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**TRIZ Review:**

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TRIZ Review is an official journal of the International TRIZ Association (MATRIZ) aimed at building an international and multidisciplinary community of TRIZ developers, researchers and users and providing a platform for publishing high quality papers related to the research and development of TRIZ, best practices with TRIZ, cases of practical application of TRIZ, and issues of TRIZ training and education.

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Dear readers and authors,

Dear TRIZ friends and colleagues,

I am very delighted to write this foreword for the second volume of *TRIZ Review* because I believe deeply in the high value of the presented materials for the TRIZ community.

Only about a year has passed since the first volume of *TRIZ Review* was published on our website. A lot of positive responses and constructive comments have been received; a great number of TRIZ researchers, trainers and practitioners are very motivated by the opportunity to share results of their research and development in the subsequent volumes of the *TRIZ Review*. It is quite indicative that people keep asking questions: “when the next volume will be published?”, “how often new volumes will appear?”, “what will be the next topics of *TRIZ Review*?”, etc. That means, MATRIZ initiative with *TRIZ Review* has been well accepted and appreciated.

It is one of the main missions of MATRIZ to lead TRIZ development worldwide. Based on the facts mentioned above, *TRIZ Review* serves as a unique platform for exchanging knowledge, experience and practical results of TRIZ application.

This second volume consists of high-quality papers submitted from different regions of the world. The process of evaluating and selecting papers for the current volume of *TRIZ Review* took a lot of time and effort from the editorial board. I would like to extend my sincere gratitude to all members of the editorial board and the Editor in Chief, TRIZ Master, Valeri Souchkov for the great and important job they have been doing.

It is my sincere expectation and hope that the *TRIZ Review* provides an effective learning experience for all TRIZ professionals and beginners.

Enjoy reading and submit your papers for the next volumes of *TRIZ Review*.

Sincerely,

*Oleg Feygenson, PhD, TRIZ Master, President of MATRIZ*





Dear Readers,

We are glad to present our second issue of *TRIZ Review*. It includes papers of a broad range: ideas to improve Function Analysis by Jochen Wessner; an overview of areas poorly supported by modern TRIZ tools by Dr. Elena Redkolis; applying TRIZ to identify adjacent markets by Dr. Oleg Abramov and his colleagues; attempt to compare analytical TRIZ tools for dealing with business problems by Anton Kozhemyako; a case of using TRIZ for process improvement in medical industry by Stefan Schaper, and so forth. We would greatly appreciate the reader's feedback on the papers published. Please send us your letters with comments on a specific paper and we will publish them in the next issue of the journal.

We also introduced sections which present news and reports from MATRIZ and its units such as TRDC, CEM, TMCC. As you know, such news and reports are published at MATRIZ website, but the journal format allows us bringing them together for those who do not check the website regularly. In this edition you will also find description of strategic priorities of MATRIZ development.

This year we have been experiencing difficult times due to Covid-19 pandemic happening together with economy slowdown. And we are proud to see how TRIZ is used to help fighting negative consequences of both. These days I often hear reports on how our TRIZ colleagues deal with challenging issues in different areas: technical – to propose non-trivial improvements of medical equipment; social – how to find creative ways to use lockdown as a resource to achieve something they always wanted; and business – while working online I helped several companies to solve their immediate problems and to stay afloat although they had chances to lose their businesses due to restrictive measures taken by governments in order to save human lives. Maybe such contributions are small considering the global scale, but they confirm that modern TRIZ can be effectively applied to solve problems from diverse areas in the emergency situations. If you have cases of such solutions, please share with us and we will publish them.

Due to uncertain situation, MATRIZ Board decided to cancel *TRIZfest-2020* conference scheduled this September in India. The dates and location of next conference *TRIZfest-2021* will be announced soon. Meanwhile, MATRIZ invites to submit papers to our next conference.

Next issue of *TRIZ Review* will appear in September 2020. We decided to split main papers to two formats: regular papers (from 10 to 20 pages) to have enough space to present authors' works and short papers (up to 4 pages) to briefly present author's ideas or findings regarding a specific single issue. We invite authors to submit papers, either regular or short. The deadline for submitting your papers is July 1, 2020. Details, guidelines and paper templates can be found at [matriz.org/triz-review/](http://matriz.org/triz-review/)

Best regards, successful solutions and stay safe!

*Valeri Souchkov, TRIZ Master, TRIZ Review Editor in Chief*



## STRATEGIC PRIORITIES OF MATRIZ DEVELOPMENT

By now, the International TRIZ Association – MATRIZ – has evolved to the largest community of TRIZ professionals, users and researchers in the world. This situation imposes a range of responsibilities on MATRIZ which are only possible to meet by maintaining the highest level of quality and performance with delivering its services to both MATRIZ and TRIZ communities that rely on MATRIZ knowledge, competence, and capabilities.

Regarding future development of MATRIZ, below we would like to outline major priorities where MATRIZ as organization shall concentrate its primary efforts:

1. **Professional organization and attitude.** Current MATRIZ includes about 40 active organizations listed as regional members in many countries. Over 30 000 people were trained by MATRIZ accredited trainers and certified by MATRIZ. Over 30 persons are continuously engaged in different activities of MATRIZ, primarily on voluntary basis. All this requires further improvement of professional attitude, cooperation, communications, and organization.
2. **Communications development.** It has not been a secret that in the past years, communications both inside MATRIZ as well as between MATRIZ and the outer world were mostly sporadic and sometimes not sufficient enough. Our closest goal is to improve this situation and create effective communication channels that will allow full-scale communication inside and outside MATRIZ without gaps and delays. Timely updates of MATRIZ community and outside world must be organized regarding changes, events, and any other important issues. It will be done through various means, such as directed personal communication, websites, social media.
3. **Reaching financial clarity and transparency.** Before 2019, MATRIZ operated without clearly defined budgets, however this situation changed. The budget committee introduced in 2019 will balance financial activities of MATRIZ in terms or evenly meeting diverse interests within the organization.
4. **Greater support of local activities and events organized by regional MATRIZ members.** Such events are of high importance since they bring together local communities speaking local languages and help with promoting MATRIZ and its activities in different parts of the world. More interaction with regional MATRIZ members and their higher involvement to local MATRIZ activities are expected.
5. **Expansion to non-technical fields.** As decided at MATRIZ Congress in 2019, equal attention would be paid to three directions of developing TRIZ under MATRIZ umbrella: a) TRIZ for engineering and engineering technologies, