analysis of attractive idea of employing the supersystem resource – chewing movements of human jaws.

Actually, there are no grounds yet to speak about the erroneous forecast of the direction on the whole. However, in any case an error was made regarding timing - 15 years have passed, and such toothbrushes are still not widely used. Besides, a conclusion was not drawn that commercially successful implementation of this direction requires break-through solutions for forecasting contradictions (See section 4.2.5).

Example 2. Intensive evolution of toothbrushes employing another resource of the supersystem – pressure head of water in the faucet - was also forecasted. This forecast also demonstrates excessive enthusiasm about available resources. This forecast is discussed in greater detail in Section 4.4.2.

Recommendations: to study deeper the essence of TRIZ methods; to overcome the so-called TRIZ stereotypes; and to study deeper the prehistory of the direction.

4.2.2. EXCESSIVE TENDENCY TO IDEALIZATION OF RESULTS (STRIVING FOR TO FIND THE "BEST" SOLUTION)

Let us see, how one can fail to notice a good comfortable path in a forest, while looking for a wide road. The author forecasted the appearance of direction of "Smart toothbrushes", which would control not only simple things - such as teeth cleaning time. In particular, there was proposed a concept of toothbrush capable of correct identifying of cleaning time expiration via estimation of overall mechanical action upon the teeth. A solution of this kind was published only in 2007 (Japanese application JP2007325806 Oral cavity sanitary unit).

However, the project team failed to notice simpler solutions, which were demanded for by the market. For instance, signaling about exceeding the threshold of mechanical action upon the teeth.

As information studies (carried out recently by the author) showed, such developments were already in progress when we were working on the project. During the time passed, a number of applications were filed and a number of patents issued for inventions of this kind. Let's indicate only the recent ones: JP2008012232A2 Toothbrush pressure measuring holder (2008), JP2008006282 (2008, Johnson & Johnson Consumer Co Inc), US20070136964 Multimedia toothbrush (2007), JP2006000361 Toothbrush for learning, and toothbrushing learning device (2006), US7383603 Flexible neck toothbrush (2006), and

US6412137 Pressure sensitive brush (2002). This list could be continued. The main goal is one and the same: prevention of excessive abrasive wear of teeth and toothbrush bristles in the course of teeth cleaning. This intensive patenting activity has already found practical implementation in a great number of products. For example, one can easily find in the Internet 34 brand names of toothbrushes with strain gauge sensors (http://www.twenga.co.uk/dir-Health-Beauty,Facial-hygiene,Electric-toothbrushes-0186671, Pressure Sensor Electric toothbrushes)

Thus, proposing a more advanced concept, a solution was overlooked, which was of great commercial potentiality, though it was far from being "the best".

In the process of improving the solution with the aim to obtain "the best" one, **there is an optimum point**, which should not be surpassed due to the reasons that are usually associated with the cost, side effects or consumer constraints (safety, ecology, etc.). From the methodological standpoint, one can use a criterion of system ideality. However, this criterion is difficult to formalize and to use it in practice. Instead, it is possible to intensify the engineering analysis of the system.

Recommendations: While trying to obtain "the best" future solution, economically optimal options should not be overlooked.

4.2.3. EXCESSIVE DEPLOYMENT – OVERLOADING WITH SUBSYSTEMS

A device for teeth cleaning with a jet of water containing air bubbles was mentioned as a promising direction in the project. The reason for that lies in the attractiveness of aerated water as a "working medium" and compliance with the trends of engineering system evolution.

However, if the analysis of this direction were performed fairly critically, it would have been possible to draw a conclusion about inevitable overloading of such system with subsystems. Here one would find water supply, gas supply, elaborate design of operating head and/or bristles... Improvements in this direction appear until nowadays - for example, WO2007118373A1 A bubble toothbrush (2007), - but actual commercial proposal would be quite limited. A forecasting error associated with **non-critical attitude to excessive deployment** of a system is observed in this case.

Recommendation. One should study the essence of TRIZ methods in greater depth and, what is more important, the practice of building actual systems should be also studied deeper. In such cases, a forecasting problem aimed at design simplification via trimming of subsystems should be set first of all. If it turns out that it is impossible to solve such problem, it is recommended to think about rejection of such forecasting concept.

4.2.4. NOT DEEP ENOUGH WORK WITH EFFECTS: OVERLOOKING/LOSS OF CONCEPTS OR THEIR ENGINEERING MERITS

The author forecasted the appearance of a direction aimed at indication of teeth cleaning quality by means of toothbrushes and proposed at least two versions for implementing concepts belonging to this direction. However, at least one concept was still overlooked - namely, indication of dental plaque simply by means of optical sensors. During the time elapsed, some developers did not miss this idea: for example, see patent US5894620, Electric toothbrush with means for locating dental plaque (1999). This fairly obvious concept was overlooked under the direction, which was successfully forecasted.

The author believes that this error is also a methodological one.

Recommendation. Careful work with physical, chemical and other effects should not be forgotten; it is necessary to pay attention to work on systematic use of patent information [7, 8, 9].

A publication should be also mentioned here [11], which is not intentionally directed at patent information, but in terms of problem statement is similar to [7,8,9].

4.2.5. INATTENTIVENESS TO KEY FORECASTING CONTRADICTIONS (EXCESSIVE OPTIMISM)

In some concepts, serious problems associated with forecasting contradictions were seen. However, there was little time for search for solutions. Therefore, we sometimes made use of the right to leave these contradictions for the future as secondary problems. It is impossible to solve all problems within the frames of a forecasting project. It is obvious that, on the one hand, excessive optimism is fraught with errors. However, it is also clear that there is still a possibility to estimate the degree of substantiation of this optimism.

For example, for chewing toothbrushes, contradictions should have been formulated that are associated with the fact that the combination of requirements to safety and hygiene should lower the actual limit of their efficiency growth (See section 4.1.3). Probability of finding solutions for generated secondary problems was estimated too optimistically. Were there justified grounds for such optimism? These contradictions and secondary problems (corresponding to them) were of high significance. However, our team did not see more or less simple solutions for them.

Fig.3. "Chewing toothbrush" for children

Despite this, these problems were left "for the future", based on a supposition that they are quite solvable. The analysis of patent documents published for the passed time, conducted by the author, shows that solving of "secondary" problems in this case leads to making the design much more complex, while in simple designs the problem of efficiency is still left unsolved. It is not by chance that, despite long patent history of chewing toothbrushes, almost only product related to this direction and offered at the market is the chewing "toothbrush" for children (e.g., Biodegradable 'Chewing' Toothbrush http://www.gogreen.cellande.co.uk /shop/products/toothbrush/toothbrush.htm, Fig.3).

Thus, the forecast has not come true yet and will hardly come true at all.

Recommendations:

- to overcome own "optimistic" stereotypes;
- if a secondary problem is significant enough, and there is no sureness in the existence of solution, it is better not to classify a certain concept with the group of promising ones, or it is better to label it with an appropriate comment.

4.3. INSUFFICIENTLY DEEP INVESTIGATION INTO TENDENCIES AND PRIOR ART

When performing forecasting projects, one should study prior art and existing tendencies as applied to:

- a field of direct interest (in our case this is teeth cleaning at home);
- related and alternative industries (for example, other kinds of oral care, dentistry, teeth whitening, chewing gums, toothpastes);
- close supersystem fields/industries (for example, medicine, food industry); and
- fields that are similar in terms of characteristic features, in which parallel lines of evolution could be observed [12] (cleaning devices of different purpose, massagers).

Due to the above indicated, information and analytical studies acquire large volume [3].

4.3.1. ERRORS IN STUDYING PRIOR ART AND TENDENCIES IN A GIVEN FIELD/INDUSTRY (UNDERESTIMATION OF PRIOR ART)

It is obvious that attained Prior Art (the term, which is well known to patent specialists) and already formed tendencies in a given field or industry represent a foundation for any forecast.

Therefore, it is necessary to analyze the possibility of multidirectional evolution of systems. Usually, subsystems and supersystem also should be subjected to analysis. Therefore, Prior Art has to be identified for many directions at once. This is one of numerous specific complications of forecasting projects. The volume of information and analytical work is rather high.

In his project our team first analyzed all available information, identified the tendencies and determined their character. In doing so we made one searching error - namely, patents for devices intended for cleaning teeth with a water jet containing air bubbles (aerated water) was overlooked. Additional study carried out by author while he was working on this article showed that at that time such solutions had already appeared. This is, for example, patent US4903688 Tooth cleaning toothbrush and system (published in 1990). We proposed this direction without knowing that it actually already existed. Moreover, we classified this direction with the ones that had high potential and promise (thus making another mistake analyzed in Section 4.2.3).

Such errors of omission are associated with problems of search for and processing of a huge body of information in the absence of time for double-checking. From the current author's standpoint, it reflected the absence of available set of tools for information and analytical work.

Recommendations. First of all, it is always necessary, if possible, **to double-check the completeness of basic information about prior art** – i.e. a foundation, on which the entire "building" of the project stands.

Secondly, it is necessary to take care of instrumental support of such an opportunity. This is provided by the same means, which we recommended earlier. Even if there is an access to high-quality commercial reports, one should conduct own studies involving the use of commercial databases of patent information. They provide an efficient set of search and analytical options and allow an analyst to obtain results that are not found and cannot be found in reviews and marketing reports. These are, for example, the bases Questel [13], Delphion

[14], STN [15], and others. Service of patent data given by **Questel** company **(www.questel.com)** is distinguished among them from the standpoint of the author in terms of offered opportunities. It supports all methodological abilities to conduct information and analytical studies necessary for performance of forecasting projects with high degree of completeness, quality and efficiency.

Thirdly: it is necessary to pay attention to published materials on system-based use of patent information [7, 8, 9] and to learn how to use it professionally.

4.3.2. INSUFFICIENTLY DEEP STUDY OF TENDENCIES IN RELATED, SIMILAR AND ALTERNATIVE FIELDS/INDUSTRIES OR INSUFFICIENT USE OF THESE TENDENCIES

There is a fine line between insufficient-degree investigation into tendencies, on the one hand, and non-application of acquired knowledge for generating forecast directions and concepts, on the other hand. However, in this article the author is not going to make distinctions between these two types of errors. The importance of completeness of such studies will be illustrated with an example.

In the course of project performance the industry of systems for teeth whitening at home was already developing. We should have identified this direction in the course of information and analytical studies, but failed to do so. And the fact that it remained beyond the scope of attention has to be assumed as a serious methodological error.

Therefore, the author believes that the absence of concepts that place an emphasis on the whitening action was a serious error in the project. History shows that other researchers did not miss this issue, though, in author's opinion, no significant achievements have been demonstrated here as yet. Nevertheless, if our team had known about home teeth whitening at that time, we would have forecasted at least the appearance of whitening toothbrushes.

Lack of knowledge in this particular case could have been compensated by system-based study of the super system – industry of oral care. At that time our team did not manage to conduct such a study with sufficient degree of completeness.

Recommendation: to pay appropriate attention to information and analytical studies, especially those aimed at studying the supersystem; to pay attention to materials on system-based use of patent information [7, 8, 9] and to learn to use it professionally.

4.3.3. INSUFFICIENTLY DEEP STUDY OF DIRECTIONS AND TENDENCIES IN MORE REMOTE FIELDS/INDUSTRIES, INCLUDING AREAS WITH PARALLEL EVOLUTION OF SYSTEMS.

Different approaches were used when doing the project. Among the issues subjected to analysis were perspectives as seen from the standpoint of directions and tendencies identified in different fields and industries.

In particular, conceptual directions were proposed that were aimed at synthesis of toothbrushes with devices for diagnostics of cleaning quality, control of correctness of movements during the teeth cleaning process (See Section 4.2.2), curative action both upon mouth cavity and upon other subsystems of human body, etc. All these directions during the time passed appeared to be reflected in new developments in this or that way (see, for example, applications and patents US20070111166, JP09192148, EP1174055, EP1700611, JP2005241335, US7328706, JP2006061486, US20060183071).

Nowadays, from the standpoint of accumulated experience, it seems confusing that there was not proposed a direction aimed at creating toothbrushes with functions of ***medical*** diagnostics of body organs state (not only of mouth cavity). During the last years this direction started developing (WO06071332, US20040049123 and other patents).

What is the reason for errors described in sections 4.3.2 and 4.3.3? Sufficiently systematic analysis of **scientific and technological supersystem** was not conducted. It is possible that someone will consider the last of the described errors to be trivial, to be such a error, which he would never do... Unfortunately, even such "evident" errors appear.

How such errors could be prevented? One should search for resources for conducting research about tendencies in different fields and industries. A strong resource for this, for instance, is a methodology of problem-oriented search in terms of actions (APOS - Action-Problem Oriented search) [7, 8, 9] and a similar methodology of Function-Oriented Search (FOS) [11] combined with the use of powerful search and analytical set of tools offered by commercial databases.

4.4. UNDERESTIMATION (INSUFFICIENTLY DEEP STUDY) OF MARKET ASPECTS OF PROPOSED CONCEPTS

4.4.1. NEGLECT OF MARKET ADVANTAGES INCLUDING ENTERING THE SEGMENTS OF OTHER MARKETS

As a rule, these errors are of secondary nature. These are cases of neglect of market advantages associated with one of the engineering aspects of the concept. Inattention to the secondary engineering opportunity could lead (when analyzing the perspectives) to potential loss of an additional market niche.

For example, a concept was proposed involving a system made of elastic polymer, which embraces entirely one row of teeth (or both rows of teeth), the said system being able to move, due to which fact the cleaning process takes place. In fact, the efficiency of teeth cleaning by means of such a system is not high; that's why we did not assign high rank to this concept when evaluating its potential. However, an opportunity of a separate application of such a system for medication delivery was missed, and a conclusion that such a device has its own market niche was not drawn. Patents that were granted later, - for example, US5993413 Intraoral administration device and system (1999), Fig.4, and US7328706 Therapeutic and protective dental device useful as an intra-oral delivery system (2008) -confirm this error.

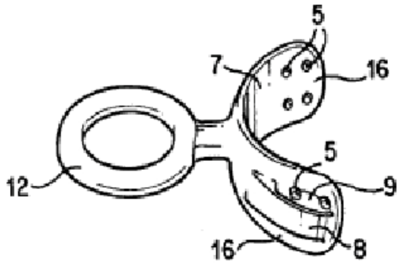

Fig.4. US5993413 Intraoral administration device and system; (9) – area of medication placement.

This is an example of how a seemingly minor technical omission in the analysis of proposed forecasting concept dramatically impairs the estimate of its market potential. In this case, a system for delivery of medications into the mouth cavity should have been forecasted, rather than a device for teeth cleaning.

Was it possible to notice this opportunity in due time? The answer is "yes". The methods are still the same: systematic study of close and remote, alternative and similar fields and industries.

The approaches recommended by the author are APOS and FOS methodologies with the use of patent bases; method of parallel evolutions.

4.4.2. UNDERESTIMATION OF CONSUMER DISADVANTAGES

Several kinds of devices for teeth cleaning employing the pressure head of water in faucets and mentioned in Section 4.2.1 are currently offered at the market. For example, devices for teeth cleaning by jet of water (Fig.5, http://www.teethjet.co.nz/2452.html) are currently sold for consumers. Therefore, it would be incorrect to say that a positive forecast for such systems was a 100% mistake. However, the supposed serious market success is not observed for such devices. This is an interesting example of a situation, when obvious market advantages of a direction could not outweigh certain market disadvantages.

Fig.5. Example of commercial product for teeth cleaning by a jet of water

Main Results and Recommendations

1. A large forecasting project (accepted by the Client as quite successful and accomplishing all stated goals) was analyzed in this article in terms of omissions and errors from the viewpoint of long period of time that has passed.

2. A number of particular methodological and other errors were identified. Their reasons were determined. Recommendations are given regarding prevention of such errors.

3. Sometimes the concepts, which were initially supposed to be implemented in the distant future, appear to be implemented already after several years. The introduction of new technologies proceeds rather quickly. However, it could also be predicted.

4. The main generalized recommendations are as follows.

4.1. Methodological recommendations:

- Overcome the so-called TRIZ stereotypes and study the essence of TRIZ methods in greater depth;
- Upgrade self-criticism, even if the forecasting character of the project formally allows to make requirements to the degree of concept development less stringent. Conduct more careful engineering analysis of concepts;
- Thorough work with physical, chemical and other effects;
- If a system subjected to forecasting is significantly more complex than the source system, a forecasting problem should be stated with the aim to simplify this system via trimming of subsystems. If no opportunity to solve the

problem is seen by researcher, the idea of rejecting such a concept should be thought over;

- If a secondary problem is quite significant and still there is no certainty in ability to solve it, the idea of rejecting such a concept should be thought over or it should be accompanied by an appropriate comment;

- In case of striving for to obtain "the best" future solution – economically optimum options should not be missed;

- Apply the methodology of parallel lines of evolution;

- Apply the FOS and APOS methods; and

- In actual work – modify the methodology with regard to peculiarities of a particular project.

4.2. Psychological recommendations

- Overcome own stereotypes, both "pessimistic" and "optimistic". Study scientific and technological news; and

- Use discussions and other methods for this purpose.

4.3. Recommendations on information and analytical support:

- Study the background (prehistory) of developments in greater depth;

- Double-check the completeness of basic information concerning prior art;

- Take market potential into account and study it more thoroughly;

- Use modern information and analytical set of tools – databases, especially - commercial patent ones;

- Learn to work effectively and efficiently with these tools; and

- Pay attention to materials on system-based use of patent information.

Conclusion

The frames of the present article did not allow the author to include all observations and give all the examples, which the author derived from project analysis. Besides, an analysis of evidently successful forecasts could probably be of serious interest. However, in this case the volume of the article would be many times larger.

Here is a minor addition to the last item of the previous section.

As it was shown in [9], system-based work with patent information is itself able to ensure solving of practically all problems encountered in innovation projects of any type. With forecasting projects, it is especially important due to a number of reasons.

1. The most serious problem of forecasting projects consists in necessity of multi-directional information and analytical studies:

- of analyzed system;
- of its subsystems; and
- of its supersystems.

2. Another serious problem consists in the necessity to study prior art and tendencies of evolution in a number of fields/industries:

- in the area of direct interest (in our case this is teeth cleaning at home)
- in similar and alternative fields (for example, other kinds of mouth cavity care, dentistry, teeth whitening, chewing gums, and toothpastes)
- in close supersystem areas (for example, in medicine and food industry); and
- in fields/industries, which are similar in terms of characteristic features, in which parallel lines of evolution could be observed.

All the above, taken together, could be named a 3D-fan of research, or even a multi-dimensional fan. In this case the system-based analysis of patent information represents an effective and efficient methodological approach to be used. Questel service [13] is the most effective and efficient one for conducting such study among all patent services known to the author.

In particular, when working on this article, the author had to conduct an entire cycle of express studies of patent information. Questel service [13] demonstrated high efficiency in this work.

And the last issue to be covered. Probably there would be a reader, who will ask: how could a project with such a number of shortcomings be successful? The answer is as follows: first of all, the analyzed omissions were identified after thorough analysis only many years later. With a less thorough approach, these omissions could be omitted even nowadays. However, in this case it would be more difficult to learn. Secondly, there would have been many more instances of conceptual success in this project, and the significance of them would be immeasurably higher than that of disadvantages, which were shown here. "Thirdly" and "fourthly" could also be given here...

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Reference

1. A.Liubomirsky, S.Litvin. Trends of Engineering Systems Evolution, 2003 (in Russian). http://www.metodolog.ru/00767/00767.html
2. J.Martino. Technological Forecasting for Decisionmaking. New York. 1993
3. B.M.Axelrod, S.S.Litvin. Main Differences Between Methodologies for Performing Consulting Projects Aimed at Forecasting and Modernization of ES // Scientific and Practical Conference on Using TRIZ in Artificial Intellect Systems. Minsk, IMCorp, 1996, January (in Russian).
4. N.B.Feygenson. S-curve – Certain Peculiarities of Stage 3 of Systems Evolution. TRIZ Journal, No.1(14), 2005, pp.55-59.
5. A.Kynin, V.Lenyashin, N.Feygenson. Engineering System Evolution. 2008 (in Russian). http://www.metodolog.ru/01488/01488.html
6. A.W.Efimov. Analysis of S-curve Evolution: Goals and Major Techniques. 2008 (in Russian). http://www.metodolog.ru/01507/01507.html

7. B.Axelrod. New Search and Problem-Solving TRIZ Tool: Methodology For Action & Problem Oriented Search (APOS) Based On The Analysis Of Patent Documents // TRIZ Future 2005. Graz, Austria. 2005, November 16-18. University of Leoben. pp.325-345.
8. B.M.Axelrod. Problem-Oriented Search by Action Involving Use of Patent Databases: New Searching and Solving Tool. // MATRIZ Conference/TRIZ Fest-2006, Saint Petersburg, Russia, October 13-20, 2006. pp.409-417 (in Russian); http://www.matriz.ru/file.php/id/f5452/name/06-works-05.pdf
9. B.M.Axelrod. Action & Problem Oriented Search: Systemic Use in Innovation Projects. TRIZ Master Qualification Thesis. 2008 (in Russian). http://www.triz-summit.ru/file.php/id/f4067/name/Axelrod_Master_Disser_2008_final.doc
Author's Abstract: Action & Problem Oriented Search: Systemic Use in Innovation Projects. http://www.triz-summit.ru/file.php/id/f4071/name /EngAxelrod_Master_Autoref_Disser_2008.doc (in English)
10. B.M.Axelrod, S.I.Axelrod. Implementing Inventor's Creative Potential to the Fullest Extent: Psychological Aspects // TRIZ Journal. 1995. No.1. P. 94-99. (in Russian)
11. S.Litvin. New Triz-Based Tool — Function-Oriented Search. ETRIA World Conference: TRIZ Future 2004. November 2-5, 2004, Florence, Italy.
12. S.Litvin, M.Gershman. Parallel Evolutionary Lines Application for Technology Forecast.// TRIZ-Based Methods for Forecasting. Collection of Scientific Papers. Library of TRIZ-Developers Summit. Issue 3, Saint Petersburg, 2010. – 280 pages.
13. Questel homepage http://www.questel.com
14. Delphion homepage http://www.delphion.com
15. STN homepage http://www.stn-international.de/stn_home.html

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System for Forecasting New Scientific Ideas

Abstract.

When speaking about forecasting, people usually confuse two completely different phenomena: short-term or linear forecasting and long-term or non-linear one. However, these notions have completely different nature, different mechanisms, and different consequences. Linear forecasting simply projects already existing phenomena in the future, while non-linear forecasting predicts fundamental changes of existing phenomena.

Since linear forecasting is perceived much easier than non-linear one, the latter is often completely excluded from consideration and analysis. For example, Eurasian International Scientific and Analytical Journal "Problems of Modern Economy" No. 1(29) defines forecasting as "scientific study of possible anticipated perspectives of a certain phenomenon or event" [1]. Forecasting of phenomena and events proper is apriori excluded from the definition.

Linear forecasting

This is the most primitive and, hence the most widely spread kind of forecasting. It consists in direct continuation in mind of already existing tendencies into the future. Such forecasting does not require special mechanisms. There are two types of linear forecasting:

– Direct extrapolation of developed tendencies.

Example 1: *(forecast of medical science evolution)* Professor Bruce Lun from Chicago University forecasts production of "unlimited number of organs for transplantation". Professor Ellen Heber-Katz from Wistar Institute in Philadelphia forecasts mass regeneration of the human organs using a "regeneration tablet". Professor Richard Miller from Michigan University forecasts growth of human life duration [2].

As can be seen from the above example, actually this is not a forecast of development of medicine as a science, but a forecast of practical application of already known results.

– forecast of filling "blank spaces" within the frames of known and commonly accepted paradigm.

Example 2: Stephen Hawking and several other physicists forecast creation of "quantum theory of gravitation" in the near future. They are troubled by the thought that the gravitational field will remain the only one, which cannot be described using quantum models. However, since three other physical fields are quanted, it could also be supposed that gravitation can be also quanted [3, S.70].

Linear forecasting could have both qualitative and quantitative form. There are no differences in them in terms of approach.

A peculiarity of linear forecasting consists in the fact that forecasts are justified for very short time intervals only, and the longer the source paradigm exists, the shorter these intervals are. And taking into account the general acceleration of changes of notions, one can assert that linear forecasting in the general scientific scale does not prove its worth.

Example 3: In 1890 Agnia Clerk wrote in her book about evolution of astronomy in the 19th century: "The issue of whether nebulosities are external galaxies or not is hardly worth discussing nowadays. The progress of studies has given the answer to this question. It could be said with certainty that not a single competent thinker, facing the existing facts, could assert that at least one nebulosity could be a star system that is comparable to the Milky Way in terms of size" [4, P.105]. However, already in 1924 Edwin Hubble has shown that quite a number of nebulosities, which are similar to our Galaxy, are located far beyond the Milky Way [4, C.111-114].

Classification forecasting

This is an intermediate option between linear and non-linear forecasting. On the one hand, this is a forecasting of new objects and phenomena, while on the other hand, a forecast is carried out within the frames of already known classification.

Example 4: Developing the theory of phase transitions, Clausius predicted the existence of evaporation from a solid body (skipping over the liquid phase) [5, P.161]. If one imagines a Table of phase transitions, the transitions "solid – liquid" (and vice versa) and liquid – gaseous (and vice versa) already exist in it. The cells "solid – gaseous" (and vice versa) turn out to be empty. One can forecast the existence of such phenomena.

Non-linear forecasting

This kind of forecasting involves substitution of paradigms or basic elements of a paradigm. This kind of forecasting is complex, and under the conditions of trial and error methods, it is considered to be unreliable. Therefore in the milieu of "normal" science it is treated with caution. Non-linear forecasting has only a quanlitative form.

It has to be pointed out that due to different reasons, until nowadays nobody ever dealt seriously with the mechanisms of non-linear forecasting. Therefore, the procedures described below will be inevitably characterized by a certain kind of retrospect. To verify, whether these procedures are characterized by prognostic features, forecasts will be given here for some of them. Time will show if these forecasts are going to come true or not.

- Substitution of analogy.

Example 5: In the 17th century, Nickolay Lemery explained chemical interaction of substances through interaction of sticky and porous atoms. After Newton's theory was recognized, chemists (Boyle, Berthollet, et al.) started explaining chemical interaction by attraction of atoms. After works of A.Volta and

G.Davie were published, a hypothesis of J.Berzelius regarding electric charges of the molecules as a reason for chemical interaction appeared [6, P. 24].

One of the ways of substitution is transfer of analogy to a different field.

Example 6: In 1913 Max Bodenstein, a specialist in physical chemistry, proposed a new analogy – chain reaction – with the aim to implement reaction of hydrogen with chlorine. 20 years later this analogy was transferred to nuclear physics [7, P.84-85].

Example 7: In 1925, a group of physicists headed by Yu.Khariton proposed another analogy with the aim to implement the reaction of phosphorus burning in oxygen – branched chain reaction. After 10 years, this analogy was also transferred to nuclear physics [6, P. 67-71].

– Direct application of procedures of talented thinking (TT).

As of today, a dozen and a half of such procedures are known. Some of them is described in the article: [8, P.150-158]. For the sake of space saving, I will give an example of using only one procedure – working out the minimum model of object/phenomenon being studied.

Example 8: Transition from segmentary observations and accidental results to actual scientific exploration in the field of chemistry started after Lavoisier proposed an idea that the minimum model of chemical substance is a chemical element [9, P.37].

Example 9: The same processes in crystallography started with the idea proposed by Haüy about the minimum crystal [6, P.127-131].

Forecast 1: There is quite a number of empirical "sciences", in which an object of study has not yet been determined and the minimum model has not been constructed.

In particular, medicine is defined as "a field of science and practical activity directed at preservation and strengthening of human health, prevention and treatment of illnesses" [10, C.789]. However, a non-controversial definition of notions "health" and "illness" does not exist. Therefore, empirical, statistic and often simply speculative models often dominate in medicine. Developing a clear view of what is understood as an elementary healthy condition and minimum pathological deviation from it will raise medicine to the level of actual science.

We observe a similar situation in psychology, in pedagogic and in a number of other sciences. There is no idea of what a minimum pedagogical action and minimum pedagogical change is.

Therefore, it can be predicted with certainty that break-through in these fields will be associated with a definition of the minimum model.

- Solving problems associated with discrepancies within a model and between the models.

Example 10: The theory of Newton is invariable, if any constant speed is conferred to the entire system. A specific speed – speed of light – is distinguished in the theory of Maxwell. An attempt to harmonize the degrees of invariability led Einstein to creation of the General theory of relativity [3, P.61-62].

Forecast 2: The principle of emergency is fulfilled by far not between all ranks. For example, physical bodies consist of atoms. The laws of structure and motion of atoms in no way determine the laws of physical bodies motion. In this case, the principle of emergency is strictly adhered to. However, the laws of motion describing the fall of a stone are fulfilled within the rank of the entire planet and within the rank of planetary system as well as within the ranks of galaxies and accumulations of galaxies. In this case, the principle of emergency is not adhered to.

A model, in which ranks of systems are not identical, but are combined into the so-called rank groups, can represent an example of solution for this contradiction. Within the rank groups, the emergency principle is not necessarily fulfilled, but it is strictly adhered to between the rank groups. Thus, the laws of rank groups of atoms don't determine the laws of rank groups of physical bodies, but within a rank group of physical bodies (starting with a stone and ending with an accumulation of galaxies), the general intra-group laws are in effect. However, they don't apply to a rank group of mega-accumulation of galaxies.

The next model of structure and development of material will be constructed based exactly on the notion of rank groups.

– Change of the model type

A following line of change in kinds of scientific notions is known: **direct analogies – classifications – periodizations – evolutions – evolutions of evolutions** [11]. Knowing the type, to which an existing model belongs, one can reliably predict the structure of a next paradigm in this field.

Example 11: From 1924 till 1929 observations of a number of astronomers allowed to draw a conclusion that speeds of galaxies motion are different one from another, and that galaxies mainly move away from the Earth. In 1929 Hubble deduced the law, according to which the speed of galaxies moving away from the Earth is proportional to their distance from it [4, P.195-199].

If the line of change in kinds of scientific notions were known at that time, it could have been asserted that regular (or even) expansion of the Universe corresponds to a stage of evolutions. Consequently, an irregular (or uneven) expansion of the Universe and trends of change of these irregularities would represent the next model. Such ideas were generated within a Great Explosion Theory, the last irregularities of which were verified in 1998 [4, P.212].

Forecast 3: Study of engineering systems followed the conventional pathway: analogies with natural systems – classifications of ES – periodization of engineering evolution – TESE (theory of engineering system evolution – it would be more correct to use this term instead of TRIZ). TESE trends imply even evolution of ES. Consequently, a model with regular irregularity of evolution would represent a next model of ES evolution. Such irregularity is already observed; there is a proto-hypothesis on where to seek for its reasons and character.

Forecast 4: Exploration into the notion of "personality" in psychology stays at the classification stage. Philogenetic periodization or even an evolutionary model would represent the next type of ideas and notions concerning personality. The first steps to constructing such a model have been already made.

It has to be pointed out here that transition to a new type of scientific ideas and notions is by far not always evident and is not always approved by scientific community. Already formed stable paradigm, phenomenon of "scientific fashion" and economic aspects of science make the acceptance of new paradigms difficult. This does not mean in any way that forecasts made on the basis of this mechanism, are not true. The implementation of these concepts is simply postponed.

Example 12: Mathematician, astronomer and biologist Pierre-Louis Maupertuis in his work "The Beauties of Nature" (1746) developed ideas of evolutionism, which were far advanced beyond his epoch, spoke about jump-like hereditary changes and about the role of selection and isolation in the transformation of taxons. <...> It is rather mysterious for us, why Maupertuis was forgotten by his contemporaries. It seems strange that until nowadays, when talking about the transformism of French enlighteners, people usually talk about Buffont and his intellectual follower Lamarck, but not about Maupertuis [12, P.9].

Possibility to construct a system intended for forecasting the evolution of scientific ideas and notions

Each type of scientific ideas and notions passes through standard stages:

– Formation of paradigm (generation of source paradigm model)

Example 13: Theophrastus (372-287 B.C.) – The generation of the very idea of classification of plants. Theophrastus has broken down all plants into two groups: trees-bushes and semi-shrubs-grasses. The trees, in their turn, were sub-classified by him into evergreen and leaf losing [13, P.15-16].

– Evolution of paradigm (expansion of paradigm model to all elements of applicability field and resolving the contradictions, which are generated thereby; elimination of discrepancies with other paradigm models; creation of particular theories within the frames of a paradigm)

Example 14: Cesalpino (1519-1603) has already broken down plants into 2 sections and 15 classes. John Ray (1627-1705) sub-classified flowering plants into bilobed and unilobed according to the number of seed lobes. He also added properties of a flower, envelope, leaves and fruits. K.Linneus (1707-1778) has broken down plants into 24 classes according to the number and arrangement of stamens. The classes were subdivided into 116 orders according to the number of pistils and structure of fruits. The orders included over 1000 genders and 10 000 species, and sometimes also sub-species [13, C.17].

– Adaptation of paradigm (coordination of discrepancies between parts of a paradigm model and resolving the contradictions, which are generated thereby; creation of small particular models within the frames of a paradigm; qualitative review of numeric values).

Example 15: M.Adanson (1727-1806) used not only the features of flower structure in his classification, but also the structure of vegetative organs. He has also introduced a new taxon – a family. He used mathematical methods [13, C.19].

- "normal science" (refinement of non-fundamental aspects of a model, often – refinement of numeric values; hiding problems by means of explanations *ad hoc* and "linguistic" explanations; coordination of non-fundamental aspects of a model with requirements of sources of financing and sources of prestige).

Example 16: A.L.Joussieu in 1789 and Au.P. Decanol in 1835 compiled still more accurate classifications based on similarity in external appearance [13, P.19].

- transition to the next model (formation of a new paradigm).

Example 17: The first philogenetic system was proposed by German botanist A.Braun (1864) [13, P.20].

It can be supposed that in addition to techniques that are common to all stages, there are forecasting techniques, which are characteristic for particular stages.

However, besides forecasting techniques, this system should necessarily include techniques for forming prognostic features of the human proper.

Example 18: W.Roentgen studied cathode rays in a vacuum tube. Once he noticed a light spot near measuring devices. He examined this spot closely. It appeared that a letter drawn on the wall with a fluorescent ink was emitting light. Roentgen started to look for the reasons of this light emission. This led him to the discovery of X-rays.
Some time earlier the Oxford-based physicist Frederick Smith, who was studying cathode rays in a vacuum tube, discovered that light-sensitive plates stored

near the cathode tube get exposed to light. To take up the burden of finding the reasons for that, Smith pushed the plates farther away from the tube... [7, P.33-35].

Conclusions:

1. There are three kinds of forecasting: **linear** (short-term, within the frames of already formed stable paradigms), **classificatory** (filling in blank spaces in incomplete classifications) and **non-linear** (long-term - associated with the change of paradigms or fundamental elements of paradigms).
2. Linear forecasting recently started losing its scientific significance in connection with acceleration of paradigms changing.
3. Main techniques of non-linear forecasting were identified. They could be used in practice.
4. Internal periodization for evolution of types of scientific ideas and notions was proposed: formation of paradigm – development of paradigm – adaptation of paradigm – "normal science".
5. A hypothesis was proposed concerning the selective action of forecasting techniques depending upon the stage of evolution of each type of scientific ideas and notions.
6. The role of prognostic qualities of the human proper and necessity to learn these qualities is demonstrated.
7. The work has started on formation of scientific forecasting system.

List of References:

1. Uskova S.I. Economics, Management and Accounting at Production Facility [online]. Problems of modern economics, [2010]. No. 1 (29). Available at: http://www.m-economy.ru/art.php3?artid=25236

2. Forecast for 2056 [online]. Vzglyad (Outlook). Business newspaper. Available at: http://www.vz.ru/society/2006/12/3/59430.html

3. Hawking, Stephen. Black Holes and Young Universes. SPb.: Amphora, 2006. – 189 p.
4. Yefremov Yu.N. Star Islands: Star Galaxies and Universe of Galaxies. Friazino: Vek 2, 2005. – 272 p.
5. Lyshevsky V.P. Hunters for the Truth. M.: Nauka, 1980. – 285 p.
6. Okhlobystin O.Yu. Life and Death of Chemical Ideas. M.: Nauka Publishers, 1989. – 192 p.
7. Gratzer Walter. Eurekas and Euphoriae. About Scientists and their Discoveries. M.: CoLibri, 2010. – 656 p.
8. Murashkovsky Yu., Rubina N. Pedagogics: New and "New" // Narodnoje obrazovanije (People's Education), 2009. No. 6. P. 150–158.
9. Lavoisier. Faraday. Lyell. Charles Darwin. Karl Bähr. Biographies in Prose. Chelyabinsk: Urals LTD, 1998. – 415 p.
10. Soviet Encyclopedic Dictionary. M.: Sovetskaya Entsiklopedia, 1989. – 1632p.
11. Murashkovsky Yu. Stages of Evolution of Scientific Ideas and Notions [online]. Available at: http://www.temm.ru/ru/section.php?docId=3445
12. Vorontsov N.N. Theory of Evolution: Sources, Postulates and Problems. M.: Znanie Publishers, 1984. – 64 p.
13. Melikian A.P. Objectives and Problems of Modern Systematics of Plants. M.: Znanie Publishers, 1984. – 64 p.

Yu.Danilovsky

Short-Term Forecasting of ES Evolution and Methodology for Taking Market Aspects of TESE into Account

Abstract

A methodology for forecasting the evolution of commodities of type "ES - Human" for the nearest future is described in the present paper. It is common knowledge that innovation process requires expenditures on scientific studies. The higher these expenditures are, the less eagerly companies follow the route of expensive innovations preferring less expensive ones. This process always existed in the history of technology evolution and has already been named "engineering mimicry" (EM). The essence of this phenomenon is reduced to the fact that external appearance of a system is made similar to that of another system, - e.g., a lighter made as fire extinguisher, a pen made as a cigarette, etc. For Phenomenon of EM, see [1,2,3,4,5,6,25,27].

However, acceleration of technology development also leads to increasing frequency of using this scenario of commodities evolution. Consequently, special tools are required for practical work and for taking these phenomena into account during forecasting.

The initial interpretation of this phenomenon (i.e. during the period 2003-2008) appeared to be oversimplified. More detailed investigation into this phenomenon conducted during recent years showed that EM phenomenon represents a particular case of phenomenon characterized by a higher rank of significance, which was named "Goods of Surprise" (GS) in the present paper (GS) [1,5].

Phenomena of EM and GS are related to sub trends (mechanisms) of the trend of coordination – discoordination in the author's system of interpretation [2,3].

A methodology of practical use of these additional scenarios from TESE represents an outcome of performed work. Application of methodology for forecasting 36 possible options of GS, including EM phenomenon, is illustrated with several examples including materials reflecting the experience of a real innovation company that have been working at the Russian Federation market since 1999 [/28,29,30].

1. Why short-term forecasting causes interest for researchers.

1.1. Reason -1 Differences in goals. "Voice of Consumer", "Voice of Engineering System", and "Voice of Manufacturer".

Subdivision into "Voice of Consumer" or VC and "Voice of Engineering System" or VES has already appeared in modern innovation and TRIZ models [16,17,18,19,20].

These terms are used to distinguish two fundamentally different approaches to designing of new commodities. The first of them – VC involves a traditional inquiry of focus groups with the aim to obtain a portrait of future commodity based on such inquiries. The first approach offers the following "epithets" for us: comfortable, cost-effective, pleasant, durable, etc.

The second approach – VES – is an approach that is based on a possibility to objectively describe the functioning of ES (or future commodity) using the language of function analysis and parameters instead of epithets. Specially developed analytical procedures enable to understand: which of the parameters can be and should be improved, so that a future commodity would represent an obvious improvement not at the level of epithets, but at the level of numeric values characterizing convenience, durability and cost-effectiveness.

The fact of undoubtful improvement at the level of parametrical approach VES reduces the risks involved in the course of introduction of new commodity to the market, which is shown in the results of work conducted by well-known American consulting company [32].

The notion of "ES ideality" existing in TRIZ and TESE does not enter into conflict with these approaches, but, to the contrary, combines them together.

However, in this connection, it has to be pointed out that the notion of Ideality is used here by the author from the standpoint of Consumer.

At the same time, one can quite clearly imagine the existence of another version of Ideality - namely, "ideality from the standpoint of Manufacturer".

Ideality of Consumer and Ideality of Manufacturer are very different. They are in the state of conflict of interests.

For Consumers, constant innovation support of commodity selected by them represents a real value. For example, the market offers over 50 kinds of toothpaste or cigarettes, but you, as a rule, become a consumer of one particular brand and continue buying it.

Your logic is simple. This brand is characterized by high enough quality, and the company producing it improves it from time to time, thus demonstrating the innovation support of this brand and care for its consumers.

As a rule, such improvements are rather small. It is not the composition of the toothpaste, which is changed, because it is too expensive, but the shape and design of the cap, case, design of the very toothpaste tube and cardboard package.

From the standpoint of manufacturer, ideality is very different from ideality of consumer. The best option for a manufacturer - absence of new models of commodities, because all this is only an item of expenditures, while the goal of any business consists in increasing income from it.

Inevitable administrative contradiction between a level of expenses on innovation activities and level of income increase resulting from the growth of sales associated with the introduction of new model to the market sooner or later is encountered in business activity of any company. The first level, in the opinion of any Manufacturer, should be minimal, while the second one should be maximal.

This knot of conflicting circumstances in engineering evolution could be formulated in a simple way - "People develop engineering in the direction of eliminating Disadvantages, trying to find the cheapest possible resources for this purpose" - or in a much more cumbersome way, which would disclose the existing conflict between Manufacturer and Consumer.

People develop "machines" (artificial systems of engineering or information character) in the direction of eliminating circumstances, **on the one hand,** and increasing profits from the growth in the number of consumers of machines ("sales"), **on the other hand**, using an algorithm of selecting the cheapest resources currently available for the attainment of these goals. In this case, a "disadvantage" is a variable parameter depending upon time; therefore, the process of development of machines-commodities is endless [10,15].

Goal of Consumer consists in satisfying any of his needs using a ***minimum*** of expenditures.

<u>Goal of Manufacturer</u> consists in making ***maximum*** profits from the act of satisfaction of consumer needs.

Let us call this circumstance "Voice of Customer".

<u>Conclusion from this section, Reason -1.</u>

There are two diametrically opposite levels of objective definition in the innovation process. Innovations (or, to be more exact, expenses on innovations) are profitable for manufacturer, if they are insignificant. For consumers, the issue of Manufacturer's expenses is not interesting at all; they are interested only in the very fact of appearance of new and modern commodity at the market. Thus, we distinguish between the notions "Voice of Consumer" and "Voice of Manufacturer".

Consequently, a Consumer (when he is a Client ordering a forecasting project) is first of all interested in the low level of expenses on innovation and minimal depth of forecasting study. The majority of companies in the world refer to medium-size and small companies. They are interested in long-term forecasting only from the standpoint of considerations "how soon should we expect a potential catastrophe in the form of appearance of a fundamentally new product".

1.2. Reason -2. The process of engineering evolution acceleration

We observe indications on acceleration in engineering evolution in the overall reduction of service life of any kind of engineering equipment [26].

Besides, data on forecasts of population growth and forecasts of gross world product growth are characterized by expressed dependence.

Engineering products, being a part of the gross world product, develop much faster than the number of people on the planet, see Fig 1. [26].

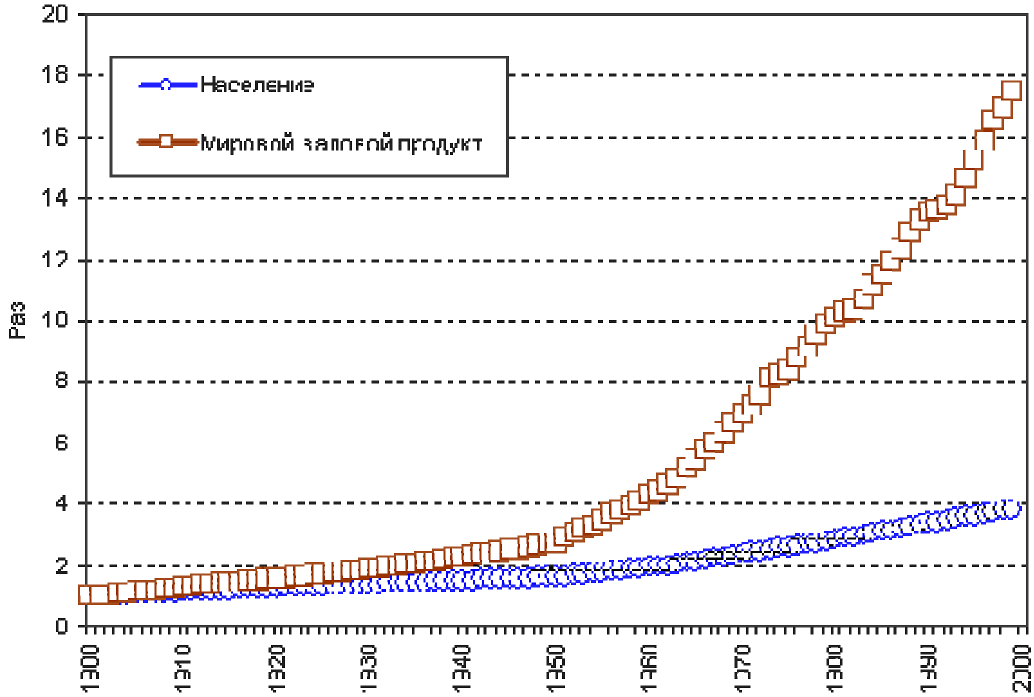


Figure 1. Growth of population and gross national product.

Official information: World population in 2300. Highlights.

ESA/P/WP.187, Draft. UN, New York, 2003, Tables A-1, A-3, A-4.

This situation should lead to the aggravation of contradiction between the necessity to participate in the innovation process and desire to reduce expenditures on scientific research, without which it would be impossible to create a fundamentally new product. A stable tendency to spend as little money as possible for each new development has emerged. How could it be provided?

2. What is a phenomenon of Engineering Mimicry (EM) and substantiation for it?

2.1. Description of Engineering Mimicry phenomenon

Resolving the contradiction "there should be innovations" because without them it would be impossible to win in competition at the market, and "there should be no innovations" because this requires expenses from manufacturer on development, purchase of new equipment and technologies (with high risk involved in these investments/expense), manufacturers have found several simple solutions long time ago.

The simplest direction in finding solutions of this kind consists in surprising buyers with unusual shape of a product. This phenomenon reminds to a certain extent a phenomenon of mimicry in the nature [6]. It was described many times by different authors in specialized publications on TESE [1,2,3,4,5,8,25].

For the first time this term appeared in 2003 in [27].

This phenomenon can be subjected to classification based on two categories of resources for engineering development. The first resource is anthropological properties of humans to have sensory organs and ES parameters, which could be distinguished by these organs, and the second resource is four main intended purposes of solutions that were identified after studying the examples of this phenomenon manifestation in engineering. This classification system is presented in Table 1, which also includes examples illustrating the manifestation the EM phenomenon.

Table 1. Phenomenon of Engineering Mimicry. Classification system.

first explanation of the morphological approach

Four simple rules for invention	person feeling organs and parameters of goods (systems)					
	eye		skin	ear	nose	taste buds
Amuse Развлекать (удивлять) F1 scare away (предупреждать) F2 Mask Маскировать (прятать) F3 Pay attention Призывать (обращать внимание) F4	color P1	form P2	Form of surface P3	sound SOUND P4	smell SMELL P5	taste TASTE P6

It is obvious that this approach offers a possibility to obtain 24 quite distinct formulas for producing new solutions within the frames of this approach.

The structure of these possible solutions is given in Table 2.

Table 2. Morphological classification system intended for describing the engineering mimicry phenomenon.

morphological matrix anthropological resource and special function

senses	eye	eye	skin	ear	nose	taste buds
Parameters of system function	form	color	Form of surface	sound	Gas, aerosol	Liquid, Solid body
Entertain	1	2	3	4	5	6
scare away	7	8	9	10	11	12
mask	13	14	15	16	17	18
Pay attention	19	20	21	22	23	24

A database of examples of manifestation of this phenomenon in engineering covering all 24 specified situations is given in Table 3.

Table 3. Simplest database of examples illustrating the Engineering mimicry phenomenon.

Sensory organs	System parameters	Amuse as additional function	Scare away Warn	Mask	Attract Pay attention
Eye	Shape	1.1. - 1 Lighter shaped as a fire extinguisher	1.2.-2 False video cameras	1.3.-3 Shocker in the form of cell phone	1.4.-4 Advertising inflated mug of huge size
Eye	Color	2.1. - 5 Blue ketchup, Shocking package	2.2. -6 Orange color of road workers clothes	2.3.-7 Camouflage color, road mine in the form of a stone, inflatable tanks and missiles	2.4.-8 Red color of a fire extinguisher

Tactile receptors	Surface shape	3.1.-9 Plastic wall panel looking like stone surface	3.2.-10 Barbed wire	3.3.-11 artificial silk, velvet paper	3.4.-12 "Chocolate gadgets"
Ear	Acoustic vibrations	4.1.-13 Sound of claxon horn as a cow bellowing	4.2.-14 Horn of car signalization	4.3.-15 Systems of active noise suppression	4.4.-16 Bell ringing
Nose and odor receptors	Gaseous substance, aerosol	5.1. -17 Felt pen with vanilla smell, Candles with the aroma of flowers	5.2.- 18 Additive of mercaptan to gas for household needs	5.3.-19 Antipolizei, deodorants	5.4.-20 Perfume industry, perfumes with feromones
Tongue and taste receptors	Liquid, solid substance	6.1. - 21 Eatable chess pieces	6.2.- 22 Bitter substances in the practice of feeding babies	6.3. - 23 Chinese cuisine. Chicken with taste of fish.	6.4. - 24 Chocolate invitation (made of chocolate).

Obviously, the use of this phenomenon can take the form of combinations of different scenarios. The general approach to the use of this Table is illustrated with Figure 1a.

Formula for use of TM phenomena = $\underbrace{(F1+F2+F3+F4)}_{}\times\underbrace{(P1+P2+P3+P4+P5+P6)}_{}$

Simple rules for invention (*Heuristic*) = Verbs F_i *with help of* Noun P_i

Fig. 2. The simplest formula for producing solutions within the frames of described EM phenomenon.

As an example, one can easily imagine a new variant of business card, - a business that is very widely spread in the world, which can use several EM mechanisms concurrently.

Example.

A. Phenomenon of change of image or inscriptions shape. Recollect a similar commodity from the field of postcards with optical effects. When you slightly rotate such postcards in your hands, a lady reproduced on the postcard starts "winking". This effect is obtained due to using a special plastic film, which is made as a multitude of very small prisms closely adhering to one another. In our hypothetical example we can characterize this as a situation when "a business card pretends to be an amusing postcard". Besides, a text of the card in Russian and Korean languages may serve as a changing visual element. In the proposed classification system, this is euristics (simple rule for obtaining a solution) number 5.

B) Phenomenon of sound emission as a result of touching. At the market of postcards, such commodity has been known for a long time. It is called "music postcards". Upon the opening of a two-sided card, one hears a melody. In our case it could be pronouncing your name and position. Euristics number 13 "surprising with the aid of sound".

C) Phenomenon of conferring pleasant odors. Felt pens with the smell of strawberries and bedclothes with the odor of frosty freshness have been known at the market for a long time. Our new ES – business card can easily "pretend to be one of these goods". In this case we can say that we used euristics number 17.

2.2. Hypothesis for explaining the phenomenon of Engineering Mimicry

There is a hypothesis that this phenomenon is characteristic of Stage 1 and Stage 3 of ES evolution. Fig.3

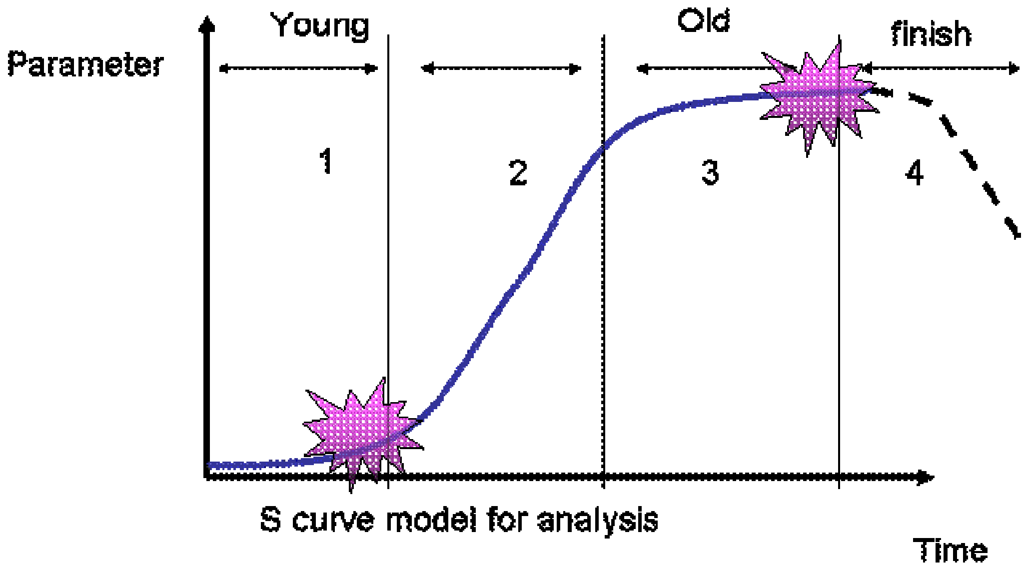


Figure 3. Location of EM phenomenon.

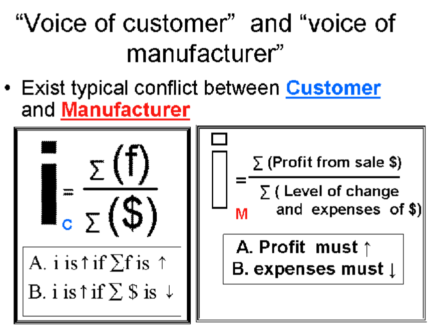


Figure 4. Two formulas of ideality, which intercross in the zone of creating systems with an option of surprise.

Motives for taking such decisions by innovation designers are understandable. Excessive novelty of commodity represents a disadvantage typical for Stage. Hence, EM phenomenon within the context of assertion “Our commodity is a well-known object” represents the opposite pole for excessive novelty. At Stage 3, when the process of reduction in sales starts, the use of EM phenomenon is changed for the context “Our commodity is the same as the one produced by our competitors, but it can surprise you and improve your mood. This is its auxiliary function”. And this decision represent an intersection of interests of two versions of Ideality, about which we spoke earlier - namely, Voice of Customer and Voice of Manufacturer. Figure 4 illustrates two formulas of Ideality.

3. What is understood under “Goods of Surprise” and possible model for interpreting them

A phenomenon of EM is a subset for phenomena, which got the name “Goods of Surprise”(GS).

Variants of definitions:

1. GS represent an insignificant additional property of commodities, which promotes sales.

2. GS represent an additional property of commodities (embedded ES) that creates an emotional impulse for purchase, which, as a rule, subsequently fails to meet the expectations of the Buyer, which leads to the situation of a “one-time purchase”.

A detailed description of the phenomenon with a large number of examples is offered in [1]. Let us give only one example for clarification: a multicolored pencil, the slate of which is made as fused-together slates of four different colors: red, blue, yellow and black. It is inconvenient to draw with such a pencil, but it will decidedly cause surprise in a buyer and at least one sale of such goods is guaranteed.

Based on this property of commodities, let's introduce the notions of Short-Term Commodity (STC) and Long-Term Commodity (LTC).

STC is a sort of commodity, which the Buyer acquires only once (being surprised by it) and does not buy once again due to disappointment produced as a result of using this commodity.

The notion of Long-Term Commodity (LTC) was described by B.Zlotin, who called them "perfect systems" in [8]. More accurate numeric values, according to which commodities could be classified into STC and LTC, cannot be given. It is natural that this classification approach implies the existence of goods with "normal duration of market life", which account for the majority of commodities.

The model of using the notion of GS in the context of forecasting projects with minimum depth.

It can be supposed that a mechanism of GS creation, which is worth analyzing when performing a forecasting project, could be described as a combination of two goods: LTC and GS. Figure 5.

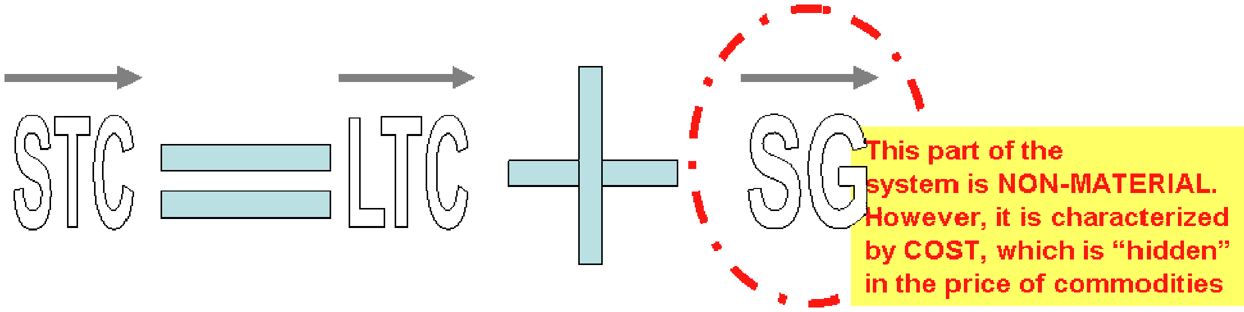


Figure 5. Possible mechanism of creation of forecasting image for STC.

3.1.Note 1. The vector sign above objects of addition operation implies what was long ago noticed in the works of S.Litvin and V.Gerassimov on integration of alternative systems and in [33], namely, non-additivity of the processes of addition of objects as applied to engineering. Integrating a notebook and mobile phone we obtain a communicator, while integrating a phone and notebook we obtain a smart phone [11]. Very many examples like this have been identified [7]. The use of vector presentation enables us not to miss this important property of engineering evolution in the future.

3.2. Note 2. The presented approach includes a new and potentially productive outlook on possible formation of additional directions in TESE. Speaking about such new parameters of ES as their life duration, we imply the possibility of existence of a new discipline and corresponding practical methodology, which could be called "engineering gerontology". The potential number of sales (which actually represents a measure of life duration), as a parameter for evaluation and comparison, would definitely be interesting for the customers.

4.The place of SG phenomenon in the system of TESE

The phenomenon of surprise was described both in Kano models [22] and in works by Durrell Mann [23,24] as a formula for developing solutions described in the language of Principles for resolving EC. According to author's standpoint, this approach is correct because the Principles should be included in TESE, and many such approaches to increasing forecasting power of TESE could be encountered in the works by V.Petrov and M.Rubin [34] as well as in the publications by A.Yefimov [35], but describing this phenomenon only using the language of principles would be insufficient.

According to author's hypothesis, the phenomenon of SG, which also includes the phenomenon of EM, represents a boundary case for three identified trends: Conductivity, Ideality and Coordination - Discoordination. A diagram describing this idea is presented in Fig.6.

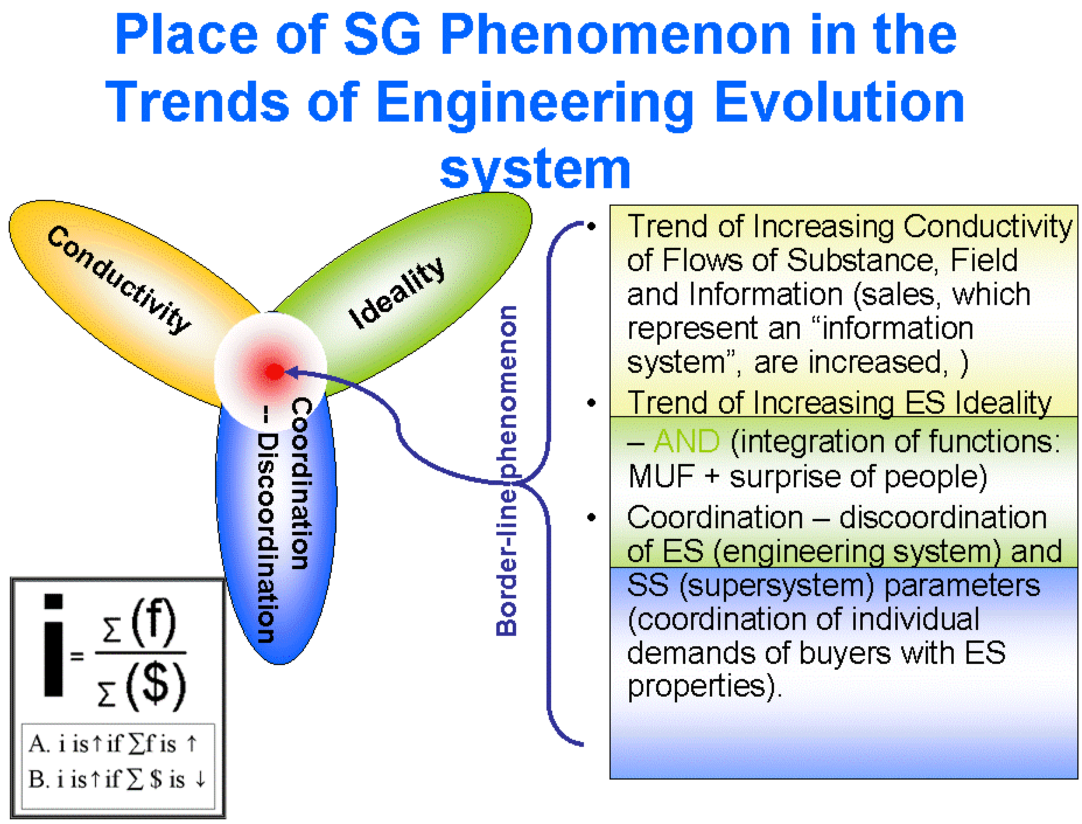


Figure 6. The place of GS phenomenon in the system of Trends of ES Evolution.

Note: Similar to the case with two versions of Ideality - namely, Voice of Customer and Voice of Manufacturer, - the phenomenon of GS is a boundary case, and it could be equally related to both to the content and sense of Trends of Conductivity, Ideality and Coordination – Discoordination.

5. Methodology for designing 36 variants of GS.

Analysis of this phenomenon allowed to name the main mechanisms for producing the process of surprise. The list of these mechanisms could be looked upon as the simplest algorithm for selecting the options.

The area of methodology application: systems of type "ES - Human", which are different from the systems of type "ES-ES" by their ability to influence the decision making by a buyer to purchase this commodity based on its external appearance. Example: a pen is a system of type "ES - Human", but the refill of the pen is an example of the system relating to type "ES-ES".

5.1.Check-list algorithm, "What could a buyer be surprised with?"

The buyer could

1. Be surprised with the shape of commodity, which looks like an animal or different ES (engineering mimicry, see 24 options of implementation from Table 1)

2. Be surprised with the aid of inversion (this is made inversely, *principle 13*)

3. Be surprised with "specialization" (goods for fans)

4. Be surprised with unusual size (giant – dwarf – slim format)

5. Be surprised with unusual color or transparency, *principle 32*

6. Be surprised with mobility of components (make immobile objects mobile)

7. Be surprised with built-in information devices and instruments

8. Be surprised with reduction in movements

9. Be surprised with price (disposable objects), *principle 27*

10. Be surprised with addition of a game element

11. Be surprised with addition of alternative channels of perception ("talking clocks", and so forth).

12. Be surprised with status of "smart things"*, *principle 23*

13. Be surprised with status of "electronic things"*

*"smart things" and *"electronic things are still "young". Therefore, they will be unable to yield stable versions of Long-Term Commodities (author's hypothesis).

All these directions for working out potentially possible forecasting solutions could be illustrated with a database from Table 2

Table 2. Resource classification of SG phenomenon with a database

Horizontal classification: resources for engineering evolution EURISTICS Vertical classification	**SUBSTANCES** Solid substance - LIQUID - GAS-plasma-phase transitions	**FIELDS** MAT-CHEM [27].	**SPACE** **0-1-2-3-00** And phenomenon of action axis pivoting [13,11].	**TIME** (economy, increase of velocity)	**INFORMATION** (mono-bi-poly-compound*)	**IN-FORMA-TION** Needs Amusement Economy
25."VICE VERSA"	Clocks with immobile hands	"Sandglass" with upward movement of the sand	Washing machine. The linen is immobile. Washing is performed by ions.	Gloss agents: for moving photographs, for immobile photographs	Glasses for 3D image are put on the screen	Hotel in a dirigible
26."SPECIALIZATION"	Washable keyboard	Pen with laser pointer	Chewing gum with bubbles	Safety cushion for legs	Mobile phone with a projector	Mobile phone for fishermen
27.SIZE giants - dwarfs	Aircraft show drawing with inverse jet flow	Piano, entertainment attraction: playing with legs	Slim format of commodities	A spade for dandelions	Underwater restaurant	Ice palace, sand sculpture

28.COLOR OR 0 (Transparent things)	Transparent body of computer	Changing the colors of the mug	Transparent washing machine (dwarf)	Transpa-rent door in a car	Multi-colored keyboard	Candles with dif-ferent color of flame
29.DYNAMICITY	"Love mea-suring" de-vice	Device producing cracking sound in the course of printing	Flying clock, disk ripper	Foldable things: chair, glass	Clock with a "notepad dial"	Sand pic-tures
30.INFORMING	Clocks with springs for amusement	Cold neon, lumines-cent wall-paper	Paper batte-ries	Batteries with in-dicator	Slippers with flash-light	Rain sen-sor in umbrella and in car
31.REDUCTION OF MOVE-MENTS	Keyboards-manipulators	Remote control for TV	Loudspeak-ers in a car	Instant porridges	Garbage can with pedal	Rebrand-ing of Marlboro cigarettes
32.DISPOSABLE THINGS	"Machine-gun" soap bubbles	Matches with pic-tures	Eatable plates	Razor with an indicator	Toilet paper with anec-dotes	Glass with a picture of nose
33.GAMES	"how a bat-tery could be sold"	Winking pictures	Gambling clubs and sales of vir-tual things	TV-set in a car	Tomogochi game in mobile phone	Canned grass lawn
34.ALTERNATIVE CHAN-NELS	Singing fountains	Mobile phone with "hand-shakes"	Fireworks accompa-nied by mu-sic	Mirror windmill produces sound to frighten off moles and birds	Abrasive xylophone	Speaking clocks
35.SMART THINGS	Smart wall-paper glue	Pressure sensor in the car wheel (tire)	Air-conditioner with auto-matic clean-ing of filters	Dicto-graph	Robotized sweeper	Smart toi-let basin
36.ELECTRONIC THINGS	Electronic cigarette	Electronic book	Digital drugs	Temin-vox	25th frame in language learning	Electron-ic devices without batteries

5.2.MINI algorithm for using Tables 1 and 2

- The disadvantage is already specified for us: "low level of sales or no sales at all"
- **Step 1:**
- Conduct genetic and component analysis of an object under study and its relatives. Certain property of past generations will be necessarily repeated, hence the importance of this analysis. Examples [11,12,13,14].
- **Step 2:**
- Solve a system of euristic equations according to Tables 1 and 2

Я хочу удивить покупателя эвристикой Номер Х | Х от 1 до 24 по таблице1 и от 25 до 36по таблице2
Я могу использовать ресурс Номер У (от 1 до 6)

An example with business card.

A) The owner of a furniture shop can have a business card shaped as a foldable table. Euristics number 26 "specialization" and number 29 "dynamicity".

B) Conventional way used for applying information on business cards is polygraphic processes. We can apply cutting-out instead of printing and record the information not by means of "printing ink substance", but via "absence of substance" or "emptiness", which was among the categories of TESE as sub-trend "increase of emptiness" 15 years ago. This example illustrates use of euristics number 25 "make it vice versa".

6. Examples of using the methodology as applied to real business

- Innovation company "Star of longevity, LLC" established by the author of the present publication functioned during the period from 1999 till 2004.

- The company sold exclusive streetlight lamps intended for landscaping design JOINTLY WITH A PATENT for a useful model (these patents were granted and are enclosed).
- Rather wealthy people, directors and owners of big enterprises in Saint Petersburg were the clients of the company.
- Short review of the history of this company could be found in [30].
- During the period of its existence the company performed approximately 120 projects, which were never repeated.
- The company management was accompanied by conducting rather detailed "business diaries", which were later on generalized and became the basis for describing these methodologies.
- In 2004 "Star of Longevity" was sold in connection with owner's moving to South Korea, where he has got a job. The new owner appeared to be unable to keep the business, because he did not have required connections and popularity in the Russian business community. In 2009 the company continued its business activity under the leadership of a new manager [1].

Described methodology is mainly based on generalizations from rich practical material obtained from experience of actual innovation business.

Detailed descriptions of two examples from the history of this company are given in [1].

1. Use of "transition to the supersystem", when two kinds of art were integrated: performance of musicians (typical LTC) and installation "Lamp piano" and "Jazz on the Stars". Figure 7, left.
2. Use of such resource as attraction inherent to many people for mystics and occult science. Fractals and the problem of health. Figure 8 (right).

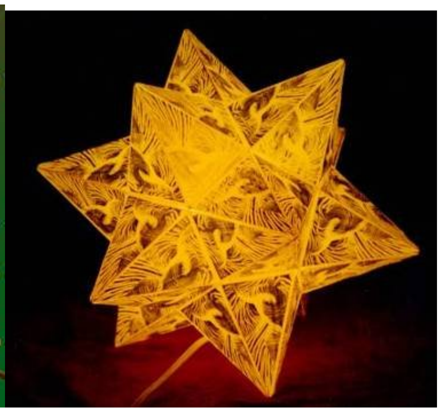


Figure 7. Program of sales of show "Jazz on the Stars"(left).

Figure 8. Program of sales of lamps with positive psychological support (right).

Note: This lamp has a very unusual ornament. This is a fractal made of papillary lines of author's palm, which was created by a special computer program. Fractals in mathematics are solutions for Mandelbrot equations. For details, see a specialized web site devoted to the sales of these services. http://fractoscope.ucoz.ru/

6.1.Application of methodology as shown by Example 1 on Figures 9 (left) and 10 (right)

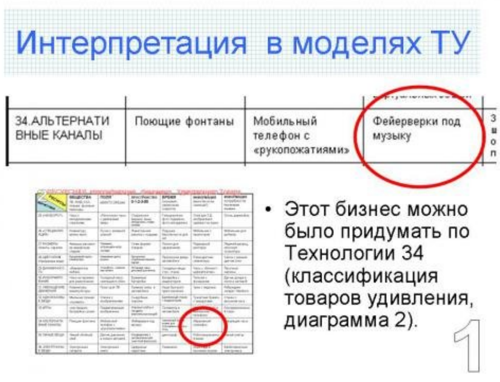


Fig. 9. Interpretation according to GS model (Euristics 34 , Prototype from DB "fireworks accompanied by music").

Fig. 10. Interpretation according to EM models, Euristics 1.1 out of 24 (Prototype for designing "Lighter in the form of fire extinguisher")

6.2. Application of methodology as shown by Example 2 on Figures 11 (left) and 12 (right)

Fig. 11. Fractals in medicine as prototype found by means of FOS.

Figure 12. Interpretation according to GS models (Euristics 28, Prototype for designing – "Candles with different color of flame")

7. Conclusions and sources of information

1. Current situation of engineering evolution is characterized by an increase in the number of commodities called GG (goods of surprise) in this paper. The growth in the number of goods of surprise (GS) is a boundary phenomenon between notions Ideality for Consumer and Ideality for Manufacturer, as well as a "border-line" phenomenon between three trends: Conductivity, Ideality and Coordination – Discoordination.

2. Practical methodology is proposed accompanied with a DB of examples, which allows to generate 36 versions of one and the same commodity within this sub-trend.

3. The methodology was worked out based on materials of actual business of specialized company "Star of Longevity" during the period 1999- 2004.

4. The use of this methodology is efficient in the case of combined application of both the Function-Oriented Search approach (FOS) [31] and MPV methodologies for identification of Main Parameter of Value [16-20,32].

5. Changing the approach to forecasting based on new terms enables one to think about creation of "engineering gerontology" – a new discipline, which does not exist yet and which would give answer to the question, "How great could be the potential number of possible sales of a new commodity".

<u>Used sources of information:</u>

1. Yu.Danilovskiy "Short-Time Forecasting of ES Evolution and Methodology for Taking Market Aspects of TESE into Account" http://www.metodolog.ru/node/526

2 Yu.Danilovskiy. Author's Abstract of Thesis "Model of Spiral Evolution of Engineering in Forecasting Projects" http://www.metodolog.ru/01666/01666.html

3. Yu.Danilovskiy. "Theoretical Substantiations for Developing Methodologies of Forecasting the Evolution of Engineering based on Use of Spiral Evolution Models as Problem Statement".
http://www.metodolog.ru/01671/01671.html

4. Yu.Danilovskiy "Methodologies of IPRI (Investigation into Phenomenon of Resources Integration)" http://www.metodolog.ru/01677/01677.html

5. Yu.Danilovskiy "THEORETICAL SUBSTANTIATIONS OF IPRI METHODOLOGIES" http://www.metodolog.ru/01686/01686.html

6. Mimicry Phenomenon. http://ru.wikipedia.org/wiki/Mimicry

7. Zlotin B.L., Zussman A.B. "What's to be Done?" Report. http://www.triz-summit.ru/ru/section.php?docId=3420

8. Yu.Danilovskiy "Search Engine for Internet" http://www.metodolog.ru/01703/01703.html

9.S.Litvin, V.Gerasimov. "Long-Term Forecasting" http://www.metodolog.ru/01709/01709.html

10. Yu.Danilovskiy, V.Lenyashin, A.Kynin.
Models of Spiral Development of Technique
http://www.metodolog.ru/01582/01582.html
or http://www.metodolog.ru/node/177

11. Yu.Danilovskiy. Training in TRIZ Prediction
How "predictors" read magazines about mobile telephones
http://www.metodolog.ru/node/182
12. Yu.Danilovskiy. Training in TRIZ Prediction
Transfer of technologies or "who" are computers from?
http://www.metodolog.ru/node/184
13. Yu.Danilovskiy. Training in TRIZ Prediction
Morphic foil of the fighter of the future: forgotten background http://www.metodolog.ru/node/183
14. Yu.Danilovskiy. "Failure-Anticipation Analysis of B.Zlotin" & "Harmful Machine of V.Lenyashin", or 12 useful questions for building forecast decisions. http://www.metodolog.ru/node/185
15. Yu.Danilovsky, V.Lenyashin. Ancient Game "Harmful Machine"
http://www.metodolog.ru/01583/01583.html
or http://www.metodolog.ru/node/178
16. M.S.Rubin, O.M.Gerasimov. "Methods for Analysis of Problem Situations and Selection of Problems. Attempt of Review".
http://www.triz-summit.ru/ru/section.php?docId=3737
17. J.Sims, S.Kogan "Bringing Innovation to the Innovation Process". Industry Week, USA, September 7, 2005.
18. S.Litvin "Business to Technology – New Stage of TRIZ Development". TRIZ Future 2005 ETRIA Conference, Graz, Austria, November 2005.
19. L.Malinin "The Method for Transforming a Business Goal into a Set of Engineering Problems". TRIZ Future 2006 ETRIA Conference, Kortrijk, Belgium, October 2006.
20. Anthony Ullwick. What Consumers Want. http://classicaclub.com.ua/product/entoni-ulvik-chego-hotjat-potrebiteli/
21. 5th channel, news, 2001 Laps_piano
http://video.mail.ru/mail/zrts7/4380/4381.html
22. Kano Model – http://en.wikipedia.org/wiki/Kano_model.
23. Durrell Mann "Design For Wow" – http://www.triz-journal.com/archives/2002/10/e/index.htm. The author of Wow-method involv-

ing the use of different TRIZ tools shows how one can produce the effect of surprise in buyers during development of new products in engineering design, architecture and literature...

24. Durrell Mann "Design For Wow 2" http://www.triz-journal.com/archives/2005/10/04.pdf

25. Liubomirsky A. "Enhancement of Coordination of External Appearance". http://www.triz-summit.ru/ru/section.php?docId=4566

26. Philosophy of Engineering, Manual for High Schools
http://www.philosophy.ru/iphras/library/filtech.html

27. The first mention of term "Engineering mimicry" dates back to 2003 http://metodolog.ru/00254/00254.html

28. Web site of "Star of Longevity, LLC" http://www.1santeh.ru/cbl/index.php?z=cbl&r=8&l=8&q=82691

29. Web site of "Star of Longevity, LLC" http://www.showsin.ru/

30. Combined Analysis of Projects performed by "Star of Longevity, LLC" CONFERENCEsammit_2010Report/

31. FOS Methodologies. S.Litvin http://www.triz-summit.ru/ru/section.php?docId=4578

32. MPV Methodologies. I. Petiy, O.Gerasimov. Technology for Performing Innovation Projects based on G3-ID Methodology. http://gen3.ru/3605/3974/

33. V. Gerasimov, S.Litvin. "Why Does Engineering Need Pluralism". http://metodolog.ru/

34. V. Petrov, M.Rubin. Requirements to Development of New Generation of ARIZ. http://www.triz-summit.ru/ru/section.php?docId=4566

35. A.Efimov. Alternative Approaches to Creating New Generation of ARIZ. http://www.triz-summit.ru/ru/section.php?docId=4566

36. A.Liubomirsky, S.Litvin. Trends of Engineering Systems Evolution. http://gen3.ru/3605/5454//

N.Feygenson, A.Kynin

Application of "Mild" Modeling to Forecasting of Engineering System Evolution

Abstract

Used methodologies for quantitative forecast of engineering system parameter variation in time allow to obtain satisfactory results only for limited number of cases. In most widely spread cases, which are of practical interest, variation of parameters of engineering systems has non-linear character. That's why the problems of forecasting the nature of emerging non-linearity and change in evolutionary process mechanisms are of great interest. To solve these problems, the authors describe opportunities for application, options and certain results of application of "mild" modeling in this article. The main specific feature of "mild" modeling consists in its orientation at development of set of notions intended for poorly formalized fields of knowledge involving the use of relatively simple mathematical models. Main principles for applying "mild" models to forecasting the engineering systems evolution are identified in the article. A generalized flow chart of "mild" modeling algorithm for forecasting the engineering systems evolution was formulated. Proposals of authors are illustrated with examples of application.

Key words:
TRIZ; forecast, engineering systems; modeling.

(Full text of this article is given in the collection of papers in Russian)

A. Pinyayev

Algorithms of Defining an Application Condition of a Functional Clue

Abbreviations

TESE – Trends of Engineering System Evolution.

TIPS – Theory of Inventive Problem Solving

Abstract

The Application Conditions are instrumental in TESE-based technology prediction and their precise definition is important for the quality of the technical prognosis. Currently, an Application Condition, also known as the functional core of the problem, is selected from a complete functional model of an elemental technical problem. The selection approach leaves plenty of room for errors related to the variability and complexity of this model. Instead, the current article proposes defining an Application Condition step-by-step, starting from a why-why contradiction describing the elemental problem. There are two algorithms, one for the problems related to the harmful actions and another one for the problems related to the useful actions. The proposed approach is better structured, more reliable and precise than the known way.

Background

The application conditions are the essential components of the system of Functional Clues (Pinyayev 2007). In addition to that, the TESE-based technology prediction can be improved if it is done on the basis of the application condition of a key elemental problem rather than on a basis of the entire technical system (Pinyayev 2010). For both of these purposes, the precise definition of an Application Condition, also known as the functional core of the problem, is a key to a quality outcome. A known approach to defining an Application Condition is to select it from a complete functional model of an elemental problem (Pinyayev 2007). However, the very process of building functional diagrams may lead to variable, builder-dependent results. Thus, one cannot be sure that a "complete" functional diagram does not omit or distort important components and interactions. If steps are taken to ensure completeness and correctness of a functional diagram (Litvin Semyon S. 1991), the result becomes very complex and difficult to analyze. Therefore, a method of defining the Application Conditions independently from building a functional model is needed. This method, proposed in the current publication, allows to significantly improve reliability and precision of the Application Condition definition. The method is well-structured and concise and in many cases saves the time needed for defining the Application Condition compared to the method of selecting it from a complete functional model.

The proposed method requires that a why-why analysis of the initial inventive situation was completed, an elemental problem was identified and expressed as a why-why contradiction via the approach described in (Pinyayev 2007). The proposed method also refers to an updated list of the standard application conditions shown in Fig. 1. This list has been simplified compared to the original version described in (Pinyayev 2007) by eliminating conditions H5, H6 and H7. The reason for this simplification is that these Application Conditions can always be converted into condition H1. In this conversion, the information needed for the use of the Application Condition is not lost and can be recovered. Both technology prediction and problem solving via Functional Recommendations can be successfully done with H1 model.

"Functional" and "Non-functional" Problems

All elemental problems can be described via the functional Application Conditions. Sometimes, however, the description of an elemental problem in terms of parameters or properties of a certain component is preferred. A good example is a contradiction between the strength and softness of a paper towel. Such problems naturally lend themselves to techniques such as Contradiction Resolution and Principles and will not be considered in the current publication. It is important to understand that each problem described as a contradiction between parameters or properties can be also expressed as a functional Application Condition if desired since each parameter or property is only important as a means for performing certain functions.

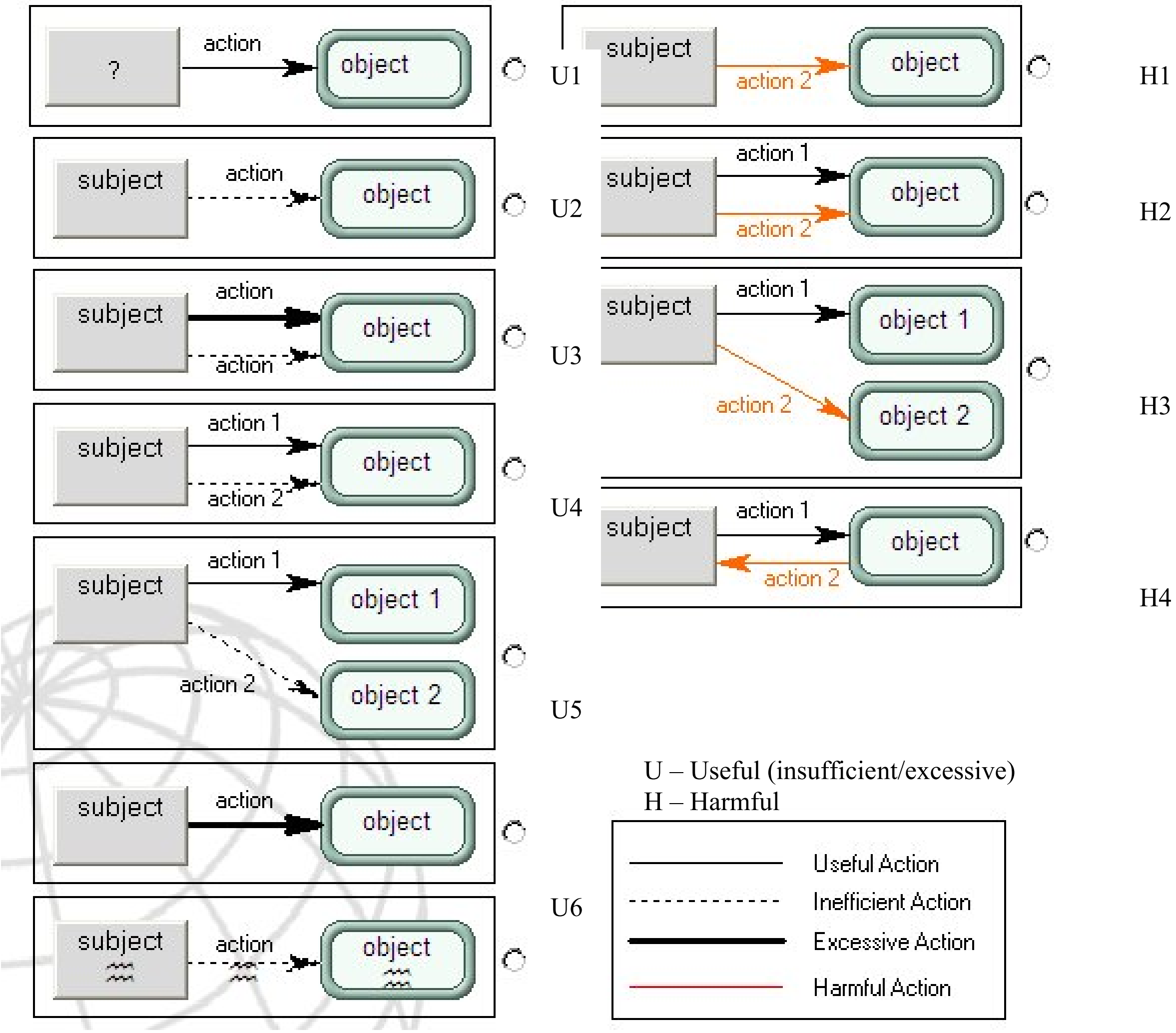
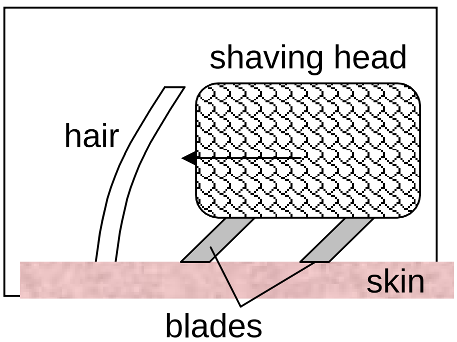


Fig. 1. Standard Application Co tions.

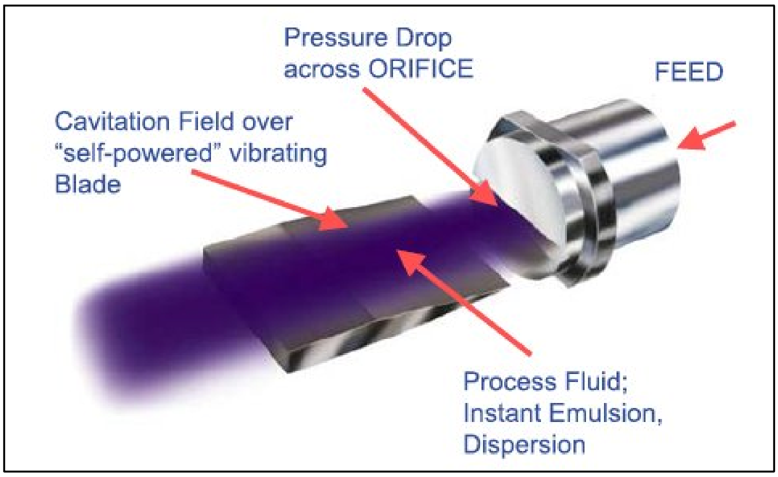
Case Studies

Below are the descriptions of the practical inventive situations which will be used as the examples in the current article. All examples are based on the actual TIPS projects.



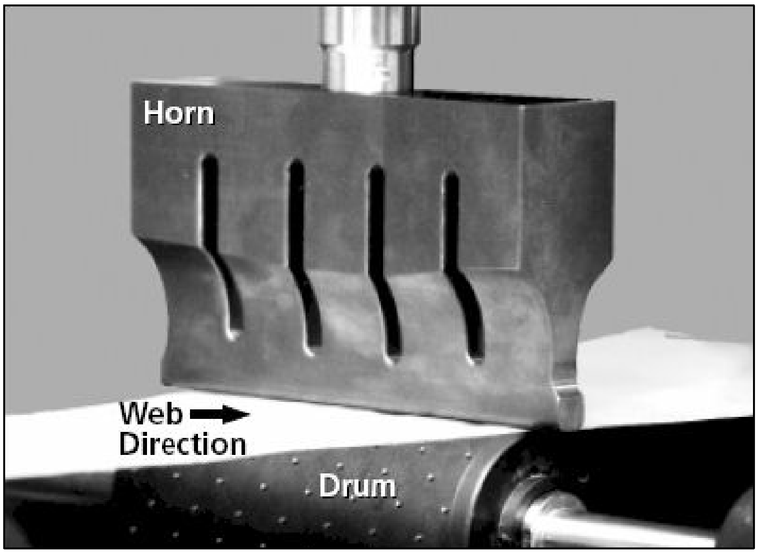
Disposable Razor Head

A shaving head of a double-blade disposable razor works as follows: as the head glides by the surface of the skin, the first blade engages and cuts the hair. When the first blade cuts, it also pulls hair out of its follicle, making the part of the hair normally hidden below the skin surface available for the second blade. The second blade cuts this part of the hair. The natural elasticity of the skin pulls the remaining hair stub back into the hair follicle and now this stub is all underneath the skin surface. This synergy of the double-blade system is supposed to significantly improve the cleanness of shaving but in fact, there is only about 10% improvement (as confirmed by a lab study). How to significantly improve the cleanliness of shaving in a double- or multiple-blade system?



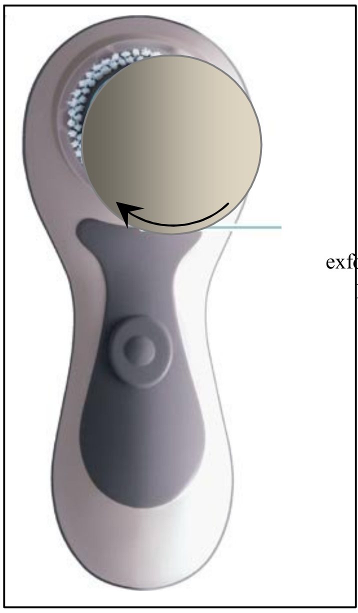
Sonolator Scale-down

Sonolator is a high-shear mixer, homogenizer and emulsifier which works via ultrasonic cavitation created when a high-velocity liquid jet impacts vibrating blade (see figure at the left). The jet is created by passing a pressurized liquid through an orifice. When jet contacts the blade, this blade starts vibrating with an ultrasonic frequency. The cavitation created by the ultrasonic vibrations thoroughly mixes, homogenizes or emulsifies the liquid. A scaled down version of the sonolator is desired in order to be able to predict the performance of the full-scale sonolator based on the results obtained with its small-scale version. However, scaling the sonolator down is not a trivial task and it cannot be achieved via simple reduction of dimensions. The most important parameter which needs to be reduced is the flow rate of the liquid through the orifice. If this reduction is achieved via reduction of the orifice size, the liquid dynamics and flow pattern change so drastically that it would not be possible to predict a full-scale version performance based on the results obtained via a small-scale version. It is desirable to scale the sonolator down without reduction of the orifice size.



Ultrasonic Bonding Process

High-speed bonding of the polymer webs can be achieved via conversion of the ultrasonic energy into heat. In ultrasonic bonding, this conversion is done by the viscoelasticity (internal friction) of the webs. Heat resulting from this conversion melts and binds the webs. For the process to work optimally, it is critical to apply significant mechanical load to the ultrasonic horn. The higher the load, the more efficient is the transfer of the ultrasonic energy to the webs. However, at the loads required by this process, there is significant drag of the web materials by the horn. The drag means localized stretching and tearing of the material. It is desired to achieve very efficient transfer of the ultrasonic energy to the webs without the drag.



Skin Exfoliation Device

Exfoliation removes top few layers of the *stratum corneum* – the uppermost layer of the skin. The skin looks younger and more beautiful as a result of exfoliation, this process also reduces visibility of fine wrinkles and lines. The methods of exfoliation fall into two categories: chemical and mechanical. Within mechanical methods of exfoliation, rotating exfoliation pad was proven to be effective. The pad is made from open-cell foam and loaded with a cream containing abrasive particles. Rotating motion, however, comes with a caveat: when the pad is in contact with the skin, the mechanical reaction from the skin pushes the pad around facial surface in a hard-to-control circular fashion. We call this phenomenon “walking”. Walking makes exfoliation process venient and interferes with the useful outcome. It is desired to achieve good foliation without walking.

Application Condition Definition Algorithms

Action Definition Decision

The analysis begins with a decision about which of the two main types the problem belongs: problems with useful (U) or harmful (H) actions (Fig. 2). This decision is made based on the information contained in the why-why contradiction. The contradictive requirements are converted into corresponding actions and the decision is based on classifying of these actions. If at least one of the actions is harmful, the contradiction is related to the harmful action; otherwise it is related to an insufficient or excessive action.

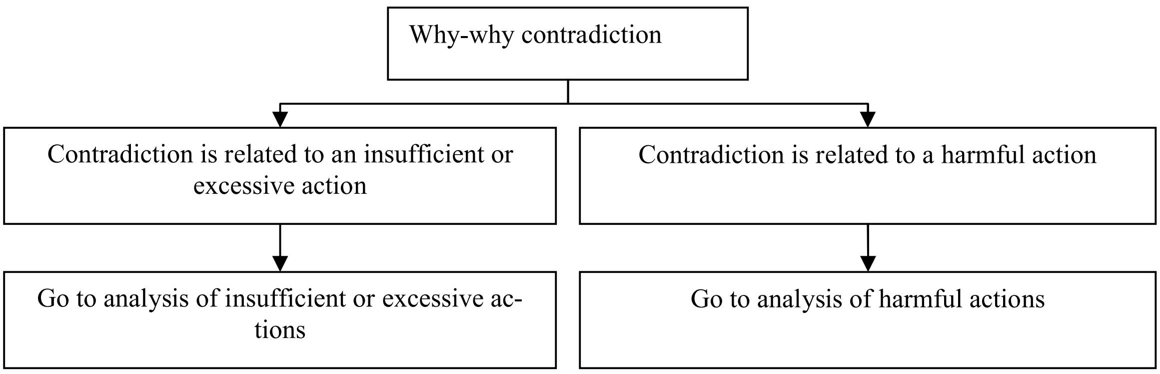


Fig. 2. Action definition decision

Below are the examples of the why-why contradictions from both U and H categories. The why-why contradictions were obtained by applying why-why analysis as recommended in (Pinyayev 2007) to the inventive situations described in the previous chapter.

Problems with useful actions (U)	Problems with harmful actions (H)
1.1. How to improve pulling action of the disposable razor blade without reducing its cutting action?	2.1. How to increase the mechanical load applied to the ultrasonic horn without increasing the drag of the polymer webs?
1.2. How to reduce the flow rate through an orifice without reducing the flow velocity and without reducing the size of the orifice?	2.2. How to eliminate "walking" of the exfoliation pad over the surface of the skin keeping good mechanical contact between the pad and the skin?

Problem 1.1. There are two actions mentioned in the contradiction: pulling and cutting, both useful, so the contradiction is classified as U.

Problem 1.2. This elemental problem deals with the flow through an orifice. Functionality of an orifice is described by two related functions [2]: *let* liquid *flow through* and *restrict the flow* of liquid. Both functions are useful, so the contradiction is classified as U.

Problem 2.1. There are two actions mentioned in the contradiction: "increase the mechanical load" (desirable) and "increase the drag" (undesirable or harmful). Because of the second action, the problem is classified as H.

Problem 2.2. There are two actions mentioned in the contradiction: "keep mechanical contact" (desirable) and "”walking" (undesirable or harmful). Because of the second action, the problem is classified as H.

Note that at this point of analysis precise definitions of the functions are not necessary. This will be done later. To make a right choice between U and H, approximate definitions of actions suffice. In most cases, we do not define objects of the functions at this first step.

Analysis of the Harmful Actions

The objective of this analysis is to define which one of the seven standard H-type application conditions describes the contradiction the best. I propose the following algorithm for this purpose.

Main Algorithm - H

1. Define the object A which is harmed.
2. Define the harmful action A on the object A.
3. Define the object B performing the harmful action.
4. Does the object B perform a useful function? (Yes/No)
   4.1. If Yes, go to the sub-algorithm for H2/H3.
   4.2. If No, go to the next step.
5. Does the object A perform a useful action on object B?
   5.1. If Yes, go to the sub-algorithm for H4.
   5.2. If No, the problem is defined as H1.

Sub-algorithm for H2/H3

1. Compile a list of the useful functions of the object B (actions and objects, including object A).
2. Do the following mental experiment with each of the useful functions in the list:
   2.1. Find practical ways to reduce (but not eliminate) the harmful action AA.
   2.2. Reduce the harmful action AA.
   2.3. See whether the reduction of the harmful action AA leads to the reduction of the useful function.
3. If the reduction of the harmful action AA *does not* weaken the useful function, delete this useful action from the list.
4. If…
   4.1. …there is only one useful action left in the list, go to step 5.

4.2. …there is more than one useful action left in the list, go to step 5 with each of the useful functions separately.

4.3. …there are no useful actions left in the list, go to step 5 of the main algorithm.

5. If the object of the useful function is different from the object A, the problem is defined as H3. If not, the problem is defined as H2.

Sub-algorithm for H4

1. Compile a list of the useful actions of the object A on object B.

2. Do the following mental experiment for each of the useful actions in the list:

2.1. Find a practical way to reduce (but not eliminate) the harmful action AA.

2.2. Reduce the harmful action AA and see whether this reduction leads to the reduction of the useful action.

3. If reduction of the harmful action AA *does not* weaken the useful action, delete this useful action from the list.

4. If…

4.1. …there is only one useful action left in the list, the problem is defined as H4.

4.2. …there is more than one useful action left in the list, you have identified several problems of H4 type, one for each useful action. These problems will have to be solved separately from one another.

4.3. …there are no useful actions left in the list, the problem is defined as H1.

Analysis of the Useful Actions

The objective of this analysis is to define which one of the seven standard U-type application conditions describes the contradiction the best. I propose the following algorithm for this purpose.

Main Algorithm - U

1. Define the useful function AA (action A and object A) which needs to be improved.
2. Define the object B performing the useful function AA.
    - 2.1. If the object B is unknown, the problem is defined as U1.
    - 2.2. If the object B is known, go to the next step.
3. Is the function AA excessive? (Yes/No)
    - 3.1. If Yes, go to sub-algorithm for U3/U6.
    - 3.2. If No, go to the next step.
4. Is the action B insufficient because of the variability of parameters of the objects A or B? (Yes/No)
    - 4.1. If Yes, go to the sub-algorithm for U7.
    - 4.2. If No, go to the sub-algorithm for U2/U4/U5.

Sub-Algorithm for U3/U6

1. Is the action A excessive in some areas of the object A and insufficient in some other areas of the same object? (Yes/No).
    - 1.1. If Yes, the problem is defined as U3.
    - 1.2. If No, the problem is defined as U6.

Sub-algorithm for U2/U4/U5

1. Compile a list of the useful functions of the object B (actions and objects, excluding action A and object A).
2. Do the following mental experiment with each of the actions in the list:
    - 2.1. Find a practical way to improve the action AA.
    - 2.2. Improve the action AA.
    - 2.3. See whether the improvement of the action AA leads to weakening of the function from the list.

3. If the improvement of the action AA *does not* lead to weakening of the function, delete this function from the list.

4. If…

   4.1. …there is only one useful function left in the list, go to step 5.

   4.2. …there is more than one useful action left in the list, go to step 5 with each of the useful functions separately.

   4.3. …there are no useful actions left in the list, the problem is defined as U2.

5. If the object of the useful function left in the list is different from the object A, the problem is defined as U5. If not, the problem is defined as U4.

Sub-Algorithm for U7

1. The variability of which object - A or B - causes the action A to be insufficient?

   1.1. If both A and B cause the insufficiency of the action A, divide this situation into two separate problems, each defined as U7. Go to the next step.

2. Define the problem as U7, indicating the variable object defined at the previous step.

Analysis of Examples

Problem 1.1. Algorithm U.

1. Action A: pull; Object A: hair.
2. Object B: blade 1.
3. No (the function "pull *hair*" is insufficient).

4. No (variability of the hair only partially contributes to the problem. The problem is still there when the parameters of the hair do not vary significantly).

Sub-algorithm for U2/U4/U5

1.

Action	Object
cut	hair
remove (from skin)	hair

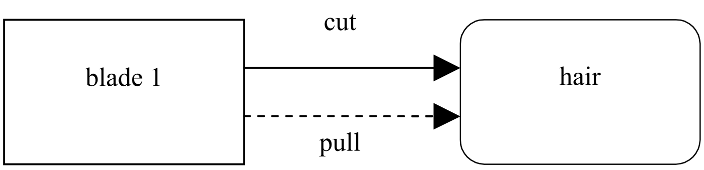
2.1. Making the blade 1 duller would improve the function "pull *hair*".

2.3. Making the blade duller weakens the function "cut hair" but does not weaken the function "remove hair from skin".

3. We delete the function "remove hair (from skin)" from the list.

4. There is only one function (cut hair) left in the list, so we go to the step 5.

5.1. the object of the useful function left in the list (hair) is the same as the Object A. The problem is defined as U4:

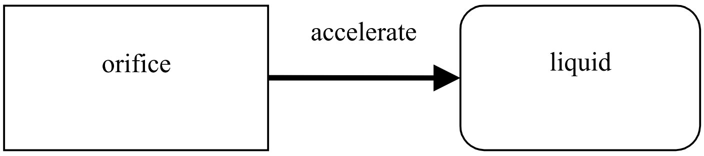


Problem 1.2. Algorithm U.

1. Action A: accelerate; Object A: liquid.
2. Orifice.
3. Yes (the volume of the accelerated liquid is too high).

Sub-Algorithm for U3/U6

1. No. The excessive action "accelerate" applies to all available liquid. We have defined the problem as U6:



Problem 2.1. Algorithm H.

1. Object A: polymer webs.
2. Action A: drag (stretch, damage).
3. Object B: horn.
4. Yes (horn perform such useful functions as “compress *polymer webs*” and “deliver *ultrasonic energy* to the webs”. We go to the sub-algorithm for H2/H3.

Sub-algorithm for H2/H3

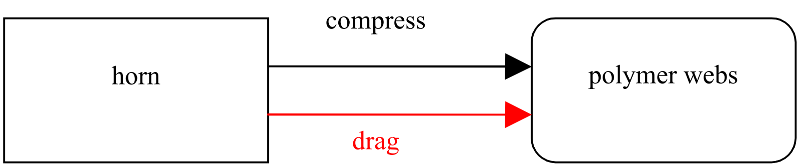
1.

Action	Object
compress	polymer webs
deliver (to the polymer webs)	ultrasonic energy

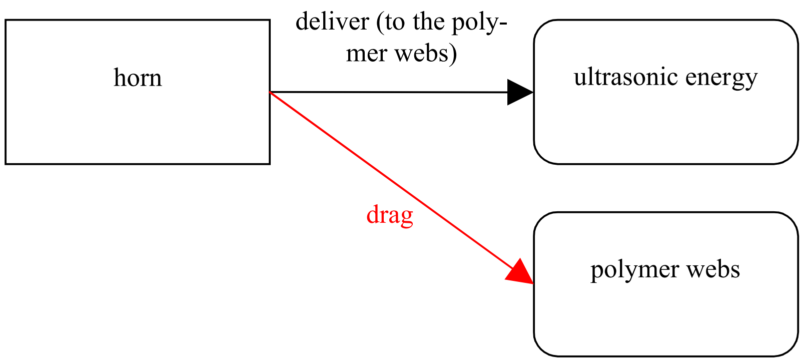
2.1. An easy way to reduce the harmful function “drag *polymer webs*” is to reduce the mechanical load applied to the horn.

2.3. The reduction of the mechanical load applied to the webs weakens both useful functions in the list.

5. a. The object of the useful function “compress *polymer webs*” is the same as the object A (polymer webs). The problem is defined as H2:



b. The object of the useful function "deliver *ultrasonic energy* to the polymer webs" is different from the polymer webs. The problem is defined as H3:



Problem 2.2. Algorithm H.

1. Object A: exfoliation pad.
2. Action A: walk (move in circles).
3. Object B: skin
4. Yes (skin supports exfoliation pad). We go to the sub-algorithm for H2/H3.

Sub-algorithm for H2/H3.

1.

Action	Object
support	exfoliation pad
protect	underlying facial tissues
sense touch of	exfoliation pad
sense applied load of	exfoliation pad
sense position of	exfoliation pad

2.1. An easy way to reduce the harmful action “walk” is to reduce mechanical load applied to the exfoliation pad.

2.3. None of the useful function in the list is weakened by the reduction of the mechanical load applied to the exfoliation pad. We go to the step 5 of the main algorithm.

5. Yes. The exfoliation pad exfoliates skin. We go to the sub-algorithm for H4.

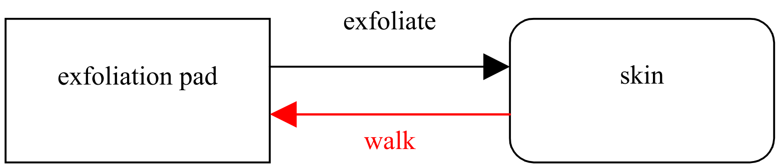
Sub-algorithm for H4.

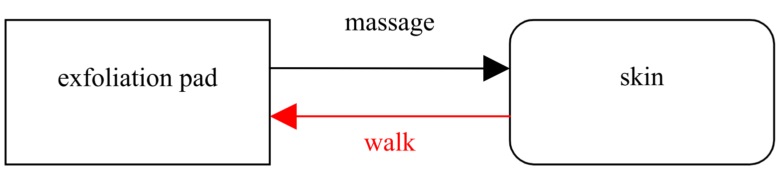
1.

Action	Object
exfoliate	skin
massage	skin
apply	exfoliating cream
carry	exfoliating cream
rotate	exfoliating particles

2.1. An easy way to reduce the harmful action “walk” is to reduce mechanical load applied to the exfoliation pad.

2.3. The useful functions “exfoliate skin” and “massage skin” weaken when the applied mechanical load is reduced. The rest of the useful functions do not weaken. We have identified two problems of H4 type:





Results and Conclusions

The algorithms suggested in the current publication allow to define an Application Condition step-by step, without reliance on a complete functional model of an elemental problem. There is an introductory algorithm, called Action Definition Decision, which leads to one of the two main algorithms: one for problems with the useful functions and another one – for those with harmful functions. The main algorithms are constructed in two layers with the first layer routing the user to one of the sub-algorithms of the second layer for a detailed analysis.

The algorithms present a well-defined, logical way of choosing one of the standard Application Conditions. They are designed to provide a reliable, precise problem definition in a form of a functional diagram. This definition can be used together with the Functional Recommendations (Pinyayev 2007) to find the solutions to the elemental problems. It can also be used for the TESE-based prediction, as described in (Pinyayev 2010). Finally, this definition can serve as a graphical model of inventive problem in the Algorithm for Inventive problem Solving (ARIZ).

References

Litvin Semyon S., G. V. M. (1991). Основные положения методики проведения функционально-стоимостного анализа. Методические рекомендации. Moscow, Inform-FSA. http://www.triz-summit.ru/ru/section.php?docId=3952

Pinyayev, A. M. (2007). A Method for Inventive Problem Analysis and Solution Based On Why-Why Analysis and Functional Clues. St. Petersburg, Russia, International TRIZ Association. **TRIZ Master:** 24 pp. http://triz-summit.ru/ru/section.php?docId=3791

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A. Pinyayev

Application Condition as a Starting Point of TESE-based Prediction

Abstract

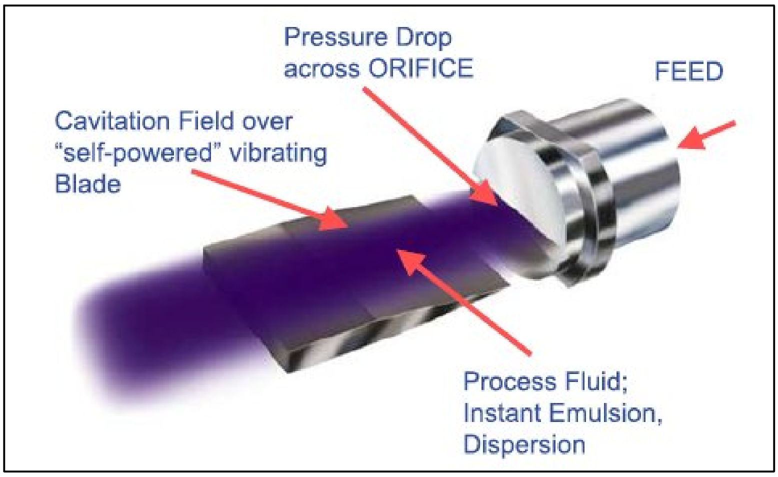
This article suggests the use of the Application Condition of a Functional Clue as the starting point for the prediction of the technical system development based on the Trends of Engineering System Evolution (TESE). It is shown that such use simplifies application of TESE. It also links TESE to the problem definition techniques such as why-why and functional analyses and creates a seamless technical system development workflow. This approach also allows to expand the database of the Functional Clues by distilling the Recommendations from TESE.

Background

In addition to solving problems, an Application Condition of a Functional Clue helps TESE-based prediction. Defining an Application Condition allows to precisely identify a part of a system or supersystem a Trend needs to be applied to. The Application Condition also contains the functional interactions of this part and defines the functional core of the elemental problem which needs to be solved in order to evolve the technical system. In other words, an Application Condition defines the starting point and direction of the technical prognosis. Knowing the part allows to correctly define its position at the evolution curve of the given Trend. The TESE allow then to identify the necessary modification of the part which leads to the next step in the system's development.

As shown in (Pinyayev 2007), the definition of an Application Condition is a result of a workflow which includes the why-why analysis of the inventive situation and definition of an elemental problem in the form of a why-why contradiction. Once a why-why contradiction is identified, an Application Condition definition algorithm must be used (Pinyayev 2010). These steps are essential. In author's experience, trying to guess an Application Condition without completing these necessary steps almost guarantees an incorrect result.

Case Study: Sonolator



Sonolator is a high-shear mixer, homogenizer and emulsifier which works via ultrasonic cavitation created when a high-velocity liquid jet impacts vibrating blade (see figure at the left). The jet is created by passing a pressurized liquid through an orifice. When jet impinges the blade, this blade starts vibrating with a sonic frequency (3 kHz). The cavitation, created by the sudden pressure drop and controlled by the vibration of the blade, thoroughly mixes, homogenizes or emulsifies the liquid.

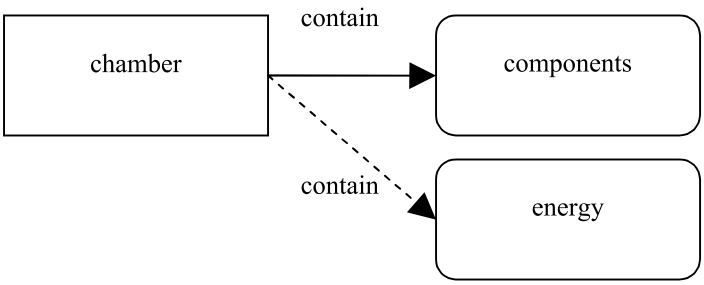
The evolution of the Sonolator will be used to illustrate the main points of the current article. A patent research has been done to reveal important developments of the Sonolator design. Throughout the article, the references to the key patents will be provided.

The Use of Application Conditions for Prediction

The use of an Application Condition for prediction allows to specify the object of prediction, to define this object's attributes and to lay out critical interactions which propel the system's development. There are two ways to use the Application Conditions for prediction: at the level of the entire system or at the level of its subsystems. These ways differ only in the object of prediction. At the system level, the object of prediction is the entire system. The definition of the Application Condition in this case is done via analysis of the supersystem. At the level of subsystems, the analysis of the system is used. The methodology of defining an Application Condition is described in (Pinyayev 2007) and (Pinyayev 2010). Once the Application Condition is defined, TESE can be applied to the objects and interactions the Application Condition consists of. Because the system of the Application Conditions provides a multi-faceted description of the system's "stress points", the Application Condition-based prediction is specific and comprehensive at the same time.

Sonolator Effectiveness Prediction

Sonolator works so well as mixer, homogenizer and emulsifier because it provides much higher specific power than lower-shear mixers. Specific power is the power delivered to the product divided by the active volume of the product. Thanks to the high shear at the orifice, effective interaction of the blade with the product and cavitation, the internal volume of the Sonolator is much smaller than that of other mixers. The mechanical power delivered to the product is high thanks to the high orifice pressure. However, some hard-to-mix products require an order of magnitude higher specific power than a regular Sonolator design can provide. The why-why analysis of this challenge leads to the following why-why contradiction: *How to reduce the active volume without reducing the Sonolator's internal volume?*



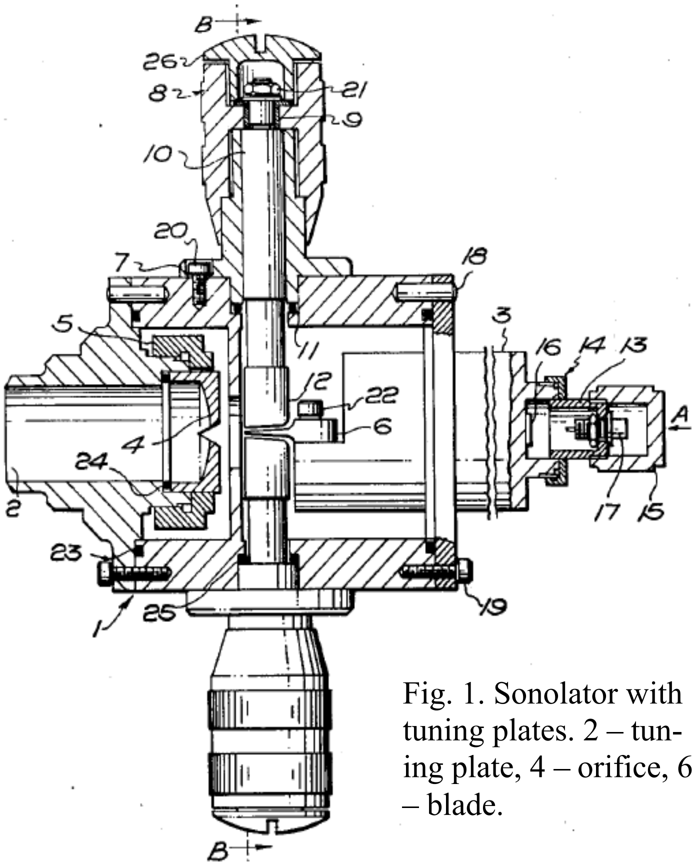
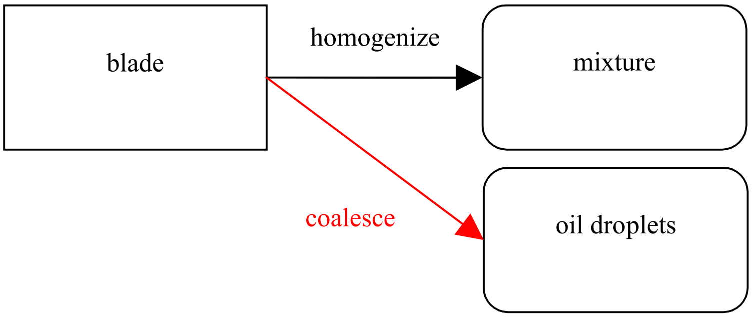


Fig. 1. Sonolator with tuning plates. 2 – tuning plate, 4 – orifice, 6 – blade.

This is the Application Condition of this contradiction defined by using algorithms described in (Pinyayev 2010). The TESE need to be applied to the internal chamber of the Sonolator. Since the chamber is a cavity, a Space Segmentation trend would apply. The next step predicted by this trend is system with multiple cavities. The Application Condition prompts that there need to be two different cavities: one for components and one for energy. The existing chamber can be used to contain components, so a new (smaller) cavity needs to be added to contain energy. The practical solution (Fig. 1) is described in (Grange 1978): the energy is contained between the two added surfaces called tuning plates which are placed in a close proximity to the blade. In addition to increasing the energy density by at least an order of magnitude, the tuning plates are able to optimize this density according to the properties of the product: the development according to the Controllability trend.

Sonolator for Shear-sensitive Fluids

The Sonolator's principle of action inevitably leads to the high shear forces imparted on the mixture to be homogenized. Some mixtures are shear-sensitive and their structure and properties can be negatively affected by the high shear forces. One example of such mixture is a well-known emulsion called mayonnaise. Too much shear applied during mixing various components into mayonnaise can destroy the emulsion by causing oil droplets to coalesce. Another example is a mixture of a liquid with a solid such as long-chain polymer or fibrous material. High shear forces may degrade useful properties of the solid. It is therefore desirable to process shear-sensitive mixtures by a very effective homogenization process similar to that of a Sonolator without applying high shear forces to the product. The why-why analysis of this challenge leads to the following why-why contradiction: *How to effectively homogenize the product without applying high shear forces to it?*



This is the Application Condition of this tion defined by using al-rithms described in (Pinyayev 2010). The TESE need to be applied to the blade of the Sonolator. According to the Introduction of Modified Substances trend, an internal additive needs to be designed into the blade to eliminate the coalescence keeping effective homogenization. An example of such additive is a weight on a free end of the blade (Fig. 2). Such weight lowers the resonant frequency of the blade. The mass of the weight, length of the blade and distance from the weight to the orifice are all selected to provide effective vibration at very low orifice pressure. This way, the modified blade keeps high degree of homogenization by mechanical vibrations and avoids high shear forces. The practical solution is described in (Semp 1999). The new design allowed to uniformly and effectively incorporate a long-chain polymer (polyacrylamide) into water, make stable oil-in-water emulsion, generate foamed adhesive and incorporate guar-gum powder into water – all at orifice pressures below 25 psi (as compared to hundreds and thousands psi for a regular design).

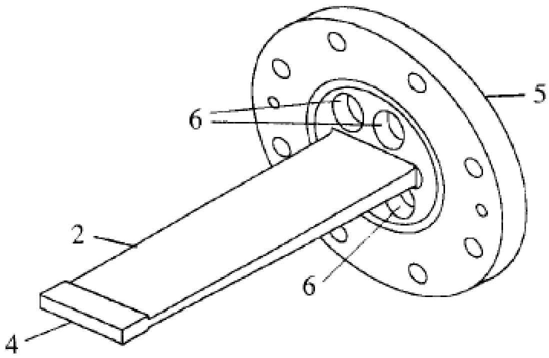
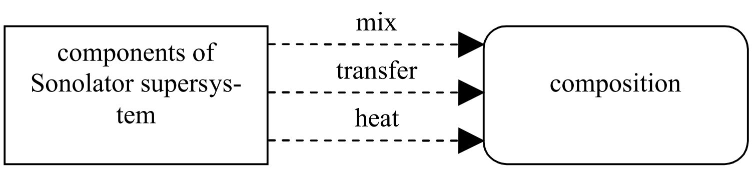


Fig. 2. Weighted blade of the Sonolator. 2 – blade, 4 – weight.

Homogenizer for Viscous Compositions

An example of a prediction at a system level is a Homogenizer for Viscous Compositions. As mentioned earlier, when prediction is done on a system level, the analysis of the supersystem is used in order to define the problem. The supersystem typical for the Sonolator is a liquid processing unit which includes product, feed tanks, pumps, process control instrumentation and plant personnel. A known challenge at this supersystem level is homogenizing multi-component viscous compositions. Such compositions include, for example, mixtures of grain powders or flours with oils and lipids. Another example of such composition is a mixture of toothpaste ingredients. Mixing, transfer and emulsification of such products in a typical Sonolator-based liquid processing unit is difficult. Mixers and pumps typically used with Sonolator are not optimal for handling high-viscosity inhomogeneous compositions. Some of the compositions require relatively high temperatures in order to melt and solubilize components such as lipids and waxes. Heat-jacketing of the entire unit leads to a significant increase of the capital cost. The why-why analysis of this challenge leads to the following why-why contradiction: *How to provide high-pressure liquid input into Sonolator without using typical Sonolator supersystem components?*



This is the Application Condition of this contradiction defined by using algorithms described in (Pinyayev 2010). This Application Condition combines three partial Application Conditions of U2 type, one for each insufficient function. Combining partial Application Conditions into one allows to clearly see that various inefficient pieces of the Sonolator's supersystem are, in fact, a Polysystem in relation to the Mono-Bi-Poly Trend for Various Objects. According to this Trend, the next step in the Polysystem development is the transition to a Combined Polysystem which performs all functions of a simple Polysystem (*mix*, *transfer*, *heat*) by a single piece of equipment. This piece of equipment is known as an extruder, so the new concept suggests feeding the Sonolator directly from an extruder (Fig.3).

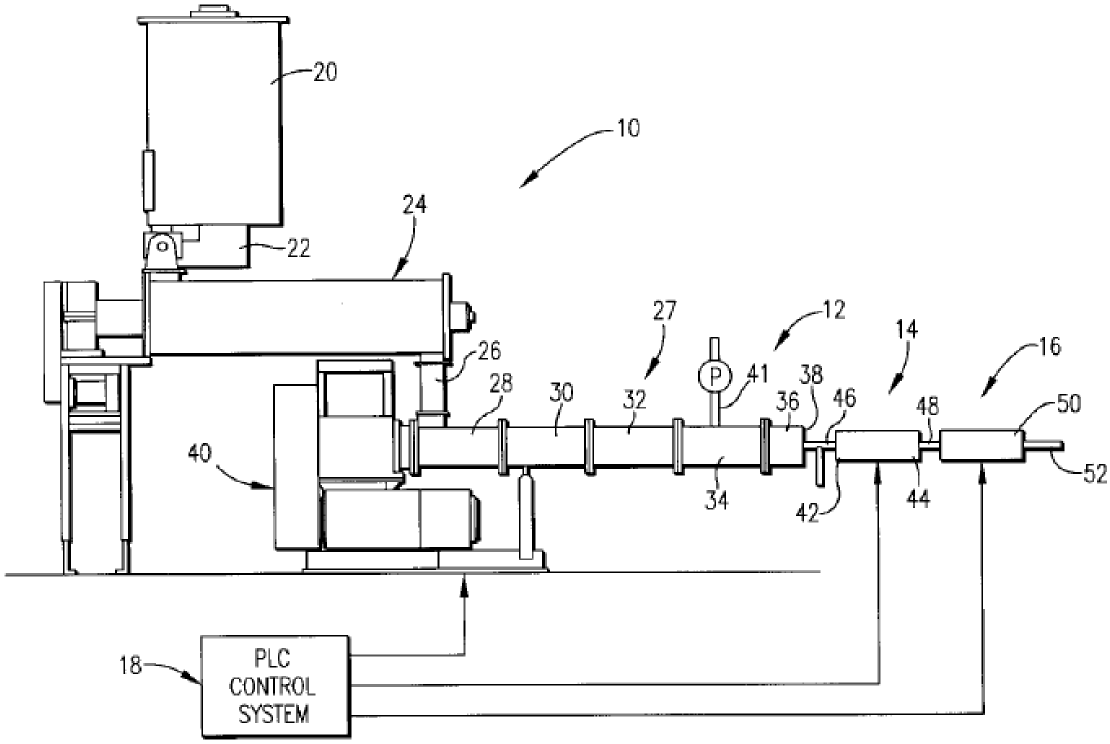


Fig. 3. Homogenizer for Viscous Compositions. 12 – extruder, 14 - Sonolator

This new design (Huber 2001) has multiple advantages when the high-viscosity, multi-component products are processed. One important advantage is that making stable emulsions of such products is possible without the use of emulsifiers since the Sonolator produces emulsions with a very small (micron and submicron) droplet size and the stability of an emulsion is strongly dependent on the droplet size. However, the most important advantage is that Sonolation of the viscous, non-homogeneous, complex products becomes feasible.

Conclusions

The use of an Application Condition as a starting point of the TESE-based prediction allows to define a component which needs to be developed in accordance with the Trends. It also allows to define a conflict that requires resolution in order to move the technical system up the evolutionary curve. This valuable information allows to make prediction focused and targeted and to increase the quality of the prediction concepts.

The workflow which is used to define an Application Condition usually leads to the multiple problem definitions called elemental problems. Each elemental problem solves the primary challenge in its own, unique way. A set of these solutions obtained via TESE allows for a multi-dimensional prediction of the technical system development. This result is an umbrella of the technical concepts which can flexibly adapt to any environment in which the technical system evolves. Depending on the circumstances, some of the concepts are reduced to practice fairly quickly and others become longer-term predictions. This multi-concept prediction approach is much more robust and agile than a stand-alone prediction.

For the complex technical system dominating modern technosphere, the approach described here significantly simplifies the application of TESE. An Application Condition provides a precise definition of the object to which TESE are to be applied. The functional interactions of this object define the direction of the development.

References

Grange, A. (1978). Apparatus for the Homogenization of Liquids. USPTO. USA, Ultrasonics, Ltd. **4,129,387:** 6 pp.

Huber, G. R. (2001). Method and Apparatus for the Production of High Viscosity Paste Products with Added Components. USPTO. USA, Wenger Manufacturing Inc. **6,294,212:** 8 pp.

Pinyayev, A. M. (2007). A Method for Inventive Problem Analysis and Solution Based On Why-Why Analysis and Functional Clues. St. Petersburg, Russia, International TRIZ Association. **TRIZ Master:** 24 pp.

Pinyayev, A. M. (2010). Algorithms of Defining an Application Condition of a Functional Clue. Summit - 2010, Saint-Petersburg, Russia.

Semp, B. A. (1999). Low Frequency, Low Shear In-line Mixing. USPTO. USA. **5,975,750:** 16 pp.

A. Pinyayev

Why-why Analysis of yet to Be Created Technical System

Abstract

Why-why analysis is an established way of defining the problem in the technical systems that already exist. This article describes how this technique can be used for the synthesis of the technical systems. The core of the proposed version of the why-why analysis is considering the potential ways of performing the required function which are legitimate but not acceptable due to the project limitations. The new technique allows to apply a proven problem definition approach for the frequent case where the system is yet to be created.

Keywords:

Why-why analysis, prediction, technical system, synthesis.

Background

This article describes the application of the why-why analysis to the frequent situation when there is a function, which needs to be performed, but a system for performing this function is not yet known. It is easy to assume that why-why analysis is not a suitable tool for defining problems in such situations. I have found, however, that why-why analysis is an excellent tool for problem definition in yet to be created systems once a certain way of performing the function is defined. This way does not have to solve the problem or address the inventive situation. The purpose of this way is to reveal a why-why contradiction, which can be resolved using one of TRIZ tools such as Principles or Functional Clues. This solution often leads to a useful and non-obvious concept of the new system. The ways of performing the required function can be found in the prior art, generated during a brainstorming session or result from a trial-and-error approach. The two requirements to this known way are: 1) to be able to perform the required function and 2) to dissatisfy one or more of the project limitations. More ways can be used to increase the number of the new system concepts resulting from the proposed approach.

Case Study: How to Separate a Semiconductor Wafer from the Stack?

This is how the inventive situation is described in [1]: “The manufacture of semiconductor parts, or “chips”, typically begins with the processing of wafers made from silicon, gallium arsenide, or other semiconductor compounds. Initially, a crystalline (or polycrystalline) boole is sawn simultaneously into several hundred thin wafers using means such as a wire frame saw. The wafers are typically quite thin, of the order of 200 microns thick, and are most often of circular cross-section. His sawing produces a stack of wafers contaminated with sawdust and sawing fluid. The wafers must then be removed from the stack, cleaned, and placed into a product carrier such as a cassette or tray before further processing.

Removing the wafers from the stack is typically done manually because the wafer material is brittle. Rough handling can easily result in breakage, or chipping of the edges, which would render the wafer useless for further manufacture. To prevent such damage, vacuum "wands" are commonly employed as a means for manually lifting individual wafers from the stack. A wand typically consists of a stem with an internal channel for vacuum, a broad tip, and a vacuum actuator switch for connecting the stem to a vacuum source. An operator picks up a wafer by placing the broad tip of the wand in the center of the planar surface of the wafer, thereby allowing the vacuum to cause the wafer to adhere to the wand. The operator can then transport the wafer from one location to another, and can then release the wafer by shutting off the vacuum to the wand.

Although adequate, manually separating wafers has a number of drawbacks. The wafers in a stack have a tendency to stick to one another, primarily due to surface tension effects. A wand alone cannot overcome these effects, requiring the operator to slide the wafers apart by pushing against their edges. This handling can damage the wafers. Furthermore, the labor required is a significant processing cost and takes considerable time." An automated method for safe handling of the semiconductor wafers is therefore desirable.

Technique of Why-why Analysis of yet to Be Created Technical System

The core of the proposed version of why-why analysis is considering the potential ways of performing required functions, which are legitimate but not acceptable due to the project limitations. Known why-why analysis technique

[2] begins by defining the starting point and project limitations. In our case, when the system is yet to be created, the starting point is the main function of this future system. Project limitations are defined as usual. As the analysis progresses, additional limitations, revealed by the analysis, can be added to the original list. For our case study, the main function is "*separate* wafer (*from the stack*)". This is the initial list of the project limitations:

- the wafers and the number of them in the stack cannot be changed;
- manual intervention is not allowed;
- damage to the wafers cannot exceed 1:20,000;
- doubles, triples, etc. cannot exceed 1: 20,000;
- capital cost of the unit cannot exceed $100,000;
- the floor space area cannot exceed 4' x 3'.

The why-why analysis shown below (Figs. 1 – 3) allowed to reveal additional limitations which were not obvious before this analysis was done:

- the semiconductor material cannot be changed;
- the wafers must be in a stack.

As mentioned above, the proposed version of why-why analysis uses potential ways of performing required functions. A primary route for obtaining these potential ways is studying prior, especially patent, art. The ideas generated during a brainstorming session can also be utilized, along with the ideas randomly originated by the members of the project team. With all of these sources, the objective is to create an information pool for the problem understanding rather than to find a solution.

For our case study, the prior art offers some ways of performing the function "*separate* wafer (*from the stack*)", such as the way used by the apparatus described in [3]. This apparatus uses a dam and jets of fluid, such as water or oil. The jets push the top wafer up and over the dam while the rest of the wafers are restrained in the stack by the dam. A feed unit continuously lifts the stack, eventually exposing each waver to the jets. This method is faster than the manual separation but it still leads to significant wafer damage by forcing the thin and fragile wafer edges against the rigid dam. This method also causes wafer damage by sliding of the top wafer against the next one. In effect, the method is capable of performing the required function but it does not meet one of the project limitations (damage to the wafers cannot exceed 1:20,000).

Another way of separating disk-like objects resembling semiconductor wafers – CDs and DVDs – from the stack is mentioned in the prior art description of [4]. According to this reference, the spacers can be inserted between the disk-like objects to prevent them from sticking to one another. Since the disk-like objects are pre-separated by the spacers, taking the top disk without affecting the stack becomes possible. However, this solution cannot be directly applied to our case study since it does not meet another project limitation (capital cost of the unit cannot exceed $100,000) since a sub-system for inserting, removing and circulation of the spacers alone would require similar investment.

Finally, various mechanical pickup designs are known in the prior art which attempt to separate and lift the uppermost disk-like object from the stack by means of inserting thin prongs or blade-like elements between this object and the rest of the stack and pulling the uppermost object upwards. This is also a possible way of performing required function which, however, does not meet two of the project imitations (damage to the wafers and the amount of multiples).

The why-why analysis of yet to be created system is done by assuming that the required function is performed by one or more ways defined at the previous step. The rest of the analysis (revealing hidden whys, defining the boundaries of the analysis, wording why-why contradictions and defining the Problem Map) is the same as described in [2]. Figs. 1 - 3 show the why-why diagrams for three of the above-described ways of performing the function "*separate* wafer (*from the stack*)". Each why-why analysis leads to multiple solutions. Each of the ways of performing the required function results in its unique solutions. More ways can be analyzed if additional solution alternatives are needed.

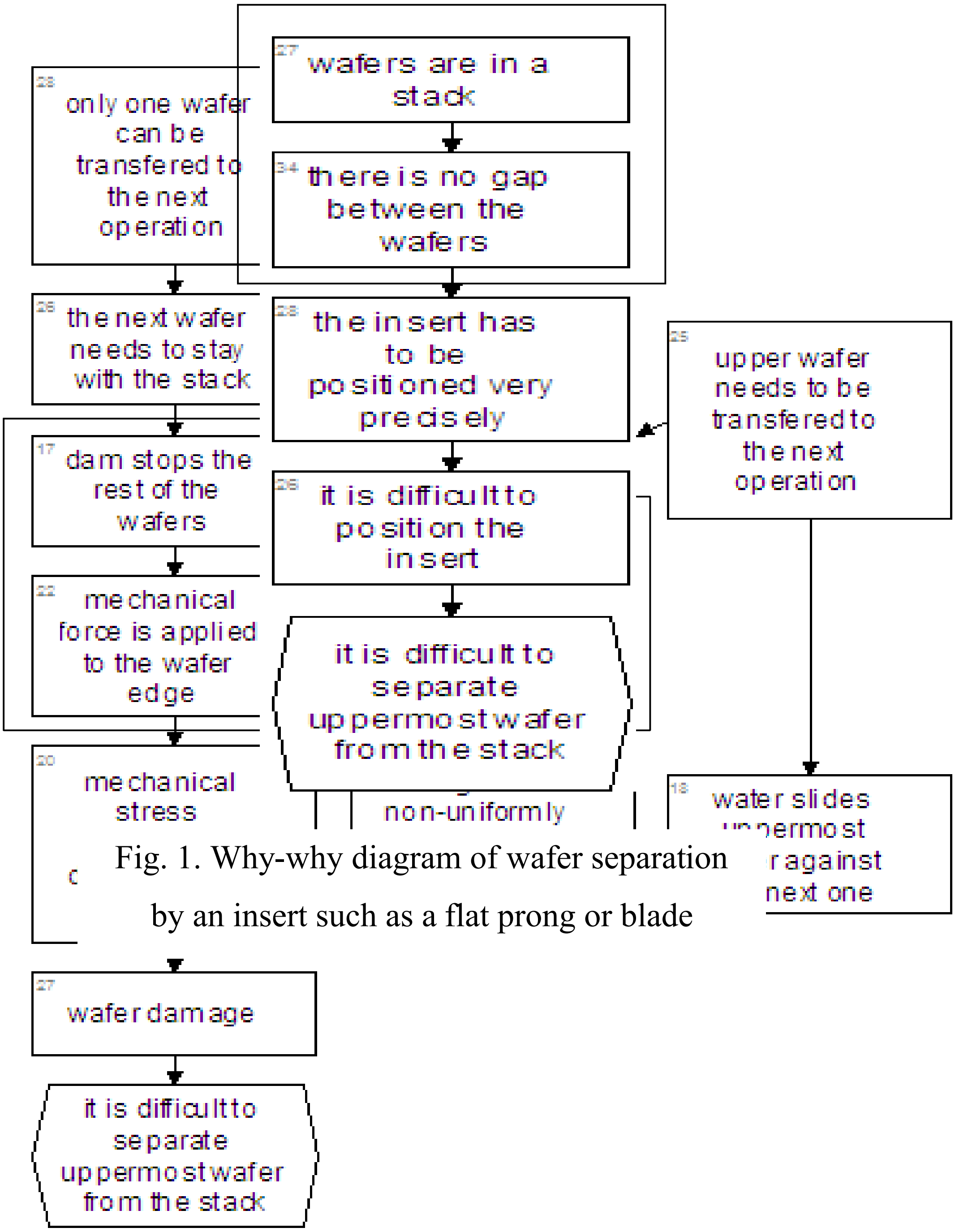


Fig. 1. Why-why diagram of wafer separation by an insert such as a flat prong or blade

Fig. 2. Why-why diagram of wafer separation by a flow of liquid and a dam

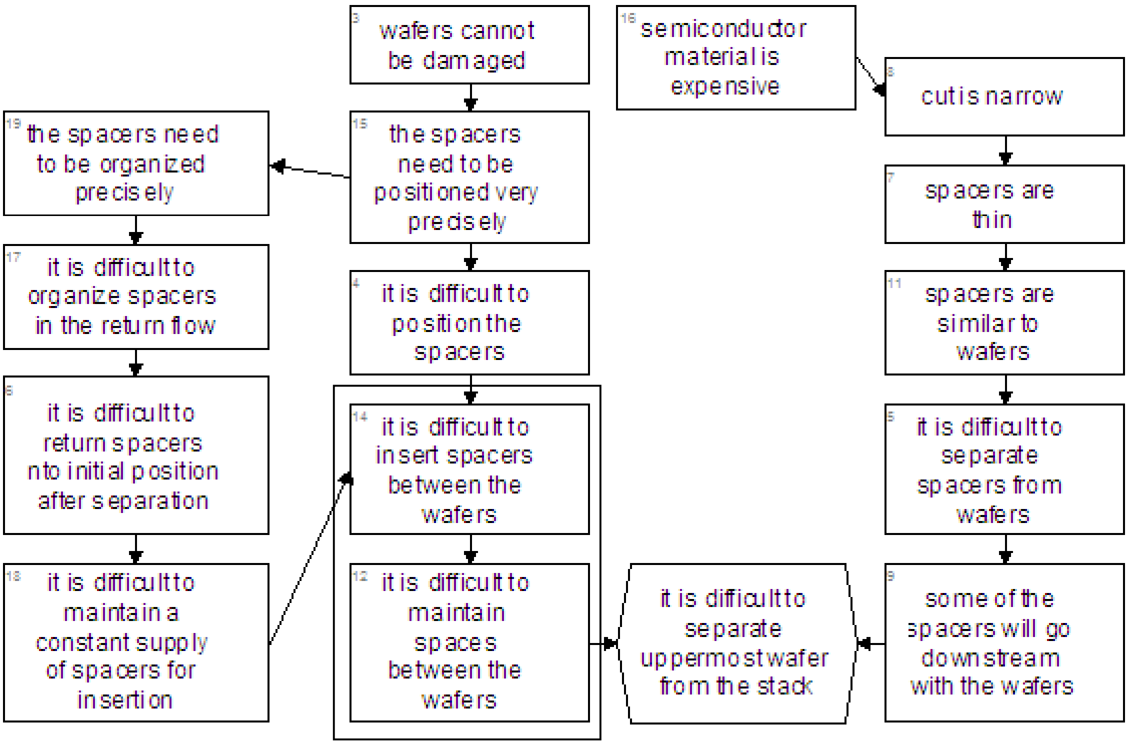
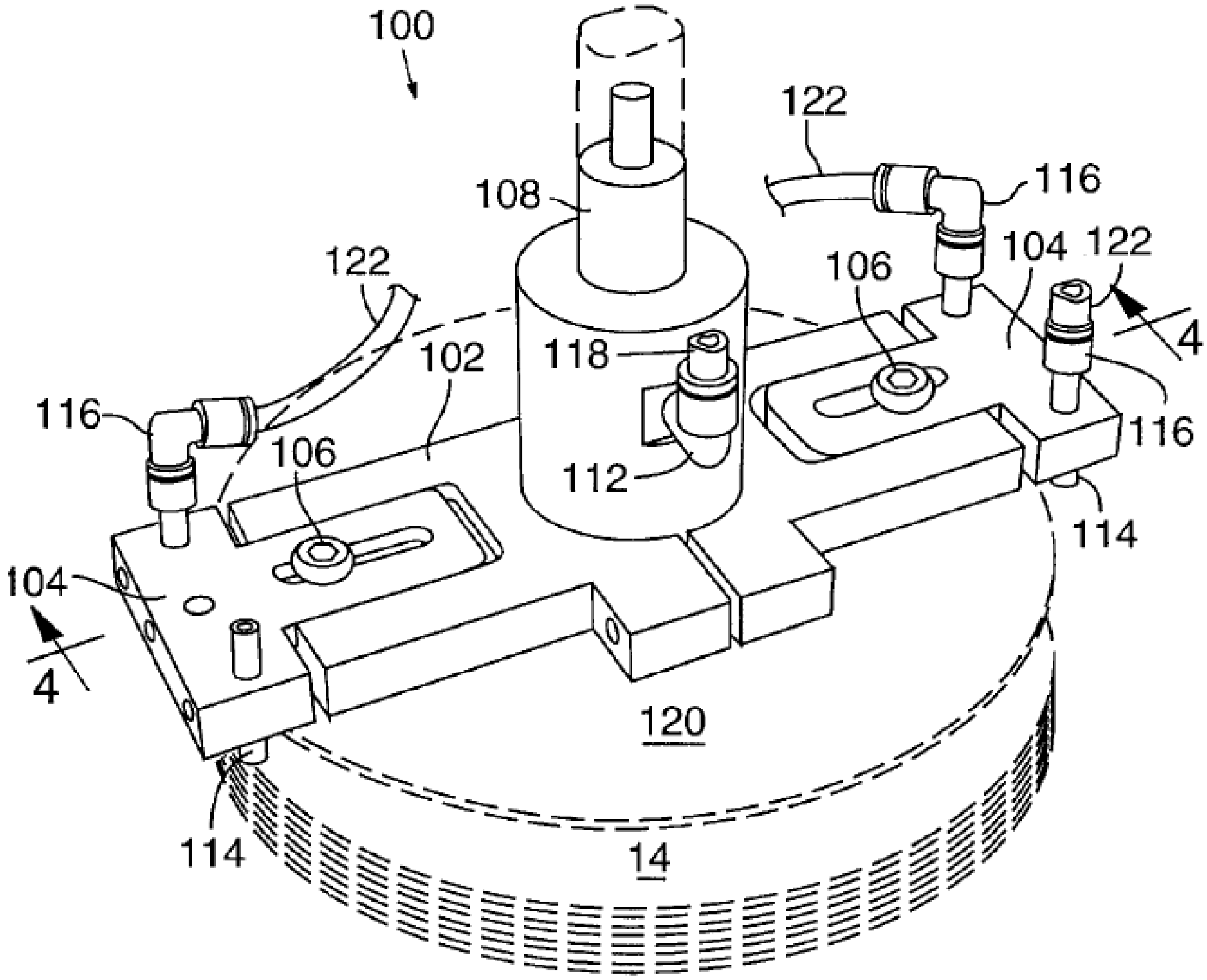


Fig. 3. Why-why diagram of wafer separation by the spacers

Synthesis of a New System Based on Why-why Analysis Results

Let us see what kinds of new systems can be synthesized based on why-why analysis done as described in the current article. I will refer to Figs. 1 – 3.

Air Jet Separator



One of the why-why contradictions derived from the analysis shown in Fig. 1 is "how to create gaps between the wafers in a stack". It is obvious that the gap needs to be created between the uppermost wafer and the rest of the stack. One of the TRIZ Principles, "Pneumatics and Hydraulics", offers an elegant solution of creating the gap by the compressed air jets. The application of this principle for our case study is described in [1] and the illustration of the proposed solution is shown in Fig. 4.

Fig. 4. Air Jet Separator. 114 – air nozzles, 116 – compressed air supply

This solution has been successfully implemented as a part of a larger wafer handling systems manufactured by Automation Technology, Inc, Salem, OR (US) – the assignee of the patent [1]. The same principle has been successfully used for separation of the paper sheets in the mailing machines, storage media such as CDs and DVDs in the label printing devices, and envelopes in the postal sorting machines.

Separation by Air Bubbles

Air plays an important role in a very different separation concept based on the hydraulic separator (why-why diagram in Fig. 2). The why-why contradiction here is "how to eliminate the mechanical force applied to the wafer edge given that dam stops the rest of the wafers in a stack and water pushes them towards the dam?" This is a standard problem of eliminating a harmful action (or destroying a harmful su-field). According to the standard solution, a protection layer, preferably made from the substances and fields already present in the operating zone, is to be applied between the dam and the wafers. An upward flow of air bubbles can be used as such protection layer (Fig. 5). In addition to protecting fragile edges from the impact by the dam, the bubbles can, actually, create gaps between the wafer edges and enable more reliable separation.

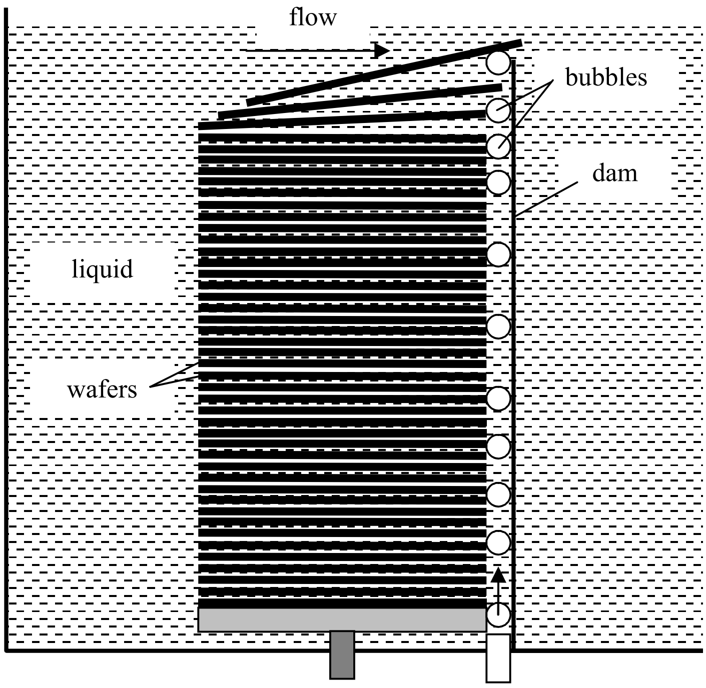


Fig. 5. Separation by Air Bubbles

Separation Without Spacers

One of the contradictions resulting from the why-why diagram in Fig. 3 is "how to maintain the spaces between the wafers without inserting spacers". The solution can be obtained by using Trimming: the function of a spacer can be transferred to the semiconductor material. This is done with a little help from the "Partial or Excessive Action" principle: a partial cut (say, 95%) of the semiconductor material leaving a common block holding the wafers together (Fig. 6). The vacuum wand attaches to the topmost wafer and the wafers are cut, one by one, off the common block. This way, the space between the wafers is maintained without the spacers.

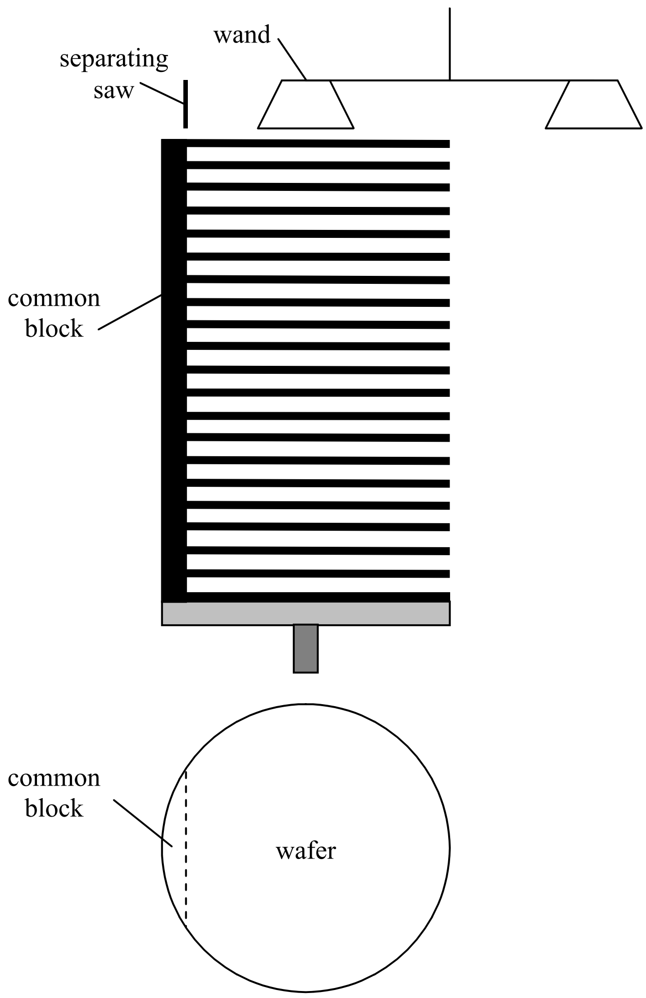


Fig. 6. Separation by Common Block

References

1. US Pat. # 6,558,109.

2. Pinyayev A. M. A Method for Inventive Problem Analysis and Solution Based On Why-Why Analysis and Functional Clues. St. Petersburg, Russia, International TRIZ Association. TRIZ Master Thesis: 24 pp.

3. US Pat. # 5,213,451.

4. US Pat. # 7,637,713.

S.Litvin, M.Gershman

Parallel Evolutionary Lines Application for Technology Forecast

Abstract

Very often engineering systems (products or technologies) pass similar evolutionary stages during their evolution. Besides, one of the systems is always at a more advanced stage compared to others. This fact enables one to forecast the evolution of a less developed system. In contrast to the well known in TRIZ Trends of Engineering System Evolution (TESE), which, as a rule, predict general directions for the evolution for practically all systems, the Parallel Evolutionary Lines (PEL) give specific directions and even suggest some innovation solutions for a restricted class of systems. At the same time comparing to Function-Oriented Search that is transferring specific technologies from the leading areas of engineering to the initial area, PEL transfers entire trends.

Knowing the evolutionary stage of a certain product or technology, one can forecast, with reasonable confidence, the evolution of parallel systems. Two major sources of similarity (parallelism) of evolutionary lines have been identified:

Functional similarity;

Action Principle similarity (physical, chemical, biological, geometrical action principles, features, and properties).

Features similarities.

The algorithm of analysis of PEL was developed and tested for numeral products and technologies in different areas of engineering. The paper is furnished with case studies from real consulting projects.

Key words: *Technology Forecast, Parallel Evolutionary Line (PEL)s, Engineering System (ES), Trends of Engineering System Evolution (TESE), Function Analysis (FA), Action Principle (AP).*

Introduction

In one of the privet conversations G.Altshuller told me that if TRIZ would never be created the most effective tool for invention would be analogies and associations. He even included one of non-obvious analogies – Clone Problems (analogies based on similarity of physical contradictions) into ARIZ as a problem solving tool [1]. Further another effective problem solving tool – Function-Oriented Search (based on functional analogies) – was incorporated into modern TRIZ [2]. However both above mentioned techniques serve to bring new specific solutions for some specific problems.

At the same time the most powerful tool of TRIZ Technology Forecast – Trends of Engineering System Evolution (TESE) is not utilizing any kind of analogies. The major idea of Parallel Evolutionary Lines (PEL) is to find similarities between different Engineering Systems (ES) and transfer the most effective trends of development from the leading engineering area to the initial one.

Types of analogies

There are different types of non-obvious similarities that may be considered as a basis for Parallel Evolutionary Lines.

1. Functional similaritie

In many cases the similarity of evolution of different systems is based on the fact that they have some common functions. Of course, the evolutionary trends should be transferred from the Leading System. Leading System is an Engineering System in which the parameters of corresponding function are more advanced or the function is performed in more severe conditions. One can expect that the Leading System moved further along its evolution. The most obvious candidates will be Alternative Engineering Systems. However the closer is the analogy, the more trivial will be the results of PEL analysis.

For example, although various transport systems – a truck, a car, a boat, an airplane, etc. – have many different specific features, they all perform similar functions, and therefore, passed similar stages in their evolution. Thus it is quite natural to expect that at some point, a truck will be equipped with an automatic gearbox, disc brakes, ABS system, individually adjustable seats, safety systems and other kind of novelties that a common in car design. However disc brakes installed on a heavy truck operate under more severe conditions as compared to disk brakes of a car. With a proportional increase in the size of the car - say, two-fold – its weight will be increased eight times, while the area of disc cooling will be increased only four times. However for this particular case we may use another line of evolution – an airplane. Based on this evolutionary line, one can anticipate the appearance in a truck of multi-disk breaks, forced-cooling breaks, and so forth.

More distant analogies have a better chance to bring some non-trivial results. The tool for identification of distant analogies is generalization of function. For example, the main function of the passenger vehicle is "to move people". The generalized function will be "to move any load". From this stand point the list of functional analogs for a car will include a pump that moves oil, posting equipment that moves envelopes, conveyor that moves small components, etc.

Comparing to Function-Oriented Search that is transferring specific technologies from the leading areas of engineering to the initial area, PEL transfers entire trends. Another important distinguish factor is the fact that unlike FOS that is a problem solving tool, PEL is a forecasting tool that predicts further development of the initial ES basing on evolutionary trends of Leading Systems.

2. Action Principle similarities

Another kind of analogy is a similarity of physical, chemical, biological, geometrical, etc. principles of operation of different ES even having absolutely different functions. For example, electric bulb and electric oven have completely different functions (to emit light and to heat some object correspondingly), but the same Action Principle – electrical heating based on ohmic resistance of the material. One of the trends in heating ovens evolution is transition from heating from the surface to volume (microwave heating from inside of the object). This trend being transferred to the light devices brings an interesting direction - lighting of the objects from insight.

3. Features similarities

Another type of analogy is similarities between physical properties and/or features of different ES. For example bread has a porous and capillary structure like sponges and solidified foams. One of the trends of evolution of foams is a transition from macro pores to micro- and even nano-pores. Micro-porous structures are stronger and lighter then macro-porous ones of the same size. It means that the micro-porous bread loaf of the same size will have less calories and may be transported with less damages. Because of better thermo-isolation properties the microporous waffle will keep the ice-cream cool even in a hot summer time, etc.

PEL Algorithm

In order to effectively apply Parallel Evolutionary Lines for the forecasting purposes the following algorithm is recommended:

1. Select the initial Engineering System – the object of Technology Evolution Forecast.
2. Formulate the function of the selected ES or its sub-system.
3. Generalize the formulated function.
4. Formulate Action Principle of the selected ES or its sub-system.
5. Formulate set of features of the selected ES or its sub-system.
6. Search for Leading Engineering Systems basing on:
   - Functional similarity
   - Action Principle similarity
   - Features similarity
7. Formulate Evolutionary Trends in the Leading ES (PELs).
8. Transfer relevant trends to the initial ES.
9. Select the most relevant and prospective results of applying PEL.

Conclusions

Different Engineering Systems are evolving along Parallel Evolutionary Lines. Knowing some steps and trends of evolution of leading ES it is possible to effectively forecast the directions of development of the parallel systems.

The PEL approach and corresponding algorithm were successfully tested in Technology Forecast projects for numeral products and technologies in different industries.

Literature

1. Altshuller G. To Find an Idea. Novosibirsk: Nauka, 1986.
2. Litvin S. New TRIZ-based Tool – Function-Oriented Search. TRIZ Future Conference. Florence, Italy, 2004

S. Litvin

Main Parameters of Value as a Tool for Technology Forecast

Identification of the correct Main Parameters of Value (MPV) is vitally important for effective product/technology forecast. Main Parameters of Value are product or technology attributes which define customer's purchase decision. Correspondingly real innovation is a significant improvement along one or more MPVs. Disruptive Innovation is an innovation involving migration to a new MPV or new action principle.

The main tool for MPV identification is Function Analysis on an upper level, i.e. analysis of interactions between the engineering system and its supersystem. MPVs may be different for:

Different stakeholders - consumers, customers, manufacturers, etc.;

Different stages of the product life cycle – production, application, operation, maintenance, storage, transportation, recovery, disposal, etc.

Different market niches – groups of population, geographical zones, ages, etc.

The algorithm of MPV Analysis was developed and tested for numeral products and technologies in different areas of engineering. The paper is furnished with case studies from real consulting projects.

Correlations between the evolution of contradictions and the law of ideality increase

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Abstract

TRIZ literature largely claims the efficiency of Altshuller's Laws of Engineering System Evolution (LESE) as a means for producing technology forecasts. Besides, all the instruments and the procedures proposed so far suffer from poor repeatability, thus limiting the adoption of TRIZ instruments as reliable means for the analysis of emerging technologies and their potential impact. In a previous work [1, 2] the authors have presented their modelling approach based on a combination of well known TRIZ techniques and traditional engineering design reference models. The outcome is a Network of Evolutionary Trends which supports decision making by positioning alternative technologies and technical solutions according to the LESE. The choice of the favourite strategic direction is still assigned to the beneficiaries of the forecast, since decisions will be taken also based on their mission and values. Besides, it is necessary providing further means of judgement to the decision makers. According to this purpose, it is useful to assess the maturity level of the analyzed technologies. The present work is a study about the correlations existing between the evolution of contradictions and the Law of Ideality increase, as a means to estimate the stage of development of a Technical System. The paper details the method proposed to make a systematic comparison of the contradictions related to each technology. The approach is clarified by means of a case study related to the production of tablets in the pharmaceutical manufacturing sector.

Keywords

Technology Forecasting, Laws of Engineering Systems Evolution, Contradictions

1 INTRODUCTION

TRIZ is founded on three postulates: (i) the existence of objective laws (LESE) governing the evolution of Technical Systems (TS); (ii) the refusal of compromises and the advancement of TS through the resolution of contradictions, i.e. conflicts between a system and its environment or between the components of the system itself; (iii) the impact of the specific situation, i.e. the resources which determine the concrete means to develop more evolved solutions.

Nevertheless, a paradoxical dichotomy characterizes most of TRIZ works: those focused on problem solving tasks, take into account the concept of contradictions, but practically neglect any relationship with the LESE, despite an appropriate application of ARIZ hiddenly implies the respect of the LESE. Vice versa, evolutionary analyses and “technology forecasting” applications are just based on the directions inspired by the LESE and/or by a few trends (e.g. the Inventive Standards of Class 2 and 3), but the notion of contradiction is missing. Somehow the resources (third postulate) are usually taken into account in both the applications.

The necessity to integrate the analysis of contradictions with the LESE in any TRIZ-based study has been already highlighted in previous works (e.g. [3, 4]), but just preliminary directions are emerging about the way to harmonize them. The present paper provides a contribution in this context through a study about the correlations existing between the evolution of contradictions and the fourth Law of Evolution (Ideality increase).

Such a correlation is a valuable resource to assess the maturity of a certain technology and it is proposed as a decision aid when multiple directions emerge from an evolutionary analysis made through the TRIZ LESE.

The present paper first positions the present research in comparison with other publications related to contradiction analysis and TS evolution. Then the third section summarizes the modelling technique, already discussed in [2], which aims at improving the repeatability of TRIZ-based evolutionary analyses. Section 4 details the original approach here proposed to identify the contradictions characterizing the evolution of the technologies to be compared and the related correlation analysis. In section 5, these criteria are applied to the past and current technologies adopted in the pharmaceutical manufacturing sector for tablets production. The case study allows to discuss about the potentiality to adopt the proposed correlation analysis as a means for maturity assessment.

2 Evolution of technical systems and RELATED contradictions

The evolution of Technical Systems follows objective laws and overcoming contradictions is the inherent mechanism which determines TS development. The first two postulates of TRIZ are clearly strictly related to each other; nevertheless, their coexistence is just "perceivable" into the classification of the Inventive Standards, while it is almost hidden in ARIZ, as well as in other items of the TRIZ body of knowledge.

As a matter of facts, in classical TRIZ there are no formalized tools to correlate the evolution of a TS with its contradictions: in [5] Altshuller, through the well known curves of system development, number of inventions, profitability, level of inventiveness (figure1), implicitly highlighted the conceptual link existing between the maturity of a TS and its contradictions, since the latter index is measured through the degree of contradiction resolution. Besides, these curves are hardly usable for practical scopes, despite what has been claimed in several publications like [6-8], also due to the lack of information about the way Altshuller himself built them (therefore, with no references about their limits of validity). In facts, in these papers the technology maturity curves are usually fuzzily rebuilt, often with relevant details missing (e.g. x and y values in [6]), and with extremely doubtful determination of the inventiveness level [7, 8].

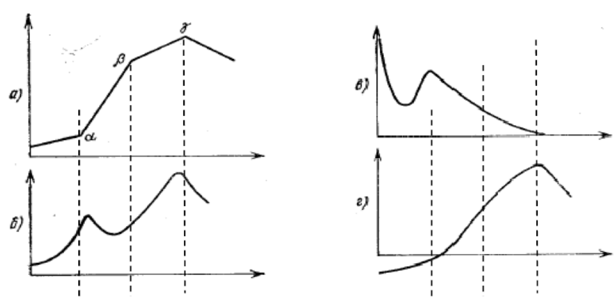

Fig. 1. Correlation between the stages of the "life" S-curve of a technical system (top, left) with the number of inventions (bottom, left), the level of inventiveness (top, right) and the related benefit, i.e., profitability (bottom, right) [5].

Indeed, numerous attempts have been accomplished to systematize the count of inventions, but just time consuming manual analyses allow to filter out not relevant patents selected through standard computer search criteria. The determination of the Level of Inventiveness evolution is even more difficult, since it is supposed to be done through a careful identification of the contradictions behind the problem solved by the patented inventions and, most of all, by the assessment of the degree of elimination of the contradictions themselves, which is extremely time consuming. Besides, no practical means still exist to speed up the identification and assessment of the contradictions approached by a patented invention, despite preliminary studies have been published in [9].

According to these issues, it emerges the necessity to find out further correlations between the maturity stage of a technology in a certain field of application and other technical information, possibly manageable with computer means to improve the efficiency of the process.

Out of TRIZ literature, Technology Assessment (TA) has greatly evolved since the early experiences of the 1960s [10], but still there isn't a single, widely disseminated and applied methodology. Many different approaches to TA have been adopted in practice, depending on the specific aims and scope of the application and its context (institutional, private firms, private or public research centres, specific industries etc.) [11]. Due to the lack of an established TA approach, neither in the scientific literature, nor in the industrial practice, the authors have decided to investigate the possibility to correlate the maturity of a technology with the evolution of the contradictions underlying its application in a certain field. The existence of such a correlation is expected according to the fifth law of evolution (uneven development of TS parts) and addressed also by Cavallucci and Rousselot [3], where the purpose is indeed different: ordering the contradictions in accordance to the fact that they present an opposition to a specific law.

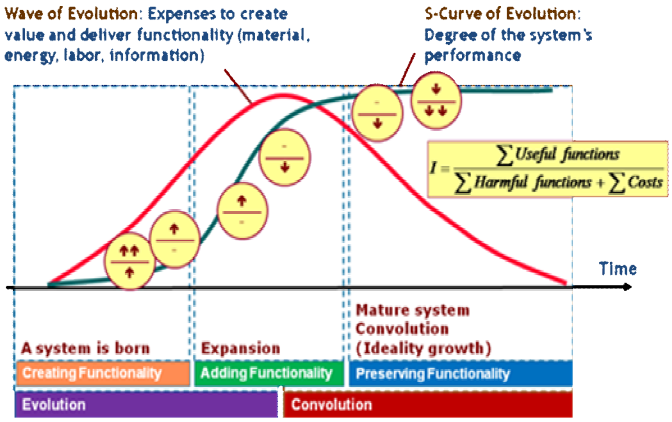

Fig. 2. Trend of Ideality increase (red line) compared with the consumption of resources (green line) which reflects the wave model by Salamatov [5].

In this paper the search for correlations between the evolution of TS contradictions and the LESE has been focused on the law of Ideality increase, due to some evidences arising from classical TRIZ literature. In facts, the growth of the degree of ideality can be compared with the consumption of resources according to the wave model by Salamatov [12], as depicted in fig. 2. By combining the S-curve of TS performance with such a bell shape resources consumption three main stages of evolution can be recognized. The specific objective of the present research is to check the possibility to correlate the nature of the contradictions acting on a TS with these stages of TS development.

3 Functional modeling for TRIZ-based evolutionary analyses

With the aim of improving the repeatability of TRIZ-based evolutionary analyses, the authors have proposed in [1], then further detailed in [2], a functional modelling approach which integrates well known models and instruments for system description and function representation and allows a systematic application of the TRIZ LESE to classify existing technologies and to identify further opportunities of development through a Network of Evolutionary Trends (NET).

The modelling procedure is based on the following reference models:

- Function-Behavior-Structure (FBS) model [13], to distinguish between the Function of a TS, i.e. the motivation of its existence, its Behaviour, i.e. the way the function is delivered according to the Laws of Nature, and the Structure, a combination of entities, attributes of these entities and relations among them, which determine the Behaviour of the TS.
- EMS (Energy, Material, Signal) model [14], to describe the Function of System and Subsystems.
- NIST Functional Basis for Engineering Design [15], to reduce ambiguity at the modelling level and to improve repeatability of the models through a taxonomy of actions and flows coherent with the EMS modelling approach.
- An extension of the classical TRIZ model of Minimal Technical System (MTS) [5], to represent the Behaviour of the TS also through Material and Signal flows (from the supply to the Tool through the Transmission).
- System Operator [5] to conduct the analysis at different detail levels (i.e. system, sub-systems etc.) with a proper hierarchical classification of system elements, by taking into account their Behaviour and modifications in time.

A detailed description of the modelling algorithm is out of the scopes of the present paper. Nevertheless, it is worth to mention its main steps:

1. The system is modelled through EMS boxes and decomposed into elementary functions until each functional unit can be described in terms of flows and actions belonging to the reference list proposed in [15] (fig. 3).
2. Then the Behaviour of each elementary function is represented by means of the TRIZ model of Minimal Technical System as follows (fig. 4):
   a. identify the Product, i.e. the object of the function which determines a transformation of the input flow into the output;
   b. identify the Tool, i.e. the element which acts directly on the Product;

c. determine which properties characterize the Tool's capability to deliver the function to the Product;

d. for each of the properties defined at step 2c, identify the "Engine" from where the properties derives;

e. complete the model of the minimal technical system, by adding the transmission from the Engine to the Tool, the control and its interactions with the other subsystems and the external supply of the engine.

3. Once that the available Behaviours have been modelled for each elementary function, a Su-Field model related to the interaction of each pair of interacting elements of the Minimal Technical System model is added (i.e. Tool-Product, Control-Tool etc.).

4. Identify the Evaluation Parameters defining the performance of each elementary function of the TS modelled at step 1.

5. Identify further Evaluation Parameters related to the harmful functions and the resources consumption of each Behavioural Models built at step 2.

The last two steps are part of the original contribution of the present paper and will be further detailed in the next section.

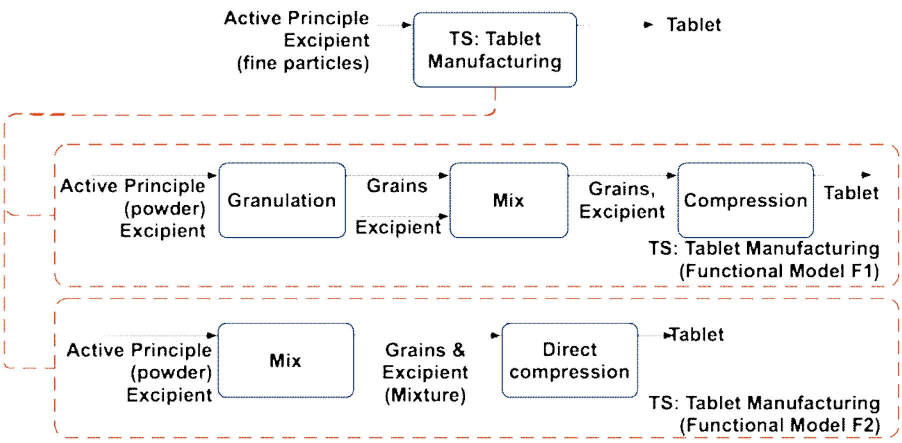

Fig. 3. Functional model of a pharmaceutical tablet manufacturing process: EMS functional decomposition.

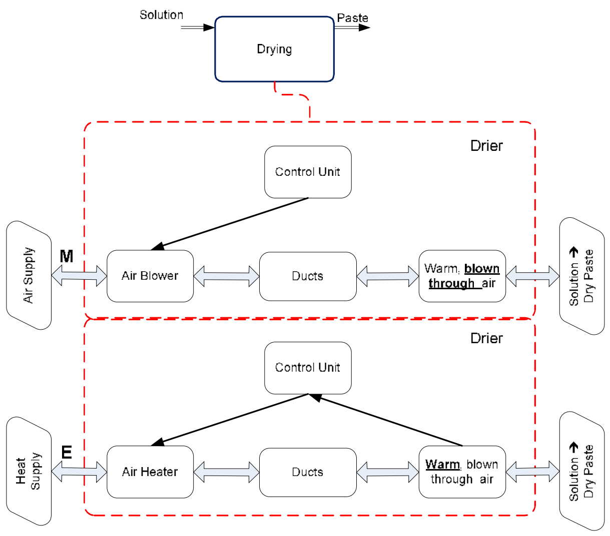

Fig. 4. Exemplary Behavior represented through the model of the Minimal Technical System associated to an elementary function described through the EMS model [2].

4 correlating ts contradictions and evolutionary stages

In order to explain the proposed approach to study the existence of correlations between the evolution of the contradictions characterizing a certain TS and its stages of development, it is worth to recall the model of a TRIZ contradiction. The authors have adopted the OTSM formulation [16], which distinguishes between Evaluation and Control Parameters (fig. 5): <Control Parameter> of <Element X> should assume <Value 1> in order to improve <Evaluation Parameter 1> of <Element Y>, but then <Evaluation Parameter 2> of <Element Z> worsens; <Control Parameter> of <Element X> should assume <Value 2> (with <Value 2> ≠ <Value 1>) in order to improve <Evaluation Parameter 2> of <Element Z>, but then <Evaluation Parameter 1> of <Element Y> worsens.

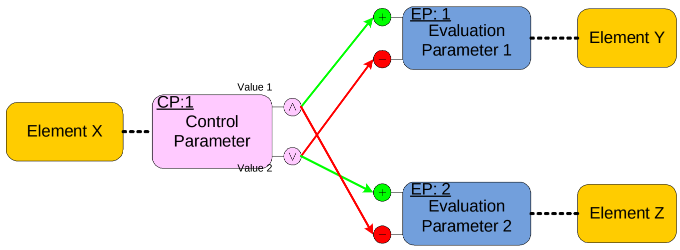

Fig. 5. OTSM-TRIZ model of contradiction [16].

Aiming at the highest repeatability of the analysis, it is proposed to identify and classify the Evaluation Parameters (EP) of each Function/Behaviour according to a set of well defined rules; similarly, the Control Parameters (CP) of each Behavioural Model (BM) are clustered on the base of general rules as detailed below. Eventually, it is necessary to check the relationships between CPs and EPs in order to identify the contradictions characterizing each BM.

4.1 CLUSTERS OF EVALUATION PARAMETERS

The Evaluation Parameters represent the overall list of requirements to be satisfied by the TS and the means to assess its degree of Ideality.

According to such a definition, some Evaluation Parameters assess the Performance of the function delivered by a TS. By definition, these parameters are just related to the function accomplished by the TS and not to its Behaviour and Structure, i.e. the way the function is delivered. Besides, other EPs represent a measure of the undesired side effects (harmful functions) and the consumption of resources to make the system work. It is clear that the latter two categories of EPs strongly depend on the nature of the Behavioural Model and the Structure of the TS.

Therefore, the authors have defined a standard classification of each class of EPs:

- Performance of the Main Useful Function and of other Useful Functions delivered by the TS;
- Harmful Functions;
- Resources consumption.

The cluster of Performance EPs can be divided into four sub-classes:

- Threshold achievement: capability to impact the object of the function with the expected extent (in order to consider the function as "sufficient");
- Versatility: parameters that characterize the capability to adapt the behaviour according to different operating conditions;

- Robustness: parameters that take into account the capability to have the same desired outcome under varying inputs;
- Controllability: parameters that consider the capability to set the function desired outcome according to the user will.

The Harmful Function cluster is divided into three different sub-classes, considering negative impacts on:

- object of the MUF (e.g. an undesired side effect caused by the same mechanism adopted to deliver the MUF);
- system and subsystems integrity (e.g. an undesired side effect on the TS or its parts, caused by the mechanism adopted to deliver the MUF);
- the external environment (e.g. an undesired side effect on the super-system caused by the mechanism adopted to deliver the MUF).

Finally, the EP related to Resources consumption are classified into five sub-clusters:

- Space;
- Time;
- Information;
- Material;
- Energy.

It is worth to notice that a comprehensive definition of the EPs related to HF and resources, should take into account also the auxiliary functions (AF) necessary to deliver the MUF, elicited during the modelling phase (from Function to Behaviour and Structure).

Figure 6 summarizes with a flow chart the EP classification process.

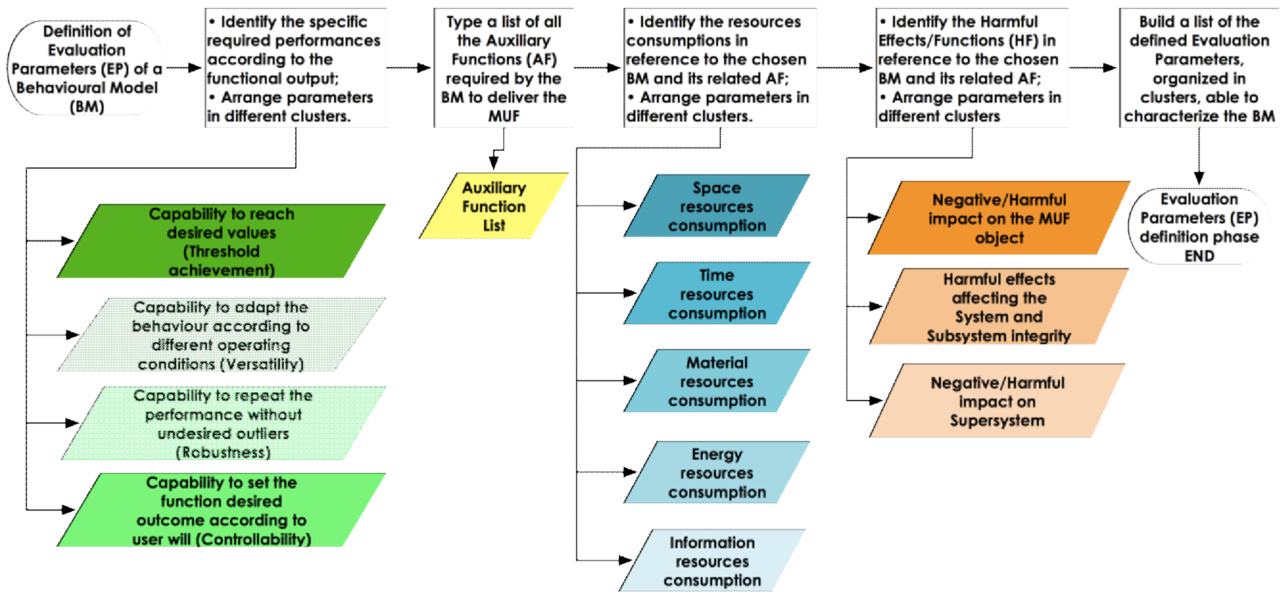

Fig. 6. Algorithm for EP classification.

4.2 CLUSTERS OF CONTROL PARAMETERS

The Control Parameters, i.e. the design parameters that can be modified to impact on the EPs, clearly depend on the Behaviour and the Structure adopted to deliver a certain Function. Nevertheless, even in this case, the authors have proposed a reference categorization described here below.

More in details, two main classes of CPs are recognized:

- CP related to the EMS flows processed by the TS under study;
- CP related to the MTS model of the TS under study.

Both the above categories of CPs can be further distinguished according to the following classification criteria:

EMS flows

- The classification of EMS flows adopts the same schema proposed in [15] by NIST, i.e. a hierarchical three levels taxonomy including 6 secondary and 11 tertiary material flows, 12 secondary and 4 tertiary energy flows, 2 secondary and 7 tertiary signal flows.

MTS elements

- Nature of the Effect underlying the Behaviour of the TS. The CPs can be classified according to the type of effect they are associated with: Chemical Effects enable to obtain some substances from others by the absorption or isolation of energy; Physical Effects enable to transform one form of energy into another; Geometrical Effects organize and redistribute flows of energy and substances that are already available in the system.

- Role in the Behavioural Model according to the MTS schematization: the CPs are classified according to the element they are referred to, among Tool, Transmission, Engine, Control.
- Type of resources: the CPs modify the way the resources are used to improve the satisfaction of the EPs; therefore they can be classified according to the type of resource involved on, as described also for the EPs: Space, Time, Information, Material and Energy.

4.3 CONTRADICTIONS CHARACTERIZING A BEHAVIOURAL MODEL

Before detailing the approach here proposed, it is worth highlighting that the goal of the present task is not solving contradictions, but modelling, counting and classifying them as a means to search for correlations with the maturity level of a TS.

As mentioned above, the reference model is the OTSM-TRIZ schema shown in fig. 5. Therefore, an elementary contradiction involves 1 CP and 2 EPs, such that opposite values are required to the CP itself in order to improve the two EPs alternatively.

Once that the lists of CPs and EPs have been built as described in the previous sections, it is necessary to assess the potential impact of each CP on each EP; then it is checked if a certain variation of a CP determines contradictory modifications on two or more EPs. More in details, the following steps must be accomplished:

1. Identify two opposite values for each CP and choose a reference orientation (e.g. from small to big, property Vs anti-property etc.).
2. Assess the impact IMP_{ij} of a CP_i variation on each EP_j (to be repeated for each CP_i):

   - $IMP_{ij} = +1$ if a variation of CP_i towards the selected reference direction determines an improvement of EP_j;

- $IMP_{ij} = -1$ if a variation of CP_i towards the selected reference direction determines a worsening of EP_j;

- $IMP_{ij} = 0$ if a variation of CP_i doesn't impact on EP_j.

Figure 7 (above) clarifies the meaning of such a classification.

3. The overall number of elementary contradictions related to a certain CP_i can be evaluated as follows:

$$CNTD(CP_i) = (\# \text{ of } IMP_{ij} = +1) \times (\# \text{ of } IMP_{ij} = -1) \qquad (1);$$

in other terms, a complex contradiction involving a CP and several EPs can be decomposed in $CNTD(CP_i)$ elementary contradictions (figure 7, below).

4. The overall number of contradictions related to the *k*-th behavioural model BM_k is evaluated as the sum of the contradictions related to each of its CPs:

$$CNTD(BM_k) = \sum_i CNTD(CP_i^k) \qquad (2).$$

According to the goal of the present paper, it is interesting to analyze the evolution of $CNTD(BM_k)$ in the history of development of a certain TS. Similarly, it is worth to study the evolution of specific subsets of contradictions, defined according to the type of their EPs and/or CPs.

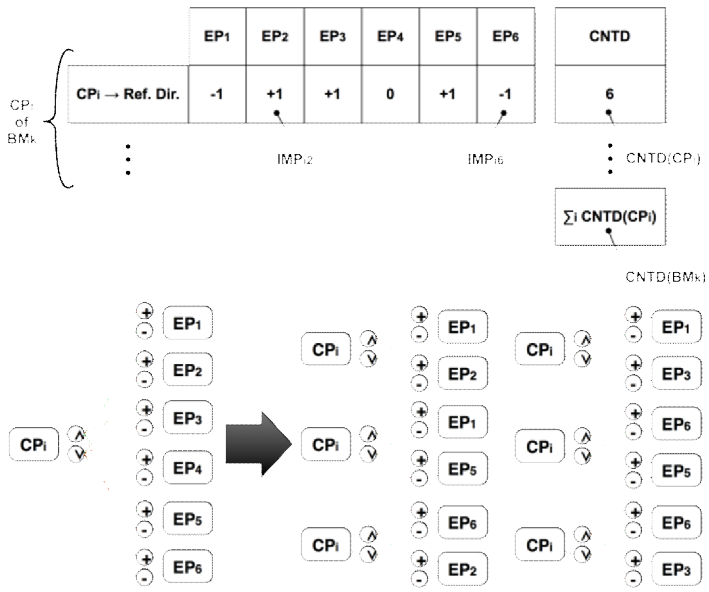

Fig. 7. Decomposition of complex contradictions.

4.4 CLUSTERS OF CONTRADICTIONS

In this paper the analysis of contradictions evolution is focused on the nature of their EPs, due to their closed connections with the Law of Ideality Increase. In facts, the three main clusters of EPs defined in section 4.1, i.e. performance of the main useful function, harmful functions, resources consumption, can be directly linked to the concept of Ideality (fig. 2). Function performances, intended as desired outcomes, can be related to the Ideality dividend; on the other hand "harmful function" and "costs" constitute its denominator.

Therefore, it is possible to organize the contradictions in clusters according to the type of their EPs conflicting pair, hence obtaining six different types of contradictions:

- Performance (*P*) vs. Performance (*P*);
- Performance (*P*) vs. Harmful Functions (*HF*);
- Performance (*P*) vs. Resources Consumptions (*RC*);
- Harmful Functions (*HF*) vs. Harmful Functions (*HF*);
- Resources Consumptions (*RC*) vs. Harmful Functions (*HF*);
- Resources Consumptions (*RC*) vs. Resources Consumptions (*RC*).

In analogy with the determination of the total number of contradictions associated to a certain BM (2), it is possible to calculate the contradictions separately for each of the 6 above listed classes, by taking into account the following recommendations:

- the count of IMP^{m}_{ij} should be limited to the EP_j of a specific class *m*, where *m* is alternatively P, HF, RC;
- therefore, (2) is updated as follows:

$$CNTD_{m,n}(BM_k) = \sum_i (\#\text{ of } IMP^m_{ij} = +1) \times (\#\text{ of } IMP^n_{ij} = -1) \quad (3)$$

where, $CNTD_{mn}(BM_k)$ is the number of contradictions involving an EP of class *m* and an EP of class *n* associated to the Behavioural Model *k*.

Similarly, since in section 4.1 twelve different classes of EPs have been defined, a total number of 78 permutations of EP pairs can be defined, thus producing 78 subsets of contradictions to be counted according to (3) for a more detailed analysis of contradiction evolution, as discussed below.

4.5 EVOLUTION OF CONTRADICTIONS

In the study of the evolution of a TS, once that its functional analysis has been accomplished according to the criteria summarized in section 3, it is possible to evaluate the number of contradictions of each Behavioural Model as detailed in section 4.4.

The rationale of this analysis is the attempt of correlating the nature of the contradictions with the stage of development of the different BMs of a given TS. Indeed, different types of EPs are supposed to be involved in a different manner along the evolution from the infancy stage to the maturity. For example, according to the wave model by Salamatov [12] shown in fig. 2, the consumption of resources changes with a definite regularity.

However, due to the complexity of the possible situations, the authors don't intend to perform any assumption about possible regularities between contradictions and stages of development. Besides, it is proposed to apply the same classification to a number of case studies in order to check the existence of correlations between them.

Such an activity clearly implies an extensive work to be done for a proper validation; nevertheless, according to the limitations of the current approaches for maturity assessment mentioned in section 2, it is worth to dedicate adequate efforts to the initiative.

5 exemplary correlation analysis between evolution of contradictions and ts development

The authors have already experienced the NET modelling approach in four case studies related to disabled walkers, wood pellets production, aseptic filling of beverage containers and tablets production; in each of these case studies conducted from September 2007 to March 2009 the role of the authors was the definition of a structured set of scenarios to support company's management in the selection of the most appropriate directions for investment. The algorithm was carefully applied to collect and classify the implicit knowledge of company's experts, as well as to direct the search for further relevant information from patent databases and other scientific sources. Two further extended applications are in progress.

In this section the proposed classification and correlation analysis is applied to the case study in the field of production of tablets in the pharmaceutical manufacturing sector, since several technologies have been developed in the last decades and it is possible to appreciate the substitution process of emerging techniques over mature ones.

5.1 FUNCTIONAL AND BEHAVIORAL MODELING

The tablet production process consists in agglomerating the Active Principle Ingredients (API) from a powder status into pills. All the existing technologies make use of excipients to improve the manufacturability and the conservation properties of the drug. Two main classes of processes can be distinguished: the largest majority of current production plants make use of an intermediary granulation phase to ease the moldability of the raw materials (fig. 8).

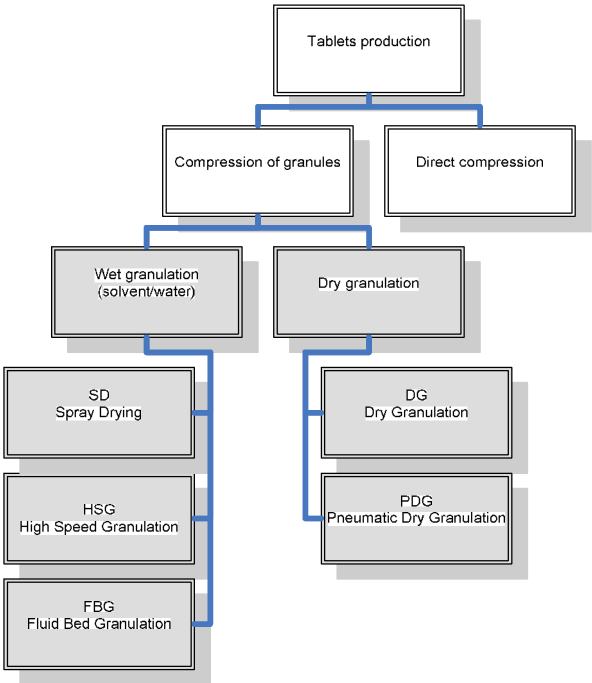

Fig. 8. General classification of tablets production technologies, based on the compression (white boxes) and the granulation (gray boxes) phases.

Recently, direct compression has been applied to some APIs. Figure 3 shows the EMS model of the whole process and the functional decompositions characterizing these two major techniques. Due to the availability of detailed information from the industrial partner of the present study, a particular attention has been dedicated to the granulation phase. In the past, granulation was performed through the production of a solution to be homogenized, dried and eventually reduced to granules. After the introduction of severe limitations about solvents usage, wet granulation technologies have adopted water to substitute solutions with particle suspensions, but still keeping the same machinery. Recently, dry granulation processes have been proposed to reduce the harmful impact of water residuals into the tablets and to improve the efficiency of the overall production process. Therefore, the detailed analysis has been performed on the following technologies: High Speed Granulation (HSG), Fluid Bed Granulation (FBG), Spray Drying (SD), Dry Granulation (DG), Pneumatic Dry Granulation (PDG) (fig. 8).

Each of the five granulation technologies has been decomposed into elementary functions according to the NIST classification, as described in section 3. Due to space limitations it is not possible to show all the functional and behavioural models built; however, it is worth to list the identified elementary functions, since they will constitute the main object of the evolutionary comparison between maturity level and contradictions types.

- HSG: Mixing (API, excipients, water), Fragmentation, Drying, Fragmentation, Sifting;
- FBG: Mixing (API, excipients), Fluidize, Agglomerate, Drying, Filtering;
- SD: Mixing (API, excipients, water), Atomizing, Drying, Sifting;
- DG: Mixing (API, excipients), Compacting, Pre-crushing, Flake Crushing, Sifting;
- PDG: Conveying (API, excipients), Compacting, Pre-crushing, Flake Crushing, Fraction.

Then, each of the elementary function has been analyzed in order to build its Behavioural Model through one or more Minimal Technical System models, as depicted in fig. 4. As a result, 14 different BMs have been recognized:

- BA1: agglomeration of fluidized powders by means of a liquid binder in a closed bin (Fluid Bed Agglomeration);

- BC1: powders compressed into a ribbon by means of two opposite counter rotating rollers (Roller Compaction);
- BD1: pneumatic conveying of particles/powders;
- BM1: mechanical mixing of powders and binders by means of moving surfaces ;
- BM2: pneumatic mixing of powders by fluidization (fluid bed mixing);
- BM3: mixing of powder by means of moving surfaces;
- BF1: mechanical fragmentation of wet mass by means of calibrated nets;
- BF2: mechanical fragmentation of dry compacts (slugs or flakes) by means of oscillating rollers: oscillating granulation;
- BF3: flakes spheronization;
- BS1: Vibro-sieving;
- BS2: PDG "smart" fractioning;
- BS3: cyclone separation;
- BE1= fluid bed drying;
- BE2= dehydration by means of a flow of warm air (oven drying).

Eventually, the EPs and CPs related to each BM have been identified: first, performance EPs are associated to each elementary function, according to the classification described in section 4.1. Then, the specific characteristics of each BM are analyzed to identify relevant resources and related harmful functions. Similarly, each MTS allows to extract the CPs impacting the behaviour of the related technology.

As a result, an elementary function characterizing different technologies (e.g. mixing, drying, sifting etc.) is evaluated through the same performance EPs, but possibly different resources and harmful functions EPs 8depending on the specific way the function is performed (behaviour). Fig. 9 depicts an exemplary analysis referred to the elementary function "mixing": above it is represented the EMS model, with details about the reference flows and actions according to the NIST classification. Six performance EPs are associated to the function, four aimed at evaluating the achievement of the useful result, three related to robustness, adaptability and controllability.

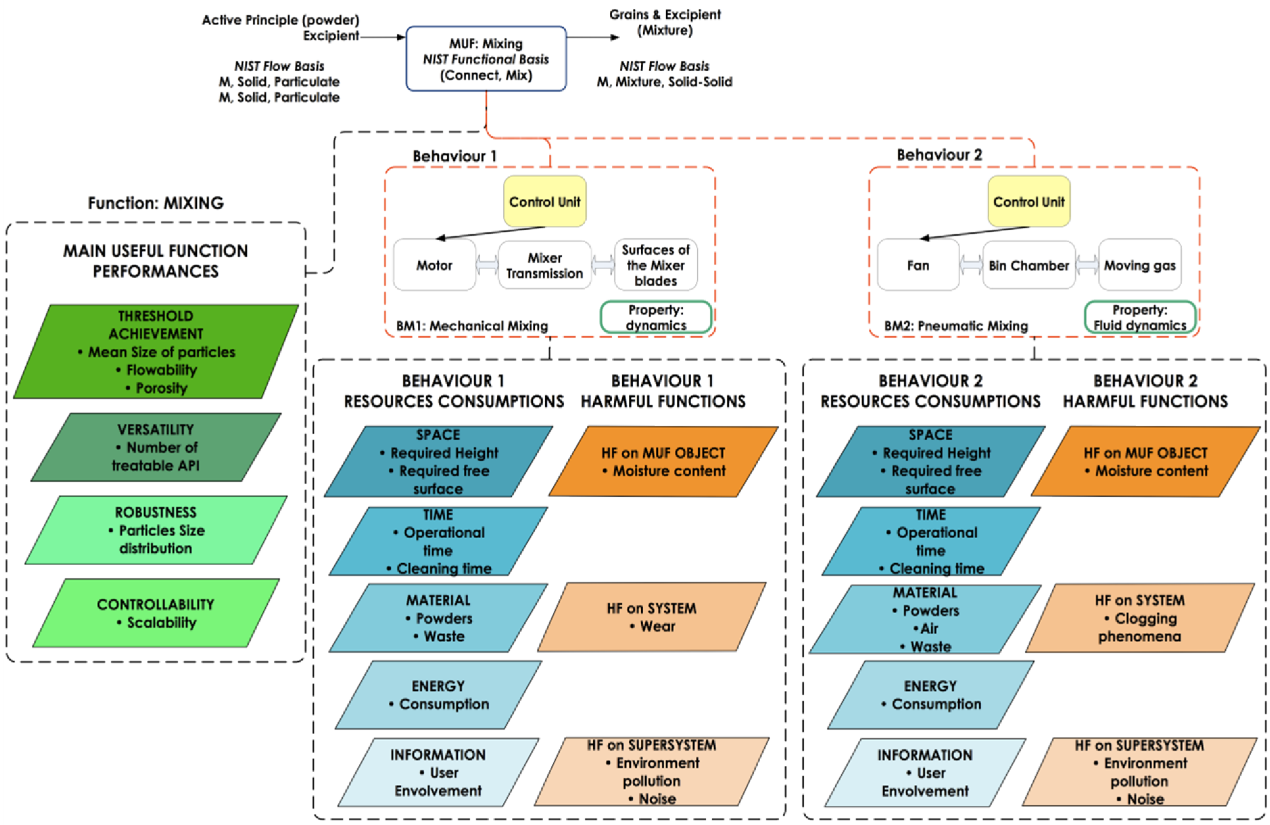

Fig. 9. Exemplary EP extraction and classification for two different Behavioral Models associated to the same elementary function.

Below, two different BMs are shown, related to mechanical and pneumatic mixing respectively. Each BM is characterized by a specific set of resources and harmful functions EPs. Similarly, each BM has a number of relevant CPs, classified according to the categories described in section 4.2.

5.2 CONTRADICTION ANALYSIS

Once that EPs and CPs related to each BM have been identified, it is possible to analyze and count the related contradictions, as described in section 4.3.

Table 1 summarizes the overall number of EPs, CPs and resulting contradictions identified for each BM. The analysis has been further detailed, by classifying the contradictions into 6 subsets, according to the criteria described in section 4.4, thus distinguishing between contradictions characterized by EPs of different types (P vs. P, P vs. R, P vs. HF etc).

BM	EPs	CPs	Contrad. count	Maturity Level
BA1	19	43	**1127**	**G**
BC1	22	16	**633**	**E**
BD1	20	16	**553**	**E**
BE1	19	23	**445**	**G**
BE2	19	22	**456**	**D**
BF1	19	18	**319**	**D**
BF2	21	18	**537**	**G**
BF3	18	14	**274**	**E**
BM1	18	29	**464**	**D**
BM2	19	29	**518**	**G**
BM3	20	19	**521**	**G**
BS1	21	11	**239**	**D**
BS2	21	26	**869**	**E**
BS3	21	21	**566**	**E**

Table 1. EPs, CPs, and contradictions identified for each BM and their maturity level estimated by the subject meta-experts: emerging (E); growing (G); declining (D).

Moreover, the maturity level of each BM has been assessed on the basis of a joined evaluation of the subject meta-experts: each technology has been evaluated as "emerging", "growing" or "declining" (table 1, right), in accordance with the traditional evolutionary stages depicted in fig. 2.

Such a classification allows to perform correlation analyses between the nature of the contradictions and the maturity level of a given technology, in order to check the existence of characteristic features (Table 2).

With the aim of identifying distribution peculiarities, it has been decided to focus the analysis only on the types of contradictions characterized by a higher non-uniformity, i.e. characterized by a bigger standard-deviation / average ratio (Table 2, below). Therefore, the contradictions involving mixed-types EPs, i.e. P vs. R, P vs. HF, R vs. HF, are assumed as not relevant for maturity assessment. The remaining contradictions types show a reducing number of P vs P contradictions, as well as an increase of conflicts between consumed resources R vs R (Table 3).

	P vs P	P vs R	P vs HF	HF vs HF	HF vs R	R vs R
BA1	5,5%	39,8%	16,8%	3,9%	18,7%	15,4%
BC1	13,6%	37,3%	24,2%	2,1%	12,0%	10,9%
BD1	8,0%	44,5%	24,6%	4,5%	11,6%	6,9%
BE1	2,5%	45,8%	15,7%	3,4%	18,0%	14,6%
BE2	2,4%	27,9%	14,9%	7,7%	27,2%	20,0%
BF1	5,6%	42,6%	13,8%	0,9%	10,7%	26,3%
BF2	3,7%	34,6%	26,8%	5,6%	18,2%	11,0%
BF3	15,0%	44,2%	22,3%	0,4%	8,0%	10,2%
BM1	2,2%	42,7%	14,9%	0,4%	11,4%	28,4%
BM2	3,5%	38,8%	13,9%	4,2%	21,2%	18,3%
BM3	1,5%	43,4%	26,3%	1,3%	11,7%	15,7%
BS1	0,0%	26,8%	30,1%	5,0%	22,6%	15,5%
BS2	7,6%	30,5%	25,4%	7,2%	18,4%	10,8%
BS3	5,8%	41,0%	21,4%	6,2%	16,3%	9,4%
MAX	15,0%	45,8%	30,1%	7,7%	27,2%	28,4%
AVG	5,5%	38,6%	20,8%	3,8%	16,1%	15,2%
MIN	0,0%	26,8%	13,8%	0,4%	8,0%	6,9%
StdDev	4,4%	6,3%	5,6%	2,5%	5,4%	6,3%
StdDev/Avg	**79,7%**	16,4%	27,1%	**65,1%**	33,7%	**41,3%**

Table2.Distribution of contradictions among the BMs.

Technology profile	**Performance vs. Performance**	**Harmful functions vs. Harmful functions**	**Resources vs. Resources**
Emerging	41,6%	17,9%	40,5%
Growing	14,8%	16,7%	68,5%
Declining	8,4%	17,6%	74,0%

Table 3. Average percentage of contradictions for BMs associated to the same stage of evolution.

More detailed information can be extracted by analyzing the 78 sub-classes of contradictions defined in section 4.4, even if it is worth to perform the analysis by taking into account a wider range of technologies, in order to have a suitable statistical sample.

6 Conclusions

The present paper has introduced a systematic approach for correlating the stage of evolution of a technical system and the contradictions characterizing its behaviour, with the aim of building a reliable index for maturity assessment. The proposed approach has been applied to the tablets manufacturing technologies in the pharmaceutical sector.

The promising results obtained so far suggest to extend the analysis to a higher number of case studies in order to check if the identified correlations can be assumed as invariant with respect to the field of applications.

It is worth to mention that the maturity level of a specific BM measures the evolutionary stage of a technology with respect to its way to deliver a certain elementary function. Nevertheless, each technology must be evaluated by taking into account the overall process, thus the whole sequence of elementary functions characterizing its process. This means that a technology overall classified as mature, can involve elementary actions accomplished with specific solutions still capable of further evolution and vice versa, emerging technologies sometimes include obsolete sub-steps. The correlation analysis proposed in this paper allows highlighting these non-uniformities, which can be leveraged to foster the development of innovative solutions and the hybridization of alternative technologies.

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LIST OF ACRONYMS

AF: Auxiliary Function

BM: Behavioral Model

CP: Control Parameter

EMS: Energy-Material-Signal

EP: Evaluation Parameter

FBS: Function-Behavior-Structure

LESE: Laws of Engineering System Evolution

MTS: Minimal Technical System

MUF: Main useful Function

NET: Network of Evolutionary Trends

TA: Technology Assessment

TS: Technical System

REFERENCES

[1] Cascini, G., Rotini, F., Russo D.: "Networks of trends: systematic development of system evolution scenarios", Proceedings of the 8th ETRIA TRIZ Future Conference, Twente, The Netherlands, 5-7 November 2008, ISBN 978-90-365-2749-1, pp. 31-40.

[2] Cascini, G., Rotini, F., Russo D.: "Functional modeling for TRIZ-based evolutionary analyses", Proceedings of the International Conference on Engineering Design, ICED'09, Stanford University, Stanford CA, USA, 24-27 August 2009.

[3] Cavallucci D., Rousselot F.: "Evolution Hypothesis as a means for linking system parameters and laws of engineering system evolution". Proceedings of the 7th ETRIA TRIZ Future Conference, Frankfurt, Germany, 6-8 November 2007, ISBN 978-3-89958-340-3 Kassel University Press, pp. 31-40.

[4] Kucharavy D., De Guio R.: "Technological forecasting and assessment of barriers for emerging technologies". Proceedings of the International Association for Management of Technology (IAMOT), 6-10 April 2008, 20 p.

[5] Altshuller, G.S.: "Creativity as an Exact Science: The Theory of the Solution of Inventive Problems". Gordon and Breach Science Publishers, ISBN 0-677-21230-5, 1984 (original publication in Russian - 1979).

[6] Mann D.: "Using S-Curves and Trends of Evolution in R&D Strategy Planning", the TRIZ Journal, July, 1999.

[7] Gibson N., Slocum M.S., Clapp T.G.: "The Determination of the Technological Maturity of Ultrasonic Welding", the TRIZ Journal, July, 1999.

[8] Gahide S., Clapp T.G., Slocum M.S.: "Application of TRIZ to Technology Forecasting - Case Study: Yarn Spinning Technology", the TRIZ Journal, July, 2000.

[9] Cascini G., Russo D.: "Computer-Aided analysis of patents and search for TRIZ contradictions". International Journal of Product Development, Special Issue: Creativity and Innovation Employing TRIZ, Vol. 4, Nos. 1/2, 2007, pp. 52-67.

[10] Wood F.B.: "Lessons in technology assessment". Technological Forecasting and Social Change, v. 54, 1997, pp. 145-162.

[11] Azzone G., Manzini R.: "Quick and dirty technology assessment: The case of an Italian Research Centre". Technological Forecasting and Social Change, v. 75(8), October 2008, pp. 1324-1338.

[12] Salamatov, Y.P. "System of The Laws of Technical Systems Evolution". Chance to adventure. Karelia Publishing House, Petrozavodsk, 1991, pp. 7-174 (in Russian).

[13] Gero, J.S. and Rosenman, M.A.: "A conceptual framework for knowledge based design research at Sydney University's Design Computing Unit". Artificial Intelligence in Engineering, v.5(2), 1990, pp. 65-77.

[14] Pahl, G., Beitz, W.: "Engineering Design. A Systematic Approach". 2nd edition, Springer, ISBN:3540199179, 544 pp., 1996.

[15] Hirtz, J., Stone, R. B., McAdams, D. A., Szykman, S. and Wood, K. L.: "A Functional Basis for Engineering Design: Reconciling and Evolving Pre-

vious Efforts”. NIST (National Institute of Standards and Technology) Technical Note 1447, February 2002.

[16] Khomenko, N., De Guio, R., Lelait, L. and I. Kaikov: “A Framework for OTSM-TRIZ Based Computer Support to be used in Complex Problem Management”. International Journal of Computer Application in Technology (IJCAT). Volume 30 issue 1/2, 2007.

SECTION II.
TRIZ SUMMIT ARCHIVE

G.Altshuller, M.Rubin

What will happen after the final victory

Eight ideas concerning nature and technology

1987.

Let us not be carried away by satisfaction
Concerning our victories over nature.
It will take its revenge for each of such victories.
Frederick Engels. Dialectic of nature.

There are three main types of destructive influence of modern technical civilization on nature:

1. Criminal destruction of nature. It is the most explicit form of destroying natural environment. For example, setting woods on fire: hundreds of thousands hectares of wood perish in fires. Drainage of wastes from the tankers - in an open sea, secretly. Drainage of wastes of chemical and oil processing industry into rivers and lakes. Exhaust of noxious gases into the atmosphere despite all sanitary norms.

Inadmissibility of criminal destruction of nature is to some extent understood by society. The laws protecting nature from barbaric annihilation are constantly getting more and more strict.

There are reserves for protection of nature here: in general, still more stringent laws could be passed any time and a more stringent control over the adherence to these laws could be arranged.

2. "Legal" destruction of nature. The laws enable to destroy nature within the scope of certain limits, which purport to be safe for nature. After a lapse of every 10—15 years it becomes clear that these limits should be made more stringent: the norms are revised, made stricter, however in most cases it is already too late... It seems that very stringent norms had to be introduced at once. However, it would destroy the foundations of engineering civilization. Thus, in order to do away with photochemical smog in Los Angeles, it is necessary to forbid car traffic. Who would venture to do this? Legal destruction of nature is dictated by economic feasibility. It is difficult to change the notion of "feasibility": our idea of human values has to be modified. Now in the discussion "a car in the center of the city or a forest in the outskirts of the city" the car unconditionally wins...

Of course, there can be such "legal" destruction, which is not dictated by a strict economic necessity. This is a situation around the cellulose resources in Baikal district. The area of drying woods in Baikal district currently constitutes half million hectares, fishes die, the chemical composition of water changes... Obtainment of a certain additional amount of cellulose outweighs - as a factor of "feasibility" - the value of unique natural region.

Sometimes "legal" destruction of nature develops not directly, but by chain. In the law there is no prohibition to construct tankers of higher water displacement. However, a big tanker means a lot of oil concentrated on one and the same ship. And a sea will remain a sea - with all its dangers, and while the wreck of a small tanker is a dangerous accident, the wreck of a supertanker, which carries half a million or a million tons of oil is a catastrophe of planetary scale.

Aviation develops intensely: the number of airplanes grows, power of motors gets enhanced and the height of air flights increases. Greater and greater amount of harmful gases is thrown into the atmosphere - again on a legal base. The law does not see the growing danger of destruction of ozone layer in the atmosphere. At the same time ozone protects all creatures living on Earth from vicious ultraviolet rays.

Power of laser devices grows – the law never thought about possible consequences of action of powerful laser rays upon the atmosphere...

The laws try not to infringe the interests of economy. The laws don’t look into the future. It explains "legal" destruction of nature, which is becoming more and more powerful.

There are certain reserves here. The legislation could be more severe and more far-looking. However, these reserves are not so great: it is impossible to significantly break economic development and scientific-and-engineering progress.

3. Necessary elimination of nature. The number of population of our planet dramatically grows. New cities are needed as well as new plants and factories, new roads... New place is needed for engineering world. This place is nowhere to be borrowed from, it has to be taken from nature.

Let us suppose that the criminal destruction of nature is put an end to, wise and thoughtful laws, predicting distant future are issued, thus putting an end to wasteful development of economy, no obviously criminal destruction of nature takes place and no “legally refuted squandering of natural resources” is observed. Nevertheless, engineering will quickly elbow out nature: the place is needed for increasing population, place is also needed for engineering devices that would provide for high level of wellbeing of the rapidly growing population of the planet.

Let us imagine something impossible: already now efficient measures are being taken to decrease the rates of growth of the Earth population. In the most ideal case the results of these measures will become tangible in three or four generations. And this period of time is more than enough for practically complete substitution of nature by engineering.

Idea 1. The modern age is still characterized by shaky equilibrium of nature and engineering, however potentially nature is doomed, it will inevitably be elbowed out by rapidly developing engineering – even if barbarous extermination of nature (illegal and “legal”) is stopped.

The thought that even in the ideal case nature will be inevitably elbowed out by engineering meets with a strong psychological resistance. “It cannot happen, because it can never happen...”

The most widely spread argument is: there is still a lot of free space on our planet. In fact, the cities, manufacturing plants, as well as roads occupy only 3.2 per cent of land of our planet; ploughed fields and gardens – 10.6; pastures – 23.2; water reservoirs, rivers and lakes – 2.4 per cent. Totally – 39.4 per cent of available land. It could seem that it is not so much – less than one half. However, what do the remaining lands look like? Glaciers, sands and lands spoiled by the humans - 15 per cent; the woods - 30; deserts – 6.9; swamps - 3; tundra – 5.5 per cent.

The territory has been already completely divided! The growth of territories, which are intended for ploughing earth has already stopped. The area of woods annually decreases by 1.7 per cent (i.e. by 0.5 per cent of the entire fund). These rates are catastrophic: if there are no woods and oceans, there will be no oxygen in the atmosphere. What if we start to develop deserts? It is a very expensive and slowly progressing business! Let us take Kara-Kum channel. Concrete bed was very expensive to construct – the channel has an earth bed, which leads to the loss of 17 per cent of water passing through it. 170 thousand liters of water per second! The level of ground waters is raised and salt lakes are formed… The consequences are predictable only in one respect: no good is to be expected. Drying the swamps? The ecological equilibrium is violated, many kinds of plants disappear, some species of animals die... Everything is necessary – deserts, swamps and forests. What could have been taken from nature, has been mainly taken already...

Another argument: engineering, in the course of evolution, has a tendency to miniaturization, modern computers are thousands times smaller than the computers of the first generation. Yes, the operation elements of modern machines become more compact, their productivity per unit of weight and volume increase. However, this particular circumstance creates conditions for a dramatic growth in the number of machines produced: the volume is thousand times smaller, however the number of operation elements is thousand times greater and this or that kind of machines occupies thousand times more space on Earth, and the area required for production and servicing of micro-engineering grows accordingly. .

One more argument: technology could be transferred to space... However, this hope remains in vain! The conquest of space requires especially intensive growth of productive areas on Earth: new mining, processing, engineering enterprises. New cities, roads and spaceports are needed...

Nature is doomed. Even if it treated with the highest degree of carefulness, it will still be elbowed out by engineering. Even if we try to brake the evolution of engineering, the braking distance will be too long.

After three or four generations humanity will live in the world, in which nature will find itself in the backyard. The woods will pass through a stage of sanctuaries, then parks, gardens and then will be converted into non-attractive small public gardens. The ploughed fields will be semi-greenhouses. The atmosphere will get dirty up to such norms, which are inadmissible for the human... Maybe, it will happen not in three-four generations, but in five or six ones – what's the difference?! Another thing is important: it will inevitably happen, it will happen irrevocably, at the most careful attitude to nature, because it has been programmed already. We won't have any time for changing our life style, we won't be able to understand that the natural values are immeasurably higher than the "automobile-related values". No time is left for us to change our mentality and to save nature.

But still there is – there is! – time to face the truth and to get ready for living in a new world – the world of engineering.

Until now engineering dealt with so-called nature-less "micro-worlds". Artificial technical worlds were created in a restricted space: in submarines, in the cabins of the aircrafts, inside spaceships, to some extent – in workshops and in living rooms. However, civilization was mainly both of natural and technical nature. Nature was not eliminated, it operated jointly with engineering (and vice versa – engineering was functioning jointly with nature). Nevertheless, of great importance for the evolution of engineering are the tasks, set forth for the purpose of creation and improvement of nature-less "micro-worlds". They were one of the main actuators of engineering progress. Creation and functioning of great nature-less technical world will demand the solving of a number of engineering problems. For long time the needs of the new world will become the main factor preconditioning the future engineering progress.

Idea 2. Design of nature-less technical world (NTW) will enable to early identify the problems, which are of vital importance for existence and evolution of civilization and to get ready for solving these problems in time. Therefore, design of NTW will yield a guideline not only for social, but also for engineering forecasting.

Now we richly pay for the realization of our wishes with the “hard currency” of natural values. When we wanted to have millions of cars, nothing prevented us from it! Thousands of square kilometers of natural space were occupied by highways, nature was ruined by oil rigging and oil processing... Development of publishing activities led to the cutting of millions of trees, while wood is a source of oxygen...

It is impossible to transfer such world to nature-less conditions is impossible: there is nothing to effect the payment with. NTW should be based on other principles.

The very thought of inevitability of a world without living nature frightens our imagination. However, let us try to switch off our emotions for some time and to sensibly evaluate the possibilities of creating NTW.

Essential implementability of NTW depends first of all, upon the possibility or impossibility to use engineering methods for doing things, which nature does “automatically” and “free of charge”: to provide humanity with oxygen, drinking water, food, energy and materials… A list of nature’s gifts could be endless... Nature “automatically” and “free of charge” supplies humanity with optimum factors of existence: force of gravity, atmospheric pressure, lighting, temperature and air humidity.

Nature tirelessly destroys wastes. It provides for necessary rhythms: change of the seasons, daily cycle, biological rhythms, etc. It offers a reliable protective complex: protection from radiation, from poisonous rays, overheating and overcooling...

Within the frames of this article we shall touch upon only the issue of technogene support of three important functions of nature – supplying humanity with oxygen, fresh water and food.

"Design of NTW", "life support in NTW" - when the problems are stated in such form, an impression is created that NTW is something the erection of which could be begun and ended, however, we are already living in NTW.

Practically we stay indoors all the time: our home, tube, bus, workshop or other room intended for work, shops, theatres and gym halls. We don't drink water from water wells and biologically clean products are a rarity in our food ratio...

This is the first, initial phase of NTW, implying that the milieu of habitation is to a large extent nature-less, however the support of life is still based on natural systems.

The next phase is an intermediate one: part of life-supporting functions will be performed artificially, while a part of them will imply the use of natural processes. And the "artificial" part will constantly grow.

Finally, the concluding phase: ideal NTW – the world in which the degree of independence from nature (to be exact, from everything, which remain from nature by that time) is rather high (about 90 percent) and continuous to grow.

Creation of NTW is a long process, including fundamentally different phases. Full (ideal) NTW is separated from us – people living in the epoch of "early" NTW, by long centuries. However, it would be reasonable to refer initial estimations concerning life support of humanity life to full NTW – ther process of its formation could appear to be a rapidly accelerating process. Another "preliminary" thought, which precedes the process of estimation is as follows. According to forecasts of United Nations by 2080 the population of Earth will stabilize and will constitute no less than 8 billion people. By this time the output of all power units will constitute approximately 7•10*10 kW. Based on this data we shall perform our calculations.

Supply of oxygen.

In order to be able to breathe, one human being needs 550-600 liters (0.83 kilogram) of oxygen daily.

In 2080 the entire humanity will need 1.6 • 10*15 liters, while the needs of technology (based on the modern structure of oxygen consumption) will amount to 6-9•10*17 liters. If oxygen is obtained from the contaminated air through deep cooling 0.0004-0.0016 kW-hours are consumed per liter of oxygen. For the entire humanity this value will amount to 1.9•10*9 kW annually or 0.27 per cent of entire energy produced in the whole world.

In order to provide for a closed cycle, it is necessary to obtain oxygen from carbon dioxide, which is produced in breathing. In the decomposition of carbon dioxide through electrolysis using solid electrolytes every liter of oxygen obtained during an hour, requires a unit, the power of which is 6-8 W. Every person needs a unit, the power of which is 150 W, the entire humanity needs 1.2•10*9 kW or 1.7 per cent of energy, generated in 2080.

Provision of humanity with oxygen in NTW is a relatively non-complicated task, if only breathing is meant. Another thing is the artificial provision of oxygen for technological needs: the amount of required energy is two times greater than the would-be entire energy generation of the world

Engineering should become oxygen-free. First of all it means the rejection of coal combustion, as well as of combusting oil products and gas. The flow of new inventions is necessary, which are aimed at the transition to oxygen-less processes. Such inventions are non-profitable today. However, they have to be made and developed right now. To-morrow it will be late.

Supply of water. The norm of water consumption per one human daily constitutes 2.5 liters, under the conditions of desert – up to 10 liters.

In big cities the norm of water consumption for household needs is approximately 500 liters. With regard to consumption of water for industrial needs every human consumes up to 6500 liters of water daily. Long-term space flights on spaceships and orbital stations presuppose the daily norm of water consumption of 2.2-2.5 liters of water per one human, besides, from 6 to 25 liters of water is consumed daily on sanitary and hygienic needs. Many physical, chemical, electrochemical and biological methods for obtainment of water through desalination of sea water or regenerating it from the wastes of human life, from used sanitary and hygienic or technological waters. Consumption of energy in this cascade could constitute 8-10 kW-hours per cubic meter of water.

Function	Daily norm per human (liter)	Annual consumption by entire humanity, (liter)	Power of units at energy consumption 0.01 kW-hour per 1 liter	Amount of energy in % from entire energy generated in 2080.
For physiological needs	3	$8.76 \bullet 10^{12}$	$1 \bullet 10^{7}$	0.014
For household needs	from 150 to 500	from $4.38*10^{14}$ to $1.46*10^{15}$	from $5*10^{8}$ to $1.7*10^{9}$	from 0.7 to 2.4
For industry and agriculture	6500	$1.9 \bullet 10^{16}$	$2.2*10^{10}$	30.9

The Table includes the data on energy consumption at different options of water consumption. The spacemen are satisfied with 28 liters of water daily and less, therefore, it is possible to anticipate the decrease of daily water consumption for household purposes at least to 150 liters per one human None of the variants for meeting the demands for water causes any special trouble – of course, except for the needs of industry and agriculture: intensive readjustment for non-water technology is necessary here.

General expenditures on energy supply will probably be no higher than 10—12 percent of generated energy, out of which only 0.014 percent of generated energy account for life supply. Water supply currently takes 0.7 percent of total generated energy.

Food supply. Energy value of nutrition of one person should constitute 3000 kilocalories daily. The annual demand of humanity is $1.16*10^{9}$ kw of “food” energy. In order to calculate the entire energy demand it is necessary to know the efficiency of system, which produces food goods. When natural systems are used (gathering, hunting) several times less muscular energy is wasted than is contained in the obtained food, however, this method requires the areas, which are 20 000 times greater and 33 times larger number of man-hours than is required by the modern technology of producing food. Saving of areas as well as time and technology decrease the efficiency of food obtainment. For example, in England 1 kilocalorie of wasted technological energy corresponds to 0.4 kilocalories of produced goods.

There are two mutually opposite tendencies in the manufacturing of food products. On the one hand, the resources of nature are constantly decreasing, which leads to the reduction of efficiency. On the other hand, technology is improved and simplified, which intensifies the effect from the energy wasted during the process of food production. For example, among the food production technologies, which are extensively spread nowadays, there is one technology, which completely excludes the stage of cattle breeding – vegetable protein is artificially converted into a protein, which is of the same value as animal protein.

No technology is known so far, which would enable to provide for a closed cycle of reproducing food products without any elements of natural systems. In the nearest future the tendencies of evolution will consist in the use of simpler natural systems with their symbiosis and their technological processes. Instead of ecosystems their fragments are used, plants are used instead of animals, cellular tissue and bacteria are used instead of plants. At the same time technology of artificial food synthesis is developing. In all cases the efficiency of foods production will be no lower (should not be lower!) than 3-4 percent. In this case $2.9*10^{10}$ kW or about 40 percent of entire amount of generated energy will be required in order to provide humanity with food. Agriculture currently consumes 10 percent of energy.

Fundamentally, provision of NTW with basic products necessary for supporting life is almost completely dependent upon “energy payment”. Even the current level of technology guarantees such power industry, which is necessary and is sufficient for erecting an NTW, which embraces 8 billion people. The population of NTW civilization will have to reject automobile transport and aviation transport (in their modern embodiment, which is associated with huge consumption of oxygen, water and precious products), however, it will be possible to live in NTW - to breathe, to drink, to eat.

Idea 3. Technologically (from the viewpoint of power resources) creation of NTW is already implementable at the modern level of technology development. This conclusion is partly sorrowful. Because the most powerful factor, which would hinder the dying of natural world. Sorrowful as it might seem, it is possible to survive without nature by creating NTW. And the nature will be quickly done away with...

Our formulae are preliminary estimations of minimum minimorum. At the same time the natural world is constructed with a colossal excessiveness. This excessiveness, from the viewpoint of the natural world itself will procure high reliability to it. And from the point of view of the human or, (if it is possible to say that) from the viewpoint of science and technology, excessiveness yields a possibility of cognition and development. Exploration and restructuring of the world are associated with mistakes. In the world, which is devoid of excessiveness, such mistakes would mean a catastrophe. The world – weather natural or nature-less needs excessiveness.

One example: the fate of Kara-Bogaz-Gol. In 1982 a 200-meter straight between Kara-Bogaz-Gol and the Caspian Sea was occluded by the dam. Such decision was taken because Caspian became shallower, which was explained by huge water extraction from Volga. Later on, when the salts of Kara-Bogaz, which had once been a precious raw material were converted into a poison carried throughout huge territories, it appeared that the losses from the drying of Kara-Bogaz-Gol are higher than the losses from Caspian becoming shallower. Concurrently it became clear that the level of Caspian Sea does not decrease, but, on the contrary – increases: the main factor preconditioning its level were tectonic processes of its bottom, but not the evaporation of Kara-Bogaz-Gol and not the water extraction from Volga... In NTW, which is not characterized by excessiveness, such a "mistake" would mean the global world catastrophe or, at any rate, an extraordinary disaster. Even significantly greater mistakes could be easily endured in the world with high excessiveness...

The design of NTW with a sufficiently high degree of excessiveness at a first approximation is reduced to the creation of energy stores and of restricted number of most important substances. Such a task is beyond the frames of reality. And the word “store” does not mean unused “store”.

In winter the mountain village Kurush in Dagestan is completely separated from civilization. Since Ancient times the fences near the houses are made of manure. If it appears by the end of winter that the amount of fuel is insufficient, the fences are gradually disassembled and their parts are used for heating. In summer these stores are renewed. In 1962 an analogous solution was put forth by the American company “Grumman Aircraft”: to manufacture part of internal partitions of the spaceships “Appollo-C” of compressed food mixture. Another option for creating stores: furniture, which includes Berthollet’s salt. When such furniture is being combusted, salt is produced.

Idea 4. It is fundamentally possible to create an NTW of high excessiveness (NTW-HE). A number of new inventions will have to be made and implemented. A higher degree of caution in exploration and restructuring of the world will also be necessary. Taking the accelerating tempos of evolution of science and technology, it should be supposed that the possibility of creating NTW- HE will manifest itself in 80—100 years. The very idea that it is possible to create NTW or even NTW- HE for some time, does not already mean a world of joy, as they say. The human needs peace for very long times, practically forever. The human should have a feeling that peace will be forever. Only in the eternal world stimuli will appear for continuation of progressing succession of generations, to preservation and evolution of civilization.

No engineering means will provide for eternity of NTW. This is a mostly social problem, provided that the construction of the WORLD is being discussed, not the construction of a well-equipped and long-term cell.

Idea 5. Socially stable and evolving (SSE) NTW (SSE -NTW, SSE -NTW-HE) should be a world, the cognition of which is inexhaustible. The beauty of this world should also be inexhaustible. Only such world will be eternal.

It is easy to provide for inexhaustibility of cognition is rather easy, for example, through the studies of micro-world (the depths of the substance) and of macro world (the Universe). It is much more difficult to create a world, which is inexhaustible from the standpoint of beauty. “Stores of beauty” is an indicator, in terms of which technology is most inferior to nature. As a rule, engineering systems acquire inherent beauty at the very last stage of their existence (this is, for example, the beauty of tea clippers or of wood architecture). “Technical beauty” is usually understood in the narrow sense – as a functional beauty (aerodynamic shape of high-speed means of transport) or such beauty, which imitates nature.

In 1982, when the work on the topic «NTW» started, we once went round the shops of electric goods, which operate in Baku. Twenty types of electric chimneys were on sale. 18 of them naively and roughly imitated “the burning of wood”. Two electric chimneys (the least expensive ones) were purely functional – they had the form of primitive electric heaters. Even the patent literature did not include a single invention, in which the beauty of physical effects, which are typical of engineering and are not used by nature, would be a constituent part.

The human being appeared and evolved in this world, which is exclusively beneficial in terms of cognitive ability and beauty. This is one of the main reasons for the humanization of the human. However the reverse process will be characterized by the same rate (it will flow even quicker!), if the mysterious character and the beauty of the world are exhausted.

Nature is characterized by a colossal “store of beauty”. In NTW it won’t be possible to create such a reserve. Inexhaustibility of beauty in NTW could be provided for only through a possibility of its constant generation and evolution.

Let us clarify this thought. Prior to creation of music there had been only natural noise: whistling of the wind, sounds, which are usually heard in the forest, the singing of the birds, the rhythm of the tide… Music started with the imitation of voices of nature. However, very soon sound imitation grew into MUSIC. This is the only indisputable case, when “technical beauty” (in the meaning of “beauty, which was generated artificially") is stronger and more inexhaustible than the "natural beauty".

Idea 6. Creation of SSE-NTW and of SSE-NTW-HE is unimaginable without many new social and engineering inventions of the type "from noise to music". The solution of these very complicated super-tasks requires huge waste of effort and of time. Therefore it is necessary to begin today. To-morrow it will be late. In a natural world it could be possible to think using trial-and-error method. Colossal excessiveness of nature covered the costs from the mistakes and "forgave" the slowness and ineffectiveness of problem solving.

Idea 7. During the construction of SSE-NTW and SSE -NTW-HE and for the life within these worlds it is necessary to have a different thinking – efficient, excluding significant failures, taking into account the dialectic of quickly developing world. To a certain extent theory of inventive problem-solving (TRIZ) could be treated as a remote prototype of such mode of thinking. Or, to be more exact, the general principles of strong thinking which constitute the foundations of TRIZ.

We are living in the world, in which material consumption is the most important thing. During a century such world "ate up" and four fifths of its beauty (the figures are approximate – only the exact order of magnitude could be mentioned).

Idea 8. In constructing NTW it will be inevitable that the consumptive way of life should be rejected, material consumption will no longer be a primary life value. The main vector of NTW should be creative activity aimed at deepening and broadening of cognition,, at the enrichment of the world's beauty. The majority of NTW population will be involved in the creative activity. A developed system of training the creative ideology and teaching creative technology of thinking. A remote prototype of such system are modern TRIZ classes.

This problem article could be finished with a following traditional address to the reader: the authors are thankful to the readers for criticism and notes. However, honestly speaking, we already know what remarks and objections are in store for us. And our attitude to these remarks is rather sad than thankful. People got used (and this is logical) to natural world. The thought of inevitability of this world in

NTW causes utterly negative emotions. A list of objections that we heard, while the work on this article was progressing, would occupy more than one dozen of pages. These objections are based on emotions (or predominantly on emotions) and are practically irrefutable. What sort of answer could be given to such an assertion: “All this is rubbish! I can’t imagine, how it is possible to live in the world, in which there will be no sky, sea, wood and animals...”. Neither is there an answer to such an assertion: “People cannot live without wars and conflicts. And in NTW any military conflict will mean the end of the world...”.

There were times, when we tried to oppose logics, ratio and calculations to emotions. We tried to prove that transition to NTW already takes place and there is no way back. We delicately hinted at the fact that neither could primeval men imagine a life without caves and mammoths. We drew analogies between NTW and a ship: there are no feuds on ships, otherwise sailing would be impossible... All this remained “an empty sound”. The opponents persistently asserted: It cannot happen, because it did not ever happen!

It is impossible to argue with emotions, to cut them off or to stop them. “Green light” should be lighted for them, let them be freely expressed. Having come across the extraordinary (with something, which seems extraordinary) the human should exclaim a thousand times (or a ten thousand times): . «It can never happen!», so that he could finally think further about another thing: «What, if…?».

So, the authors are thankful to the readers for criticism and notes. And they promise to necessarily take all objections into account.

S.Litvin, V.Gerassimov

LONG-TERM FORECASTING OF ENGINEERING SYSTEMS EVOLUTION BASED ON VEA AND TRIZ

<u>Need for long-term forecasting</u>

Until recently there was no special need for accurate long-term forecasting: cost-based mechanism of economy functioning made the directors of enterprises live within the frame of current day. Nowadays the situation is changing. Several factors appeared, which determine the need for reliable long-term forecasting of engineering systems (ES) evolution.

1) Having obtained a substantiated forecast, the management of an enterprise will get an opportunity to more efficiently operate the capital investments and to work out prospective plans of production development. An accurate forecast decreases the degree of risk for an enterprise in mastering of new technologies and equipment.

2) Efficient long-term forecast enables to prepare in advance work specifications for the development of necessary materials, equipment, and accessories, thus providing dramatic reduction in time period required for technological preparation of production during further mastering of new technologies and equipment.

3) Accurate forecast will enable to attain the level of fundamentally new designs and technological processes, which would be significantly superior to the current world level. Even if the use of qualitatively new engineering solutions is extended in time, an enterprise would have some reserve regarding the engineering-and-economical performance characteristics of production facility. In this process, the use of new ES, the appearance of which was predicted in advance, may continue for a rather long period of time (dozens of years) until they become inferior to new world-level systems once again. A consequence of such increase in "service life longevity" of engineering systems will be a dramatic decrease of people, who deal with the design and creation of such engineering systems.

Classical forecasting methods yield an utterly low level of accuracy of long-term forecasts. According to different sources, the truthfulness (i.e. reliability) of long-term forecasts amounts only to 7-20%.

Classical forecasting methods

What tools were there in the inventory of forecasters until recent times? First of all, all methods of forecasting (and nowadays over 100 such methods are known) could be broken down into two major groups: normative methods and research methods. Normative methods are used mainly for short-term forecasting and are essentially the planning methods. Different variants of constructing "goal-means trees", prospective graphs, and so forth refer to this group. The most widely known method from this group is the PATTERN system - assistance to planning with the use of technique for assigning coefficients of relative importance. The disadvantages of all normative methods are subjective character of evaluation and ambiguity of forecasts.

The methods of research forecasting, in their turn, are subdivided into three groups.

Analogy-based forecasting methods. As it is clear from the title, these methods are based on analogies in structure and evolution of different ES between themselves, as well as engineering, biological and other systems. The main disadvantage of these methods consists in the study of purely external analogies, rather than the objective trends in the evolution of different systems.

Extrapolation methods are based on studying and projecting into the future of the tendencies of evolution of analyzed ES. These methods forecast the quantitative growth of ES characteristics with mathematical accuracy, but they are in principle unable to predict any qualitative jumps.

And finally, the methods of expert evaluations are based on identification and analysis of opinions of qualified specialists on an ES, which is an object of forecasting. Even the best of these methods, like the famous "Delphi" method, cannot offer an accurate long-term forecast. Moreover, it happens rather often that the opinion of a team of specialists only deepens the "psychological inertia" of old conventional engineering solutions.

All above-named methods are characterized by a number of common disadvantages, which reduce their efficiency and in the case of long-term forecasting actually discredit themselves completely. Let us indicate the main disadvantages of known methods for long-term forecasting.

1. All these methods are based on selection strategies (trial-and-error method); in the best case this selection strategy is objectivized by the identification of tendencies, external analogies, application of mathematical statistics, and so forth.

2. Not particular engineering solutions are forecasted, but only the general direction of evolution.

3. Only the quantitative changes within the frame of existing design and technology are forecasted, not the qualitative jump.

4. Forecasting is oriented at the current world level. Fundamental contradictions, which retard the evolution of ES to be forecasted, are always identified with a significant delay. It is the "healing of ES diseases", which is usually forecasted, not the control of reasons for these "diseases".

5. Forecasting is often non-systematic and has a one-dimensional character - it embraces only certain characteristics and tendencies.

6. Forecasting of new functional opportunities of ES is practically absent. And it is just these new functions that predetermine the qualitative jump in ES evolution.

Forecasting on the basis of TRIZ and VEA

The application of TRIZ based on objective trends of engineering evolution, as well as the use of analytical inventory of VEA opens new opportunities for efficient long-term forecasting.

For example, since the end of 1940-ies G.S.Altshuller, applying the trends of evolution of ES and ARIZ, has formulated a number of engineering ideas, which in essence are long-term forecasts of evolution of analyzed ES. Here are only several examples of such forecasts.

1. Costume for mine-rescue men (use of liquid oxygen for respiration and cooling) - 1948.

2. Manufacturing of plate glass (melt tin instead of rollers) - 1959.

3. Separator for oil products (liquid ammonia instead of disks and brushes) - 1962.

4.Drying of cement (melt metal instead of chains) - 1968.

5. Ice-breaker (semi-submersible ship) - 1968.

20-30 years after these forecasts were recorded, they started coming true one after another. It is possible to state a fact, which is astonishing for long-term forecasting: all forecasts of Altshuller have been fully come true or will obviously come true in the nearest future.

At the end of 1970-ies, the first publications on TRIZ-based forecasting appeared, and then this work became rather extended. G.S.Altshuller, B.L.Zlotin and A.V.Zusman, Yu. P.Salamatov and I.M.Kondrakov as well as a number of other TRIZ specialists gave not only theoretical recommendations on TRIZ-based forecasting, but also (in keeping with TRIZ tradition) particular forecasts on the evolution of heat pipes, submersible pumps and other systems. The authors of this publication also conducted similar work. Further recommendations are based on our experience of such work.

<u>Principles of long-term TRIZ-based forecasting</u>

Let us first define more precisely the meaning of the term "long-term forecasting". It is usually understood as obtainment of a forecast for a rather distant future - 10-15 or more years ahead. However, from the standpoint of TRIZ, the range of the forecast is by far not a time-related notion. For example, the history of engineering shows that the implementation of some fairly simple engineering novel idea may often last for many years (for example, structures made of shape-memory alloys), while at the same time some fundamentally new ES are introduce into practice rather quickly (e.g., television, laser).

So, what do we understand under the long-term forecast of evolution of a particular ES? What are the main principles of long-term forecasting (LTF) from the standpoint of TRIZ and VEA?

1. LTF should be based on objective trends of ES evolution within the system analysis of an object of forecasting, i.e., based on all types of analysis - namely, component analysis, structural analysis, function analysis, parametrical analysis, and genetic analysis.

2. LTF should lead to a new operation principle of ES, provide for a qualitative jump, not for modernization within the frames of old design and technology.

3. Long-term forecast should be backed up by specific engineering solutions. It is not sufficient to say that a system will be, let us say, more dynamic, it is necessary to demonstrate, how this effect would be attained. Only such approach guarantees the accuracy and truthfulness (reliability) of the forecast.

4. LTF should bring ES to such level of characteristics, which are significantly superior to modern world level. In this case, if the forecast comes true (even in case the implementation periods are rather long), a substantial reserve of characteristics is left to the developers of a new ES, and hence a reserve of time for manufacturing the "advanced products". It is clear that for such a dramatic breakthrough, long-term forecasting should be able to state (identify) and solve the problems, which are not ordinary, but rather advanced, of prognostic nature - the ones, which are not present in the existing ES.

5. LTF should be directed not at the elimination of disadvantages of existing ES, but at the identification and elimination of reasons for these disadvantages. In this case forecaster has to perform such a deep analysis, which enables to identify the deep physical constraints retarding the qualitative evolution of ES.

6. Long-term forecast should be multi-dimensional - in terms of all trends of engineering evolution. The forecast in terms of only one particular trend is more often than not turns out to be wrong.

7. LTF should discover new unexpected functional potentialities of ES. The human and humanity don't even guess what else could be demanded from this sys-

tem. However, each ES is a potential carrier of a multitude of latent functions, which are based both on available resources of ES and on potentialities of a new operation principle, which is obtained as a result of LTF.

Scope of Work on Long-term Forecasting for ES

1. Analysis of the prototype ES.

1.1. Component analysis - study of ES hierarchy and composition.

1.2. Structural analysis - study of interrelations between ES components.

1.3. Function analysis.

The identification of all ES functions (including functions performed in respect of supersystem objects), of ES relations with other ES of different rank, with the environment, and with humans. The analysis of trends in the changes of external functions and requirements within the ES being studied. The analysis of alternative variants of performance of external functions and so forth. Construction of a functional model of the ES.

1.4. Genetic analysis.

The analysis of the history of ES evolution, identification of evolutionary trends. Study of the non-uniformity of ES components evolution. Identification of new features and properties, which emerged due to changes made in the ES.

1.5. Parametric analysis.

The identification of physical limits of ES evolution, which determine key contradictions preventing further evolution of the ES. These "fundamental evolutionary limits" are determined by physical, economic, environmental and other factors.

1.6. Formulation of prognostic engineering contradictions of the 1st type (PEC-1) - i.e. the engineering contradictions determined by fundamental limits of evolution of the prototype ES - based on results of work described in items 1.1. - 1.5.

2. The analysis of the prototype in terms of trends of ES evolution.

2.1. The determination of ES position on the "evolutionary line" - i.e., on the the graph reflecting the changes in the main ES characteristics in time.

2.2. Applying the following trends (identified in TRIZ) of ES evolution, their mechanisms and specific techniques to the ES being studied:

2.2.1. Trend of Increasing Ideality.

2.2.2. Trend of Increasing Dynamicity.

2.2.3. Trend of Coordination of the Parameters of Interacting ES.

2.2.4. Trend of Increasing Su-Field Nature (degree of structure organization).

2.2.5. Trend of Increasing Completeness of the ES Parts and Components.

2.2.6. Trend of Increasing Universality

2.2.7. Trend of Increasing Degree of "Emptiness".

2.2.8. Trend of Transition to the Supersystem.

2.2.9. Trend of Transition of the Working Members of the ES to the Microlevel.

2.3. Formulation of PEC-2 of the type "according to the trend, the system should be (specify a state, a feature, or a new property); but it would lead to inadmissible worsening of (specify the undesirable effect)" based on results of work described in items 2.1. - 2.2.

3. Functional Ideal Modeling (Trimming) of ES Components of the Upper Hierarchy Level of the ES.

3.1. Formulation of Trimming Conditions.

3.2. Construction of the Functional Ideal Model.

3.3. Formulation of prognostic requirements to model components.

3.4. Formulation of PEC-3, which provide for the implementation of the model.

The essence of PEC-3: how to provide for the fulfillment (or even overfulfillment, i.e. a qualitative jump of parameters) of the external functions of ES using the minimal number of components left after trimming?

4. The analysis of possibilities for the employment of the set of known physical, chemical, geometrical, and biological effects for the performance of the external functions in a new way.

The formulation of PEC-4 of the type: "employment of this effect drastically increases the efficiency of function performance, but it also leads to inadmissible worsening of (specify the undesirable effect)".

5. The identification of an a priori supereffect, i.e. of additional potentialities for supposed resolution of prognostic EC.

5.1. The identification of changes that would take place in an ES due to PEC resolution: enhancement of the functional potentialities of the ES; emergence of new features, properties, and parameters, which comprise a potential base for new possible functions of the ES; possible undesirable consequences of PEC resolution.

5.2. Correcting the set of PEC based on the results of item 5.1: elimination of a part of the problems as a result of the supereffect without solving these problems; reformulation of remaining problems; formulation of new problems on the basis of the negative supereffect (PEC-5, i.e. an ahead-of-time statement of problems that will appear in case the problems of the preceding layer are solved).

5.3. The identification of the key PEC, the resolution of which would give the biggest number of additional positive effects.

6. Aggravating of the identified PEC to the maximum degree possible.

7. Resolution of the key PEC by means of TRIZ.

8. The identification of the supereffect from the obtained solution (similarly to item 5).

9. Repetition of procedures described in items 6 - 8 for all subsequent key PEC.

10. Coordination (with one another) of individual forecasting lines connected with resolution of different PEC. Compilation of a summary forecast - a description of a new design and technology of the ES.

11. Working out of Work Specification for the development of required materials, equipment, accessories and so forth needed for the fulfillment of the forecast on the basis of the long-term forecasting results (forecasting preparation of production).

12. Compilation of a "business forecast" - namely, a plan of production reorganization required for the fulfillment of the forecast.

M.Rubin

Future Is Projecting on the basis of TRIZ.

1999 [7].

The present paper is devoted to the qualitative method of forecasting on the basis of the Theory of Inventive Problem Solving (TRIZ).

Inventions and solutions for major contradictions existing in a system are considered to be important turning points in the development of social, social-economic and social-technical (or engineering) systems.

A system of multilevel forecasting methods on the basis of multiscreen scheme of talented thinking (well known in TRIZ) has been worked out. It is based on a system of ideal forecasts: system, super-system and subsystem. Ideal forecast is formulated in the form of an ideal model or image, e.g. a city without vehicle, water without water pipe, and so forth. For certain social and social-engineering systems (e.g., a city) it is impossible to formulate the main function and hence an ideal model or image is designed (an ideal family, an ideal personality, etc.).

Proposed approaches and methods for forecasting and TRIZ-analysis of social-engineering systems have been employed several times since 1989. In particular, for forecasting the evolution for civilization, tidal energy systems, cities, municipal transportation system, water-supply system, scientific method and sports. TRIZ analysis for Tulomskaya Hydroelectric power station and Apatitskaya Termo-Electric power station and some other objects have been conducted.

Conclusions.

1. TRIZ methodology created by G. S. Altshuller can be applied for forecasting the evolution of social and social-engineering systems.

2. Application of TRIZ methods for forecasting requires their adaptation to specific features of complex social systems.

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[7] The Bulletin of Academy of Forecasting #1, Moscow, 1999. ETRIA WORLD Conference TRIZ Future 2002, Strasburg, 6-8 November 2002.

3. TRIZ-based forecasting requires professional skills in application of G. S. Altshuller's theory.

4. Proposed methods require testing and refinement. They can be used in combination with well-known methods for qualitative and quantitative forecasting.

5. TRIZ methods provide an approach to solving forecasting tasks on the basis of system evolution forecasts. They represent a scientifically valid approach to forecasting. When using them, forecasting becomes a non-stop iteration process of projection into the future.

6. Proposed methods are universal. They can be applied for forecasting and TRIZ analysis of social-engineering systems as well as for solving specific problems from different spheres of activity. Common methodological approach for the development of social-engineering systems is under development.

1. Forecasting on the basis of key contradiction resolving method. Contradiction and Ideality as Forecasting Methods

Any invention can be regarded as a forecast. In fact the process of inventing and working out high-quality forecast differs only in those fields where problems and resources available for solving these problems are considered. The methodological basis of solving engineering problems and working out high-quality forecasts is the same.

Resolving a contradiction means a qualitative step forward and fundamentally changes an image of a system. Automobiles and urban transportation vehicles appeared instead of carriages. Absolutely different systems appeared instead of city walls - namely, regular armed forces, frontier, air-defense, and so forth. It is quite possible to predict the appearance of such qualitative steps forward in system evolution using TRIZ technologies, which help to reveal key contradictions in the system, to conduct the analysis of available resources, and to find solutions corresponding general tendencies in systems evolution.

With social and social-engineering systems, it is not always possible to formulate the single main function, it can change together with the evolution of the system. For instance, at the beginning the main function of a town was to protect people. Nowadays different cities can have different functions, e.g. scientific, industrial and others. On the contrary, as a rule, it is possible to identify "main" key contradictions, which restrain the development of these systems. Key contradictions are usually not obvious - they are hiding in the shadow of other contradictions or problems. It is typical for key contradictions that well-known and generally accepted measures are taken to resolve them. For instance, the more an urban transportation system is developed, the more difficult transportation problems are encountered by people. The ideal solution consists in creation of "cities without transport", to be more precise, cities with information and other technologies, which eliminate the necessity of traveling within city territory. The ideal solution of a key contradiction may at first cause some kind of misunderstanding and necessity to solve a set of new problems.

Steps of Forecasting on the Basis of Key Contradiction Resolving.

One can identify several steps in working out a forecast on the basis of revealing and resolving contradictions.

1. Statement of problem, and selection of an object for forecasting.

2. Analysis of the selected object: components of a system, relationships, hierarchy, and changes.

3. Gathering of information collection. A search for available forecasts and published materials on object for forecasting.

4. Analysis of the information fund and identification of contradictions inherent to the chosen object.

5. Selection of main key contradictions, identification of contradictions of the type "the more you invest to resolve the contradiction, the more difficult to resolve it becomes".

6. Formulating the ideal solution: there is no object, but its function is performed.

7. Analysis of available resources.

8. A search for and analysis of possible solutions. Identification of a group of new problems.

9. If necessary, repeated analysis of the situation from item 1 taking into consideration the analysis conducted before and obtained solutions.

It must be pointed out that the methods in full can be used only on the basis of TRIZ methods and approaches.

The proposed method for forecasting isn't practically limited by the hierarchical level of social-engineering system under consideration: it can be a single engineering system, a social-engineering system such as a factory, a city, or a civilization as a whole.

2. Method of Systematic Forecasting on Multiple Levels

Forecasting on the basis of resolving key contradictions, as a rule, is not sufficient for working out a forecast of full-scale value. Changes resulting from resolving main contradiction of a system call for solving the newly arising problems. It is possible to make a full-scale forecast only within a systematic approach to consequences resulting from suggested solution. The main idea of systematic forecasting on many levels consists in the analysis and working out a forecast on the basis of system operator proposed by G. S. Altshuller.

The main steps of systematic forecasting on many levels are as follows:

1. A forecast is formulated on the basis of key contradiction solving method (or on the basis of any other method).

2. A transfer is made to the supersystem or to a subsystem from field "the future of a system" to filed "the future of the supersystem" or to field "the future of a subsystem". Thus it is determined how the supersystem or subsystem should look. Thus a forecast "on the vertical axis" is made.

3. Then an object of the supersystem or subsystem is chosen, for which a new forecast is formulated.

4. Then an analysis "by horizontal line" (the past, the present, the future) is made for the chosen object. It's more convenient to conduct this analysis step by

step according to approach described in the method for key contradictions identification and resolving

5. Results of forecasting by "horizontal line" and "vertical line" are then compared.

6. If everything was carried out correctly, a forecast by "horizontal line" should coincide with the one by "vertical line". To achieve this, forecasts should supplement, specify and extend one another.

7. A forecast by "vertical" and "horizontal lines" can theoretically contradict one another, (which hasn't, however, happened in our practice). In this case it is necessary to carry out a supplementary research, which can be carried out from items 1, 2, or 3. An additional gaining of information of specific research in a certain branch of industry may also be necessary.

8. Taking the obtained forecast as a basis, then we conduct the following analysis. In this process a transfer to the supersystem or subsystem may become necessary.

9. On the basis of the above-described procedure for repeated multi-step analysis, a system of interdependent forecasts is worked out.

3. From Social Engineering Forecasting to TRIZ-Analysis.

Paradoxical as it is, it's impossible to see an image of the real world in social engineering forecast worked out on the basis of the above-described methods. It's more of an ideal image, a project on the basis of which an edifice of the real world is built up.

TRIZ-analysis is necessary to pass over from building up an ideal forecast to making precise decisions on supplementary research work. This method allows taking into consideration various factors (e.g., specific situation, specific time, place, available resources, and so forth) to make one or another decision.

TRIZ-analysis is a tool that links and adapts a general forecast for a specific situation and specific resources. TRIZ-analysis is aimed at identification of main contradictions of a specific social-engineering system (a city, factory, group of enterprises, a commercial structure, etc.) and resolving the identified contradictions.

The above-described methods were used in working out a forecast for the evolution of civilization (G. S. Altshuller, M. S. Rubin "Eight Ideas on Nature and Engineering"), forecast for the evolution of cities, urban transport, tidal energy industry, water-supply systems, science, sport, and other social and social-engineering systems. Works on TRIZ-analysis were carried out for the Cascade of Tulomskaya Hydroelectric Power Stations in Murmansk region in Russia and for other enterprises.

V.Petrov

LAWS OF DEVELOPMENT OF NEEDS

Abstract

The article contains a description of trends of needs developed by the author and the methodology for using them[8].

Keywords: Ideallization, Law, Needs, Danamization, Coordination, Integration.

Introduction

The distance from the generation of an idea of an engineering system to the implementation of this idea and to the business success from the said implementation is rather long. It is known that only one out of 3000 ideas[9] gets developed to the stage of business success.

In connection with that, it is important not only to select the right idea, which corresponds to the trends of engineering system evolution, but also to correctly identify the need for this idea and the demand for it.

According to the research performed by Clayton Christensen and described in his book "Innovator's dilemma"[10], the demand for new marketable product changes in the following sequence:

1. First the consumers are ready to pay for better **functioning** (bold type supplied by V.P.);
2. After that they don't pay for better functioning, but they are ready to pay for the enhancement of **reliability** (bold type supplied by V.P.);
3. At the next stage they don't want to pay for reliability, however they are ready to pay for the **convenience of use** (bold type supplied by V.P.);
4. Further on, they don't need any conveniences, however they will readily buy a **cheaper** product (bold type supplied by V.P.).

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[8] Vladimir Petrov. Laws of Development of Needs. – TRIZ Futures 2005. 5th ETRIA Conference. November 16 to 18, 2005. Graz, Austria. pp. 151-174 conference. – The TRIZ Journal. http://www.triz-journal.com/archives/2006/03/02.pdf

[9] Greg A. Stevens and James Burley, "3000 Raw Ideas = 1 Commercial Success," in May-June 1997 Research Technology Managhement review.

[10] Clayton M. Christensen. The Innovator's Dilemma, Harper Business, 1997.

Christensen writes that it is of great importance for the manufacturer to get complete understanding of what the consumer wants at the given moment and not to try to offer the consumer reliable goods when the buyer is ready to pay for the convenience of use.

Thus, for the business success the manufacturer of the product should exactly determine, when the consumer is ready to pay for the enhancement of functionality, when – for the enhancement of reliability and when – for the enhancement of convenience of use, and when the consumer wants to get a cheaper product. These issues are very important for the forecasting of need. The laws of evolution of need are not analyzed in this article.

Analysis according to the diagram of Noriaki Kano[11] (Fig.1) is widely known. It is a model of studies of three different types of needs which can be expressed by the consumer with regard to goods and services. These three groups include: one group of "spoken" needs and two groups of needs, which remain "unexpressed" and which could remain unnoticed in the course of study.

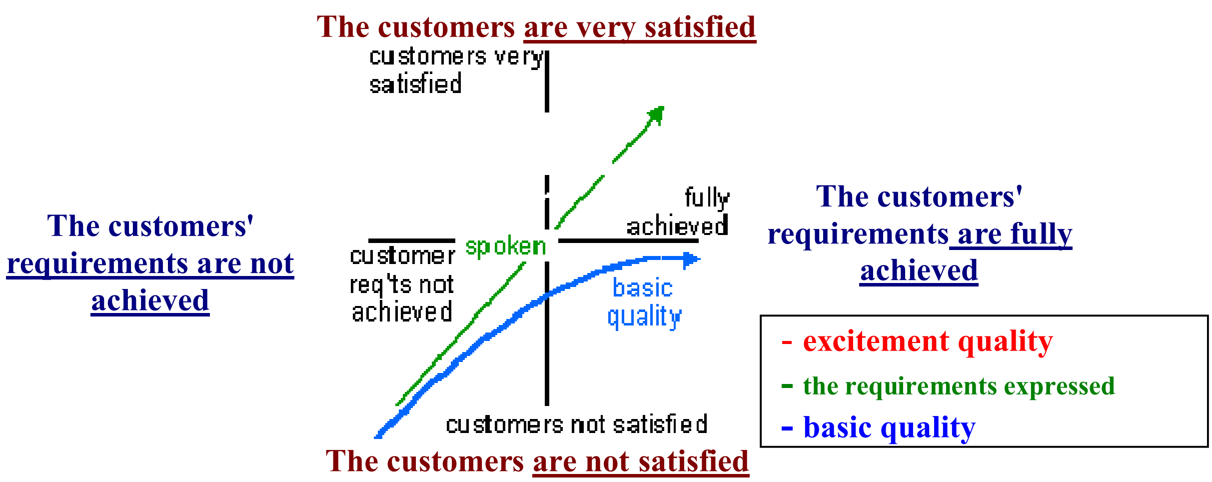

Fig. 1. Kano's diagram

[11] The presentations were made at the annual meetings of Japanese Quality Control Society, N.Kano and F/Takahashi "Motivator and Factor of Quality Hygiene " October.1979; N.Kano, Sh.Tsuji, N.Seraku, "Attractive quality and obligatory quality" (1), (2)" October. 1982.

"Spoken needs" are rather evident. They refer to such aspects of goods or services, which can be determined fairly distinctly.

The second group includes the first direction of "unexpressed" needs – these are the needs for "basic quality". They are also fairly explicit, however, they can be easily missed – especially when the consumer and the supplier relate to different "cultures".

The third group are "unexpressed" needs, about which the consumer even never thought. Kano called them excitement quality needs. They are characterized by features, which make the marketable product or a service more valuable for the consumer.

Kano's diagram enables to take three indicated kinds of needs, which makes it easier to develop a strategy of relations with consumers, however does not offer any way and tendency of needs evolution and first of all of "excitement qualities" evolution.

In this article we shall analyze the laws of needs evolution.

Based on the laws of needs evolution it is possible to determine the needs of the future and to identify, what functions and systems could be used for satisfying these needs. It also includes the identification of essentially new directions of engineering system evolution (pioneer solutions).

The most detailed description of human needs was proposed by Abraham Maslow [12]. He analyzes seven groups of needs:

1. Physiological needs (for food, clothes, lodging, relief from pain, etc.).
2. Need for safety (reliable protection from premature death, from physical injuries, loss of means for satisfying physiological needs, etc.).
3. Need for love and heart attachment to other people (friends, beloved, wife, children).

4. Need for respect of other people and for self-respect.
5. Need for self-expression and manifestation of individual endowments.
6. Need for learning and understanding the surrounding world, which contributes to satisfying the needs 1-5.
7. Aesthetic needs.

A.Maslow arranged the groups of demands in the order of their priority. According to his study the satisfaction of needs moves in the direction from group 1 to group 7. If the needs of the lower level, for example, the needs of group 1 are not satisfied, the human does not think about the needs of the next level. The pyramid of needs according to Maslow is shown in Figure 2.

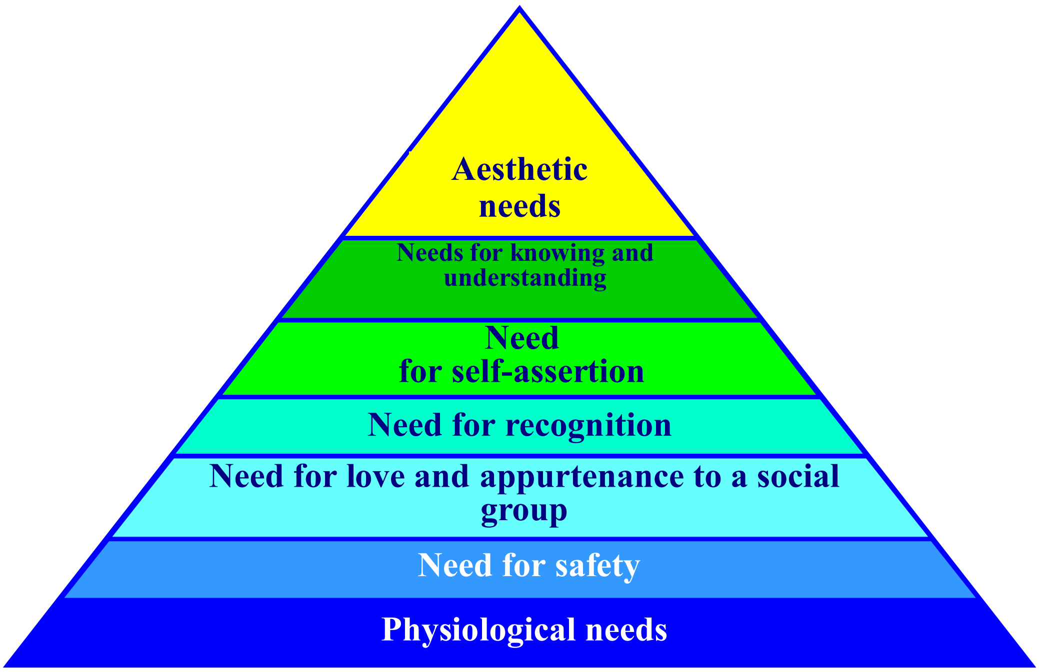

Fig. 2. Pyramid of needs according to A.Maslow

William Tally[13] uses the hierarchy of needs developed by Maslow, however, he asserts that there is no such dependence of needs. The needs of lower levels can be compensated for by the needs of upper levels. He proposed a meta-model of needs

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[12] Maslow A.H. Motivation and personality. Brandeis university. New York. Harper and Brothers, 1954. 411 p.

[13] W. Tally, Motivation and Personality, Rew. Ed. Van Nosiran, 1982.
W. Tally, Tally Needs Inventory, Monterey, Calif. Brooks/Cole, 1986.

and a cartogram of personality, which can be used for the evaluation of needs. An example of cartogram is shown in Fig. 3.

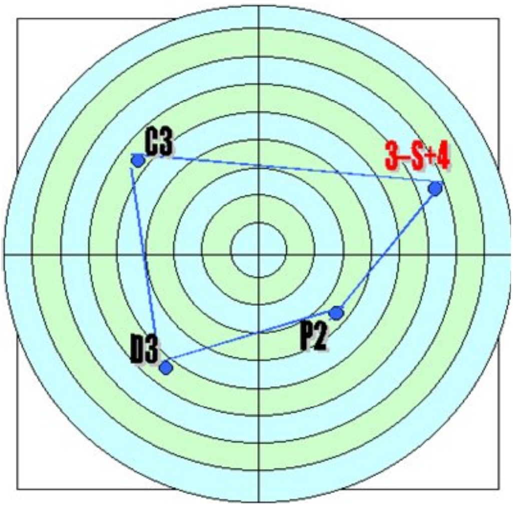


Fig. 3. Personality cartogram according to W.Tally

The laws of needs evolution are subjected to the **Trend of growth of needs.**

The general tendency of needs evolution develops from the satisfaction of **primitive needs** to the satisfaction of aesthetic needs. A.Maslow did not describe one more category of needs - **intellectual and creative needs**. We refer these needs to the highest needs of the human. The need for the elimination of human involvement in the processes of creating goods and offering services. As a consequence the process of constant increase in the amount of spare time of the humans and the need for occupying this spare time.

To primitive needs relate a need for food, sleep, protection from acts of elements and other humans, sex. The evolution of these needs leads to the increase in the number of different methods of satisfying them and to the enhancement of their quality.

Each of the types of needs is also characterized by hierarchical structure. One type of needs causes the appearance of another type, which in its turn, causes the appearance of a new one.

Example 1. Satisfying the needs for food led to the appearance of another need – for food procurement. This need caused the appearance of a need for procurement of food and cooking it. In its turn, it triggered the need for different methods of getting food from nature (hunting, search for plants and gathering them) and independent cultivation of food products (agriculture). Each of these kinds of needs leads to the appearance of next needs. Hunting requires the development of hunting methods and the appearance of means for hunting. They lead to the appearance of separate industries, producing means for hunting, which causes the appearance of another "embranchment" of new needs. The development of agriculture caused the foundation of specialized scientific centers and industries.

Individual kinds of needs often get integrated and a new branch appears.

Example 2. Thus, the consumption of food was integrated with the branch of spending spare time. Restaurants and other institutions of this type (dining places) appeared. Special rooms were required for them as well as equipment, entertainment programs, etc.

Therefore, the laws of needs evolution follow two directions: **appearance of essentially new needs and the development of existing needs.**

Example 3. The growth of the need "occupation of spare time" led, for example, to the creation of industry of entertainment. It includes different shows, game-playing machines, computer games, etc. All this leads to a need for developing appropriate engineering and technology, i.e., to secondary needs. Thus, the performances of modern pop-musicians caused the necessity not only for the modification of sound-reproducing equipment, but also to create new light effects. Now lasers and devices creating smoke effects are used alongside ordinary color organs.

It is possible to suppose that in future the equipment will appear which will be able to act upon other sensor channels, for example, the equipment generating odor, sensation of vibration and movement, variation of temperature, etc. with frequency and amplitude modulation. The performance of the described functions could imply the engineering systems which already exist and besides, new efficient systems will be created, which will use other physical, chemical, biological and geometrical effects.

Example 4. An example of a new need can be the generation of any sensations according to the human wish. This need could be satisfied using known means (hypnosis, alcohol, drugs). These actions don't always lead to adequate results and are not safe for health. The same need could be satisfied using new means, for example, the action of electromagnetic fields upon certain zones of the human brain.

This approach will enable to effectively control human health and mood and could become a new trend in the system of education, in art, etc. The information will be more versatile, since not only visual and oral sensor channels are going to be activated. Even today tactile information is extensively used for communication with blind people, since they cannot decipher information by the movement of lips and by the gestures.

In mobile phones it is possible to use vibration signal instead of sound signal ("ring"). Based on the same principle, it will become possible to create "phones" for deaf and blind humans. The information will be transmitted by changing the frequency and/or amplitude of vibration or dynamic modification of the surface, which will correspond to certain letters or words.

The use of odor can become revolutionary in the dissemination of information, in teaching, in the appearance of new kinds of art, different amusements, medicine, etc.

These needs will cause the appearance of new engineering systems. At the initial stage known engineering means will be used. Then new features of the existing engineering devices will be identified and these devices will be used in new functions. Further on, specialized and, maybe, essentially new means for satisfying these needs will be created.

Example 5. Delivering odors through E-mail.

British company Telewest Broadband and American scientists from Trisenx developed a device connected to a computer, which generates an aroma, "associated' wit the E-mail message and this aroma may vary from the odor of a violet, smell of the beach and coconuts to the odor of juicy beef steaks, which are being roasted on coals, etc. (Fig. 4).

Fig. 4. Delivering odors through E-mail

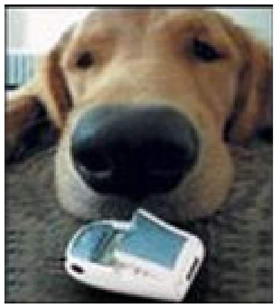


Fig. 5. "On-the-phone" odor

Example 6.   "On-the-phone" odor.

Scottish company Electronic Aromas developed a technology for delivery of odors through mobile phone (Fig. 5). The apparatuses are equipped with chambers filled with molecules of different substances. The corresponding phone call will stimulate the formation of certain molecular combinations.

Example 7.   Problems and potentiality of transmitting odor information.

The delivery of odor information will most probably face certain difficulties. The odor spreads throughout the entire room. To substitute it for a different odor it is necessary, first of all to eliminate the existing odor, which also needs the application of certain engineering means or definite chemical agents, and besides it will need time consumption. It leads to the fact that such system is rather inert and consequently the transmission of information will be rather long.

As a rule, such contradiction is solved in space. The source of information should be as close to the "receiver" of information as possible. Consequently the odor should be delivered directly to the nose. Then it will take little time to eliminate one odor and to deliver another one. Besides, only diffusive odors should be used.

Example 8.	Modern perfumes.

Use of diffusive perfumes is a tendency in modern perfumery. It was assumed earlier that the more stable the scent was, the higher its quality was. Modern ladies would like to use different scents at different times of the day. The perfumes are changed depending upon the type of activity or contacts with different people. In connection with that perfume manufacturers started producing diffusive perfumes.

Example 9.	Tactile information.

Tactile and temperature information could be delivered, for example, through special gloves, which could include built-in sources of temperature, oscillations, modification of shape, surface, rigidity and other features of materials, which could be perceived through tactile sensations. Thermal pipes, piezo-materials, materials with shape memory effect, etc. could be used here.

Example 10. Action upon the human brain.

Action effected directly upon certain sections of the human brain obviously require additional research so that different people should experience adequate sensations. From the standpoint of engineering such devices could take the form, for example, of a helmet with a versatile system of electrodes and sensors. Different electromagnetic fields acting upon the brain and causing definite sensations, transferring specific information will be delivered through these electrodes. The sensors are required for the control of developing virtual processes.

1. Structure of Trends of Needs Evolution

Satisfying the needs can be implemented through **known and new functions** (Fig.

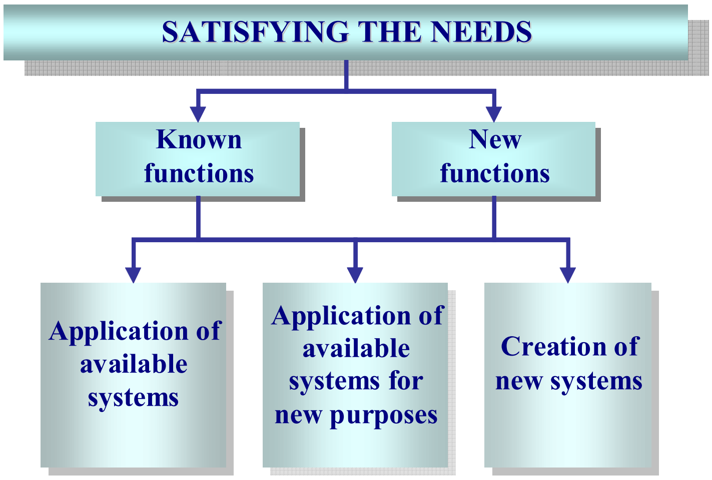


Fig. 6. Satisfying the Needs

6), the change of which is subjected to definite trends.

Known functions can be performed **by existing systems** or **by newly created systems.**

New functions can be performed **through the use of available systems for new purposes** or **through the creation of qualitatively new systems.**

The evolution of each kind of needs is subjected to definite trends.

The author formulated the following **trends of needs evolution**:

- **Idealization of needs.**
- **Dynamization of needs.**
- **Coordination of needs.**
- **Integration of needs.**
- **Specialization of needs.**

Idealization of needs **is performed** through **dynamization, integration or specialization** and the subsequent **coordination of needs** (Fig. 7)**.**

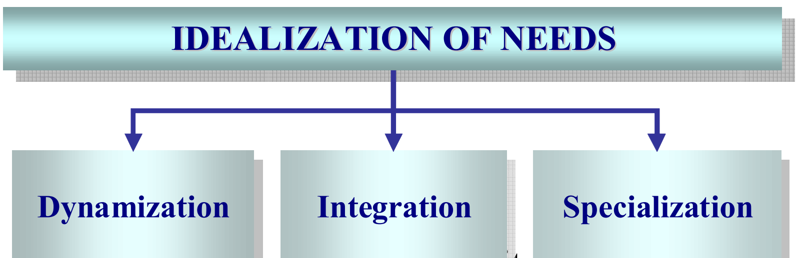


Fig. 7. Idealization of Needs

2. Satisfying the needs using functions

As it was noted above, satisfying the needs could be performed through **known** and **new functions** (Fig. 6).

2.1. Satisfying the needs using known functions

To perform known functions it is possible to apply **existing systems** or to **create new systems**.

2.1.1. Use of existing systems

Example 11. A need for shaving beard and moustache with an electric razor appeared. Similar function was originally performed by a hair-cutting machine, which was used for shearing hair on the head (Fig. 8 a). After that a special machine was manufactured (Fig. 8 b), which also sheared eye-brows, hairs in the nose and in the ears.

a) Hair-cutting machine   б) Special hair-cutting machine

Fig. 8. Hair-cutting machine

Example 12. "Boeing-747" will be equipped with a battle laser.

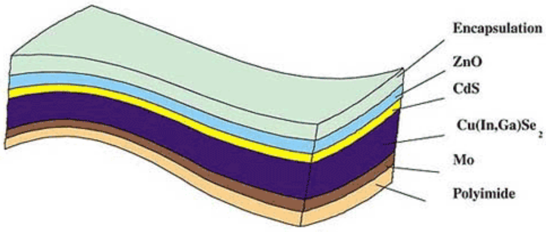
Boeing corporation modernized the transport aircraft 747-400,

Fig. 9. "Boeing-747" will be equipped with a battle laser

installing a battle laser on it (Fig. 9).

Further on, a special carrier of battle laser will be created. First a ready-made aircraft was used.

Example 13. Solar batteries can be printed on a jet printer.



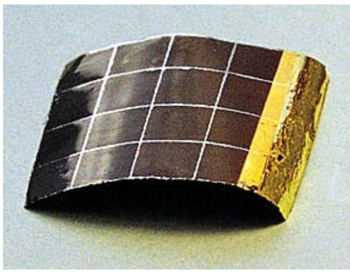


Fig. 10. Solar batteries can be printed on a jet printer

Scientists Ghassan Jabbour and Yuka Yoshioka from Arizona University in Tascona used an ordinary jet printer for the manufacturing of semi-conductor devices. They made use of an **old cartridge**, filling it with a fluid organic substance from which a polymer with features of a semi-conductor is generated afterwards.

So far this technology was used only for development of relatively simple semiconductor systems – photodiodes and photoelectric cells. The developers think that in future it will become possible to use it for manufacturing of different devices. The new method is a multi-purpose method: semi-conducting polymer can be applied practically over any kind of material from fabric and plastic to silicon plate or glass and the polymer film remains practically invisible for the human eye.

The next step will be construction of a **special printer**.

2.1.2. Creation of new systems

To satisfy a new need, first of all it is necessary to find, if there are systems performing similar functions. If such systems don't exist, new systems are developed.

Example 14. Solar batteries of nano-tubes.

In California University (Berkeley) photoelectric cells were developed, which are manufactured of carbon nano-tubes applied over the plastic substrate. Due to miniature dimensions of nano-tubes quantum effects act and the degree of absorption of rays of a certain part of spectrum is increased approximately two times.

2.2. Satisfying the needs using new functions

To perform new functions existing systems can be used **for a new purpose** or **qualitatively new systems** can be **generated**.

2.2.1. Use of existing systems for new purposes

When a new function appears, first attempts are made to perform it using existing systems, which performed this function previously or which had this function, however it was used as a secondary one, was not used at all or was treated as needless or even harmful.

Example 15. When the electric contacts are circuited, the spark generated thereby spoils the contacts (leading to erosion of metal). This phenomenon was soon used for metal processing (processing of metal through electric erosion).

Example 16. Wounds and cuts were covered with sponges and bandaged. The function of glue sealing of wounds did not exist. In 1920 Earl Dixon proposed the idea of bactericide plaster, which was manufactured by the company "Johnson and Johnson".

In the USSR the workers used insulating tape for glue sealing of cuts.

Some workers glued the cuts with an alcohol-based glue (in the USSR such glue was called BF-2). After than glue of similar kind with antiseptic additives began to be used for gluing the wounds (in the USSR such glue was called BF-6).

2.2.2. Creation of qualitatively new systems

Example 17. New function of laser.

Queensland research center developed a laser tweezers (Fig. 11), which is used for seizure of micro-particles.

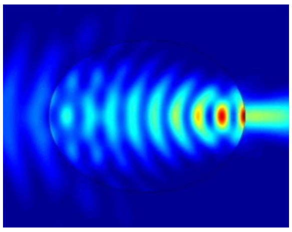


Fig. 11. Laser tweezers

Micro-particles move to the place, where the light ray "is stronger". When the laser beam is not uniform, the particle is attracted to the area of maximum intensity of radiation. Translating the focus of the beam it is possible to move 'captured" objects and make them perform complicated movements.

The tool is used for studying DNA cells, mechanisms of delivery of medicines to thick organs of the human body, penetration of medicines through the membranes, diagnostics of cancer.

Using a laser of high illuminating power it is possible to study chemical reactions which last for billion portions of a microsecond. Optical tweezers enables to measure very small forces, of the order of magnitude 10-12 H and rotation force. Measuring of rotation forces is important for the evaluation of dynamic features of biological elements and solutions.

Example 18. A robot could be mixed up with a real woman

Kokoro Dreams and Osaka University created the prototype of an anthropomorphic robot of new type – a woman, who can imitate human speech and wink (Fig. 12).

Fig. 12. A robot could be mixed up with a real woman

The robot is able to realistically reproduce facial gestures of the human.

Example 19. Mobile phone for dogs.

Finnish company Benefon, Arbonaut and Pointer Solutions company created a mobile phone for dogs (Fig. 13).

Fig. 13. Mobile phone for dogs

Pointer dog-GPS consists of two parts. The main part is a modified Benefon Esc – two range GSM-phone with a 12-channel receiver GPS. It can contain maps and routes of movement, SOS signal with exact coordinates, etc. The module can maintain communication with three dozens of transmitters, which are carried by the dogs.

Another part is secured on the dog's collar. It enables to trace and to memorize the route of the dog. The body of the device is water-resistant and shock-proof. The phone can function in hot weather and in severe cold and the collar itself is equipped with light-reflecting elements. If the dog stays in the zone of coverage of GSM-operator, it is possible to obtain connection to the microphone which is carried by the dog.

Example 20. Detector of love

"Detector of love" is being created, enabling to identify and to analyze the emotional state of the interlocutor during the conversation (Fig. 14).

Fig. 14. Detector of love

Example 21. 3-dimensional display for mobile phones

South Korean company Samsung developed the first-in-world-history display for portable devices, which enables to see 3-dimensional images without using special spectacles and practically at any angle (Fig. 15).

Fig. 15. 3-dimensional display for mobile phones

Users of mobile phones, communicators or pocket computers, equipped with 3D displays, will have an opportunity of switching between 2D and 3D modes. Besides, it will be possible to view 3-dimensional images even in such cases, when the screen is turned by 90 degrees.

3. Trend of idealization of needs

Trend of idealization of needs presupposes the improvement of the needs' quantity, needs' quality, decrease of time consumption and means intended for satisfying these needs as well as the reduction of harmful actions (payment factors).

Degree of idealization of needs could be presented in the following form:

$$\boldsymbol{I} = \frac{\sum_{\boldsymbol{i=1}}^{\infty} \alpha_i \boldsymbol{Qn}_i\ \boldsymbol{Ql}_i}{\sum_{\boldsymbol{i=m}}^{\boldsymbol{0}} \beta_i \boldsymbol{C}_i + \sum_{\boldsymbol{i=n}}^{\boldsymbol{0}} \gamma_i \boldsymbol{H}_i} \Rightarrow \infty;$$

Where:

I – degree of idealization of needs;

Qn – number of needs;

Ql – quality of needs;

α,β,γ – coordination coefficients;

C – consumption of time and means for satisfying needs;

H – harmful actions (payment factors);

i – index number;

m – maximum amount of expenditures *C*;

n – maximum number of harmful actions *H*.

Features of ideal need.

Ideal need is a need, which is satisfied at the required moment in the required place at required circumstances.

Ideal need is a need, the requirement of which is not a necessity. The need has become needless or it gets satisfied all by itself.

Example 22. The need is satisfied at the required moment in the required place through the use of different folding or inflatable objects.

Example 23. Let us analyze the satisfaction of need for food. Initially the human ate everything, what he could obtain (as a rule, the food was always the same) and wasted much time on it. Modern age is characterized by a huge versatility of different kinds of food, the cooking of which either don't require any time whatever (food is ready for eating) or everything is cooked very quickly (ready-to-cook foods). Therefore, the need for food "procurement" disappeared.

Example 24. Let us analyzer the process of need idealization on the example of washing dishes.

Earlier the dishes were washed manually. The places, which are especially dirty had to be scratched with a brush for a long time. Scratches were left on the dishes. After that the evolution of this process took several directions.

Different detergents appeared, which accelerate and improve the washing process. The only thing to be done after the application of these agents is to wash away the dirt.

The next step for idealization of this need – the need gets satisfied itself – *the dishes get washed themselves* – a dish-washing machine.

Further idealization of the need – *rejection of need* (need for dish washing became useless), i.e., the function of washing dishes became useless with the appearance of disposable dishes. Another method is to make the dishes edible. The foodstuff is put into salad leaves, cabbage leaves or pita.

Example 25. There is a need for heating or cooling of foodstuff or drinks. This need is satisfied through heating on gas (electric) stove or in microwave oven, while the food gets cooled in the frosting chamber.

The idealization of this need – rejection of necessity to heat or to cool. Self-heating (Fig. 16) and self-cooling (Fig. 17) containers.

Fig. 16. Self-heating container **Fig. 16. Self-cooling container**

3.1. Increase in number of needs and improvement of their quality

3.1.1. Increase in the number of existing and newly appearing needs

Increase in the number of needs could take the form of **appearance of new needs** and **diversification of available needs.**

1. Appearance of new needs.

Example 26. Implantation of electronic microchips

A need appeared to identify animals, especially expensive ones. A microchip was developed (Fig. 18), which is implanted into the body.

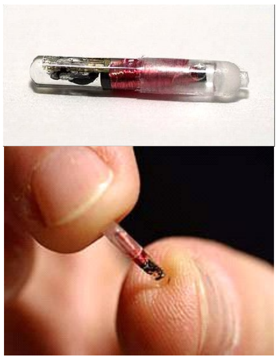


Fig. 18. Implantation of electronic microchips

All data on this animal and its owner is recorded on a microchip. The information is read using a special device.

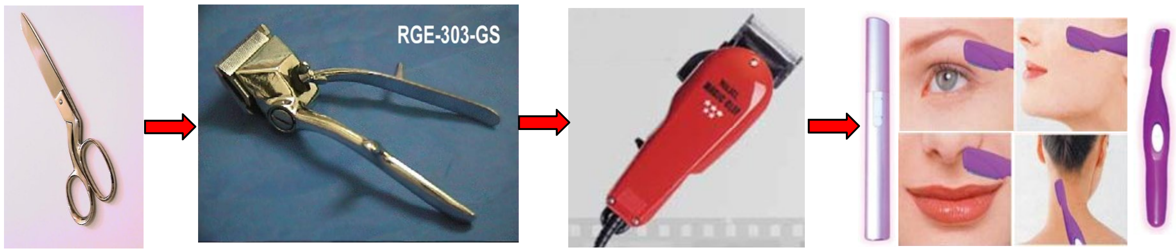
Consequently the microchips were implanted into human bodies. Using a microchip I is always possible to identify a human and to know about his (her) location. It will enable to prevent the kidnapping, to monitor his (her) state of health, etc.

2. Diversification of existing needs.

For example, through specialization of needs or invention of additional means.

Example 27. When soap was invented, it was used for all cleaning procedures. Nowadays there is special soap for face, individual detergents for washing dishes, individual detergents for washing oily dishes, etc.

Example 28. First scissors were used for shearing (Fig. 19 a). Then mechanical machines for shearing appeared (Fig. 19 b). They were substituted by electrical machines for shearing (Fig. 19 c). Later on, specialized machines for shearing eyebrows, hairs in the nose, in the ears, etc. were developed (Fig. 19 d).



а) **б)** **в)** **г)**

Fig. 19. The trend of scissor development

3.1.2. Quality improvement of existing and newly appearing needs

It is possible to improve the quality of needs through **development** and/or **use of more progressive means** or **the invention of essentially new means,** satisfying newly appearing needs.

Quality improvement of existing and **newly appearing needs** can be implemented through:

1. **Development** and/or **use of more progressive means.**

Example 29. Need for improvement of TV image quality was satisfied by transition to digital transmission of images.

2. **Invention of additional or essentially new means,** satisfying newly appearing needs.

Example 30. Hair cutting machines were equipped with caps, regulating the length of the remaining hair (Fig. 20).

Fig. 20. Hair cutting machines

Fig. 21. Toothbrush – iones

Example 31. Toothbrush – ions.

The stick of the toothbrush (Fig. 21) is manufactured of titanium dioxide (TiO_2). When exposed to light, this stick releases electrons, which due to conducting saliva while contacting with acid contained in the dental plaque generate positive ions of hydrogen, destroying dental plaque and bacteria. Teeth get cleaned due to photo-catalytic features of titanium stick. Need for toothpaste and even for water disappears.

This is an example of creating **an essentially new means**.

3.2. Decrease in consuming time and means on satisfying needs and decreasing the number of harmful actions

3.2.1. Decrease in consuming time and means on satisfying needs

Reduction of expenses of time and means on satisfying needs is implemented through:

- **Concurrent satisfying of several needs;**
- **Satisfying of several needs using one means only;**
- **Satisfying of new means using available resources.**

Concurrent satisfying of several needs.

Example 32. Need for travel in space, for example, driving a car and concurrent obtainment of information was satisfied, when a radio set was incorporated into a car. A similar example - the use of cellular phones in cars.

Satisfying several needs using one means only.

Example 33. Computer can perform several types of work concurrently .

Example 34. Video-camera can be used not only for shooting, but for viewing as well.

Satisfying new needs through available resources (of existing systems, processes, services, etc.).

When new needs appear, first the available engineering means are used, and the existing technological processes are used for manufacturing of new products. New types of services are first offered by the available companies. At the next stage specialized products, processes and services appear.

Example 35. A need for extinguishing fires on water appeared. This function was first performed by ordinary vessels, then special fire-fighting vessels appeared.

3.2.2. Decreasing the number of harmful actions (payment factors)

Decreasing the number of harmful actions could be implemented via preliminary analysis of needs with the involvement, for example, of elements of TRIZ and "failure anticipation analysis".

Some ways of decreasing the number of harmful factors:

1. **Use of non-waste and balanced technologies**
2. **Use of resources**
3. **Use of effects, first of all, biological**

Example 36. Jet printing of circuit boards.

Seiko Epson company developed a technology for jet printing of circuit boards, the size of which amounts to 27x24 mm, which consist of 20 layers and the thickness of which without substrate amounts only to 200 microns (Fig. 22). It is possible to locate 30000 transistors on such circuit board.

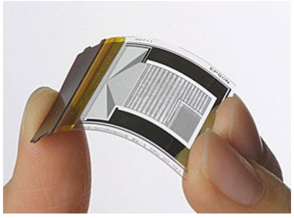


Fig. 22. Jet printing of circuit board

Methodology of photo-lithography is currently used for the manufacturing of printed circuit boards. This is a rather expensive and labor-consuming process, consisting of several main stages: development of photo-masks for individual layers, formation of electric connections, etc. And it is **necessary to use special chemicals, utilization** of which creates **additional difficulties**.

Technology of jet printing of circuit boards is destined to significantly **reduce the expenditures** on manufacturing of microcircuits and **to reduce noxious emissions** into the environment.

4. Trend of dynamization of needs

Trend of dynamization of needs presupposes the change of needs:

- **in time,**
- **in space,**
- **in structure,**
- **according to a definite condition.**

The needs get adapted for:

- definite location,
- a group of people or a particular person.

The needs are satisfied at the time, in the place and in the form, which is required.

The needs can take into account specific features of:

- national peculiarities,
- occupation,
- age,
- sex,

- level of education,
- religious convictions,
- season of the year and time of the day, etc.

Needs for elimination of human involvement in labor processes (mechanization, automation, cybernetization) can also be related to dynamization of needs.

Example 37. The most explicit manifestation of dynamization is clothes. It changes depending upon the season, time of the year, upon its function. There are many types of labor clothes. For example, clothes for firemen, aviators, medical workers, etc. Outer clothing is very versatile - ball dresses and dinner jackets, wedding clothes. The fashion constantly changes and every person can choose his or her own style.

Example 38. Another example could be a need for creation of living conditions, for example, temperature. Different heating devices were created, which heat not the entire room, however, could generate a flow of warm air, which is directed to the required place.

Modern air conditioners not only generate different air temperature in different rooms. They can also change it according to selected or specially composed program, they can generate specific temperature in the selected point. The conditioners can regulate humidity and generate definite odors.

5. Trend of coordination of needs

Coordination of needs can be implemented according to:

- **the needs proper** (coordination of needs between themselves)**;**
- **parameters;**
- **structure;**
- **conditions;**
- in **space;**
- in **time.**

In particular, **coordination** could be **dynamic**.

Non-coordinated needs often lead to disappointment, conflicts, bankruptcies, different cataclysms, wars, ecological catastrophes, etc.

Coordination of needs is also understood as dis-coordination of needs induced intentionally (intensification of maximum difference between the needs).

Example 39. Many people like to eat much and to eat delicious foods. It often leads to fatting, which not only makes the figure less attractive, but also negatively tells upon the human health. Another need - to have a beautiful figure and to be healthy, is the opposite to the preceding need. To preserve the figure it is necessary to eat little and not always delicious food. Special subcaloric food was invented for the purpose of coordination of these needs, for example, different kinds of soy foodstuff. Different additives reducing weight were proposed. Special kinds of physical loads were developed.

Coordination of needs according to parameters was described in the example with an air conditioner. Temperature, humidity and odor perform the function of coordinating parameters in this example. This is an example of dynamic coordination.

Example 40. Imagine a situation, which occurs very often. People, staying in one and the same room can have diametrically opposed needs. For example, one person would like to enjoy silence, while another would like to listen to pop-music at the full volume, which the music center can offer. Coordination of these kinds of needs can be resolved in time – one person has his or her rest, while another person does not disturb him (her); in space – it is possible to listen to the music in one room and to have rest in another one; in structure – the place where they listen to the music or have rest has sound-insulating interstices, or earphones are used (Fig. 23).

Fig. 23. Earphones

Example 41. At a certain place a manufacturing plant is erected, which contaminates environment. The inhabitants of this region would like to live in ecologically pure environment. The needs are not coordinated. One of the ways of resolving such contradiction – to coordinate the needs of the plant's owners and of the inhabitants of this region. A law is passed that the owner of the plant should pay a large amount of money as a fine for contamination of environment and it appears to be more profitable for him to install a purification system.

Coordination of needs can be implemented, in particular, through the **integration** of these needs or through selection of a **special** need.

6. Trend of integration of needs

The integration is performed in such a way that the useful (necessary) features are summed up and intensified, while harmful features are either mutually compensated for or remain at the former level.

There are several ways of integration:

1. Integration of **similar** (identical) needs.
2. Generation of **similar needs with shifted characteristics**. Needs with shifted characteristics are understood as similar needs with different parameters, features and characteristics.
3. Generation of competing (**alternative**) needs.
4. Integration of **heterogeneous** needs.
5. Integration of antagonistic (**opposite**) needs.

Example 42. It happens often that identical shops, for example selling furniture or lighting devices are located in close proximity one to another. It is convenient for the buyers. This is an example of integration of **similar needs**.

Example 43. In great trade centers there are several clothes shops, however, these are the shops of different trade companies. This is an example of integration of similar needs with shifted characteristics.

Example 44. A sports car is transformed into a high-speed cutter through pressing a button (Fig. 24). The machine can develop the speed of up to 180 km/hour on land, in a floating variant its speed can attain 50 km/hour. The amphibian is equipped with an engine, the power of which is 175 horsepower and it has a fuel distance without refueling amounting to 80 km. This is an example of integration of **alternative needs.**

Fig. 24. Amphibian Vehicle

Fig. 25. Radio-earphones

Example 45. An air conditioner integrates several needs at once: to cool and to heat air (integration of **opposite needs**), generate certain level of humidity and certain smell (**heterogeneous needs**).

Example 46. A restaurant integrated a need for food and a need for amusement (integration of **heterogeneous needs**).

Example 47. Integration of needs for doing sports and obtainment of information led to the appearance of players and radiosets in the form of earphones (Fig. 25). This Example illustrates the integration of **heterogeneous needs.**

Example 48. Toothbrush.

The American company OHSO developed a toothbrush (Fig. 26), in which the toothpaste is collected using a special piston. During the process of teeth-cleaning the paste is pressed out using this piston.

Fig. 26. Toothbrush

It would be ideal, if the need for toothpaste disappeared. It was described above, in example 31 (Fig. 21).

Integration of needs often leads to the creation of **multi-purpose** objects.

Example 49. Multi-purpose halls are constructed, in which different concerts and sports competitions can take place. These halls can be divided into different rooms or, vice versa, integrated into a big complex. They are quickly transformed.

Therefore, integration can take place:

- **in space,**
- **in time,**
- **in structure.**

Example 50. One and the same person can have a need for possessing an ordinary car and a jeep. An ordinary car has good aerodynamic characteristics therefore, it wastes much less shell than jeep. However, an ordinary car cannot move along wood, mountain and village roads. Jeep has a higher suspension mount and a more powerful engine. It is not only expensive to have two cars, but also it is necessary to have a large garage.

AUDI company started manufacturing a combination of a car and a jeep Audi Allroad Quattro (Fig. 27). Its body has wonderful dynamic characteristics. The body can be raised and lowered down.

Fig. 27. Combination of a car and a jeep Audi Allroad Quattro

In parking the body is always pressed up as far as it can go (it is raised) – in order to make getting into the car and out of it more convenient.

Special tires and many other innovations enable to create a car of high passing ability.

It is an example of integration of **homogeneous needs with shifted characteristics**.

7. Trend of specialization of needs

Trend of specialization of needs is directed at the selection of one "narrowly understood" need, which satisfies the available need more accurately and at a higher quality level.

The improvement of need specialization is performed in the following sequence:

1. To select the most important part of need;
2. To develop this part of need;
3. To provide for better conditions of satisfying this part of need.

Example 51. The need for separation of special kinds of food appeared, for example, kid's food, kosher food, food for healthy nourishment. Or in a narrower sense - diet food, etc.

Example 52. There are special halls for concert-goers – philharmonics. Special sports-oriented edifices exist for individual kinds of sports (swimming-pools, basketball, volley-ball and football fields, etc.).

Example 53. Toyota company developed a car for one person – Toyota-PM-Personal-Mobility (Fig. 28).

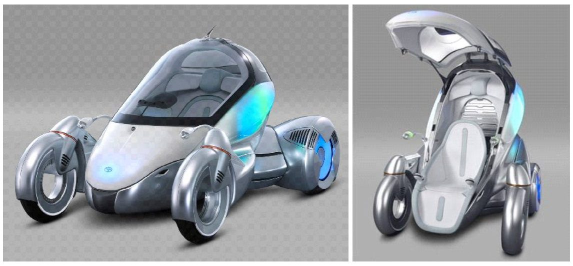


Fig. 28. Toyota-PM-Personal-Mobility

This is an electromobile (battery vehicle), which is embodied as a drop-shaped structure. The body of the automobile can acquire three positions: high-speed movement – the body acquires horizontal position and is pressed to the road, attaining the best aerodynamic characteristics; for driving in the city the body is raised to a certain extent, providing for a better observance; when people get into or out of the car, the body should be closer to a vertical position and the seat is moved forward providing for more convenient getting into or out of the car. Front wheels are able to turn irrespectively one from another to provide for more convenient parking. If they are turned inwards, the car will be able to rotate on the spot. The control is effected using a computer, equipped with a holographic interactive display. The display of the computer shows all the data, including the location of other private cars. Personal cars exchange information between themselves, enhancing safety and convenience of travel.

8. Development of new needs

8.1. Stage of identification of new needs

Based on the trends of **needs** evolution, it is possible to identify the needs of the future and identify, what functions and systems could be used for satisfying these needs. Also it will be possible to identify cardinally new directions in the engineering systems evolution (pioneer solutions).

The stage of identification of new needs is performed by the author in three stages:

1. Identification of latent needs
2. Identification of new needs

3. Forecasting future needs (identification of tendencies for development of future needs).

8.2. Methodology of identification of latent and essentially new needs

First all non-identified disadvantages of the analyzed system as well as potential disadvantages, which can appear in future are identified using this methodology. After that follows the identification of non-satisfied wishes, which the clients have today and latent wishes, about the existence of which the client does not even know yet.

The analysis is performed in stages.

1. Latent (non-identified) disadvantages are identified using the elements of TRIZ and "failure anticipation analysis".
2. Future disadvantages are identified using the trends of systems and needs evolution.
3. Systematization of existing and future disadvantages.
4. The forecast of future needs is performed based on the methodology of needs forecasting, which, in its turn, is based on using trends of needs evolution.
5. Special inquiry. The goal of the inquiry is to identify latent needs. It is performed according to special methodology, involving the recruiting of a relevant group and a series of specialized questions aimed at identification of latent needs of the clients.
6. The comparison of data of inquiry and analytical research. As a result, a tree of latent and radically new needs, which will appear in future, is constructed. These data serve as material for development of new goods and services.

Let us demonstrate the methodology of latent needs identification.

Example 54. Object of research is pantyhose.

First the **disadvantages of pantyhose** are identified. They are as follows:

1. Pantyhose is easily torn;
2. Defects of skins are visible (spots, roughness, pimples);
3. With some ladies synthetic pantyhose is a source of skin irritation;
4. Pantyhose are not air-permeable ("they don't respire");
5. Pantyhose conduct water (water-permeable);
6. Pantyhose require washing.

Known methods for elimination of disadvantages.

1. Ladies have a spare pantyhose in their handbags. However, there are cases, when the spare pantyhose also gets torn.
2. Skin defects are hidden by wearing colored and fashion pantyhose. The ladies often want to have flesh-colored and transparent pantyhose.
3. Silk pantyhose don't cause irritation, but they are much thicker and less beautiful.
4. In order that pantyhose should conduct air, they are made net-like. Such pantyhose does not protect from external environment.
5. All known types of pantyhose are waterproof.
6. Pantyhose can be disposed of instead of washing it, however, this is expensive.

Demands to pantyhose, which are put forward

1. Pantyhose should not tear, or there should be a possibility of changing pantyhose several times, but they should not occupy too much place.
2. Pantyhose should hide the defects of skin, bit they should be transparent.
3. Pantyhose should no cause skin irritation.
4. Pantyhose should conduct air (should "respire") and they should not conduct water (should be waterproof).
5. Pantyhose should be disposable and inexpensive.

Solution. Nagoya company started manufacturing spray stockings – Air Stocking (Fig. 29).

Fig. 29. Air Stocking

A thin silky layer is sprayed over the legs. There are several color shades of spray. The coating conducts air and does not conduct water. Skin defects are covered several times and they are not visible. The coating is washed away in soapy water. There are 20 pairs of stockings in a spray container.

Example 55. Object of research is – protection of humans from hooligans and bandits.

There are protection means: battle pistols, gas pistols and aerosol containers with tear-gas, shockers.

Battle arms can kill the attacker. This is inhuman. The human should also have enough time to take the protection means out.

It is desirable that the hooligan should not be able to touch you or you could shock him distantly. At that the protection means should be always ready – no time should be wasted on taking it out.

One of the solutions – shockers are masked acquiring the shape of other objects, for example, of mobile phone (Fig. 30).

Fig. 30. Shockers – mobile phone

Fig. 31. Ring with tear-gas

Solution. Shocking clothes was invented – contact-less jacket – it is but an elegant jacket. If the owner of the jacket has a feeling that she is threatened by something, the jacket will be immediately converted into a ferocious arms of self-defense. Anybody, who touches the jacket, will get a shock of 80 000 Volt.

The jacket is powered by a 9-volt battery. It is completely insulated, and the owner of the jacket is not threatened by a danger of electric shock.

Another solution. A ring with tear-gas (Fig. 31).

8.3. Methodology for development of new needs

Development of new needs includes a stage for construction of tree of needs, which is performed in compliance with the methodology of constructing the tree of goals, developed by the author[14].

Let us describe the possible sequence of steps for development of new needs.

1. **Identification of field, in which a new need should be found** (one of the primitive needs, a need for creation, etc.).
2. **Construction of trees of methods for satisfying needs.**
   - **2.1. Formulation of need.**
   - **2.2. Description of methods for satisfying the given need.** All imaginable (real and fantastic) methods of satisfying needs in this field should be described.
   - **2.3. Analysis of methods for satisfying needs.**

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[14] Methodology for construction of tree graph of goals was developed by V.M.Petrov in 1975-76 for a course of lectures on system analysis. This methodology is published in:
V.M.Petrov. system analysis of selection of engineering problems.- Methods for solving inventive and design problems. – Riga, 1978, p.p.73-75.

V.M.Petrov. Principles of composing high-quality scenario – Methodological problems of engineering creativity. Abstracts of scientific papers. (Riga, December, 13-14, 1979). – Riga, 1979.

V.M.Petrov. Identification of interconnections in the process of engineering systems development. – Problems and practice of teaching euristic methods of solving scientific and engineering problems. Materials of scientific and practical seminar of March 10-12. – L: LDNTP, 1981, p.p. 51-52.

V.M.Petrov. Principles of constructing the model of controlling the process of scientific research. - Scientific organization of labor and management: results, problems, perspectives. Abstracts of scientific papers read at branch scientific and practical conference on April 15-17, 1981. – L: Central research institute "Rumb", 1981, p.p. 219-223.

2.3.1. Definition of completeness of methods description.

2.3.2. Identification methods which are currently applicable and non-applicable.

Note. A method of satisfying needs which was non-applicable earlier, can constitute a new need.

2.3.3. Identification of disadvantages in the methods of satisfying needs.

Note. Identified disadvantages – these are the needs, which should be satisfied.

2.3.4. Identification of existing means, which can eliminate the disadvantages of described methods.

2.3.5. Extension of methods, described in paragraph 2.3.4 (extension can be also performed through invention of new methods and means providing for the implementation of these methods)**.** The entire inventory of TRIZ tools can be used for invention of new needs.

The same tree of needs is constructed for applicable and non-applicable methods of satisfying needs. Analysis of such trees of needs enables to identify new needs.

Let us quote an example of using the above-described sequence of steps.

Example 56. Let us select the need – **travel in space.**

Let us describe the methods of **travel in space**.

It is possible to travel:

- **On the ground,**
- **In the ground (under the ground),**
- **On water,**
- **Under water,**
- **In the air,**
- **In space.**

As of today, there are methods for travel on the ground, on water, under water, in the air and in space.

It is possible to travel underground only through specially constructed tunnels, for example, by tube. Free underground travel does not exist nowadays. Ice-breakers partly travel in ice, but the largest portion of the vessel travels in air 9above the ice) and underwater (under the ice). The travel inside ice does not exist, for example, in Antarctic or during ice falls inn the mountains. Therefore, free travel underground and in ice are **new kinds** of **needs,** which are not yet satisfied.

First of all, the disadvantage of underground travel should be identified. Let us imagine that there are means for free underground travel. Then the main disadvantage is that they can "dig through" large spaces of land and the ground surface will fall through. Consequently, such vehicles should either repair these tunnels or reinforce them. Though it is possible to move underground in a bulk (like the airplanes move in the air), however we cannot make use of this analogy because of the disadvantages identified. Therefore, let us use the analogy with land transport. Underground tracks can be laid under the earth. These tracks can be one-way only. The tracks should be located at different levels, in this case they will no cross. In order that the vehicles moving at different speeds should not run one against another, it is possible to have only one speed at each track, for example, to create something like an escalator. Then there is no necessity to organize a new kind of "road" police. There will be intercontinental high-speed tracks. The transport will move in them at speeds, which are close to the speed of an airplane. The system of traffic movement will be entirely automated. Selection of kind of transport will be performed by a computer depending upon the requirements, which are put forward by the passenger.

However, in order to provide for such movement it is necessary to develop the minimum of all required parts: means for energy supply, repair stations, etc. Existing means can be used or special means can be invented.

Example 57. Let us analyze one more type of need – the struggle for safety of traffic. It takes several directions: improvement of roads, improvement of cars, control of road traffic, including regulation, etc.

Special shock-absorbers are installed on the roads in places of turns, separation barriers, special strips, warning the driver that he pulls off the road (the tires begin to squeak and vibration is generated – so that the driver wakes up), etc.

The brake system of the car is improved, which enables to significantly decrease the braking way even on a slippery road, safety belts and safety cushions were introduced, car is automated, etc.

Radars appeared, which measure the speed of car movement, automated cameras appeared, which record the violation (over-speeding). With the appearance of radar the drivers developed a need for knowing, when the police records the speed of movement of their cars. Detectors appeared, which inform about that. Besides, means for prevention of over-speeding appeared. For example, in USA a silhouette of a police car is installed on the roads, which is made of plywood. The driver, who has noticed such a silhouette, reduces the speed to the permissible level. First the police took measures against the persons who acquired radar detectors. Of late, it does not only permit it, but even insist on the acquisition of a detector. Generators were installed on the roads, which imitate the radar signal. The drivers, who have heard this signal, immediately slow down.

Example 58. A special computer has been created, which helps to control the car. The destination point is entered into it through the indication of a point on the map, or through oral or written message in the language selected by you. The computer prompts the route and indicates it on the map. It warns the driver about over-speeding and other violations.

A car, which does not need any control at all, also exists. It has no steering wheel (Fig. 32).

Fig. 32. Car has no steering wheel

The only thing you have to do is to name the destination point and the machine will carry you itself. There are built-in sensors in it, which issue information on the situation on the road. Besides, there is a connection with satellites. The car moves along the road, taking the general traffic situation into account. It lays the optimum route and drives along the tracks which are least loaded. The car has a much better reaction than the human. Therefore, it is much safer to travel in such a car.

Example 59. There is a kind of unsatisfied need – the majority of people want to have their personal car. The buyer wants to have a car with wonderful consumer properties. As of today, industry is able to satisfy this need. However, not all buyers can afford to buy a car and there is a lack of high-quality roads.

Currently the car producers have started to manufacture cheap cars of small cylinder capacity. A tendency appeared to create a class of inexpensive cars (Fig. 33).

Fig. 33. Mini car

To reduce the cost of a car and to make its operation easier, a disposable engine has been developed. It will be inexpensive enough (no more than $300), while it will be operating for the same period of time as modern engines prior to overhaul. The substitution of such engine will take no longer than 10-15 minutes. Other parts of the car are being gradually developed according to the same principle.

Other ways of satisfying the described need.

The cost of car and the cost of its operation should not exceed the cost of travel by social transport, then it will be accessible to everyone.

Disadvantages of the social transport are as follows.

- It functions according to time-table, which is not always suitable for a particular person.
- It does not reach the place which is exactly required.
- The number of people using social transport is greater, than that of people using private transport, which does not suit everybody.
- The level of comfort is lower than in private transport.

Disadvantages of private transport.

- High acquisition cost and cost of operation.
- It is necessary to serve the car and to have a place where to store it.
- It is necessary to control the car.
- The car stands idle, when it is not in operation.

Of course, there are taxies, which meet the majority of demands, however taxi is also rather expensive.

Let us proposed a project of the future, which would meet all requirements.

It is necessary to develop an automated transport system. Each vehicle is completely automated and is connected to the united transport system. It moves in strict compliance with the general movement. All cars moving along one and the same way at the same speed, so that the crashes are impossible. Strains of movement is eliminated to say nothing of traffic jams, since the movement is directed along the roads, which are located at different levels above the ground or underground. The roads on the ground are either not used at all or used only for the purpose of providing an ability for the car to reach a particular building. Access routes will also be located either underground or above the ground. Then the lifts and escalators are used.

To use this transport system, it is necessary to order a corresponding car and to enter the time of arrival and the destination point. Automated system of transport control will lay the optimum route itself. At high-speed tracks the car will move in a high-speed "train". (Fig. 34). At the final stage it will travel independently and connected to another vehicle.

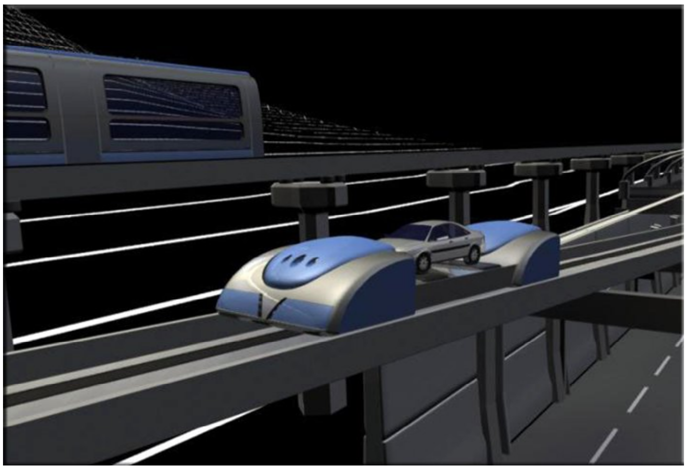

Fig. 34. At high-speed tracks the car will move in a high-speed "train"

Operational expenditures will be borne by the company, which will maintain these cars.

Conclusion

The trends described here enable to predict future needs and the tendencies for changing them. Satisfying the identified needs will lead to the appearance of new goods and services.

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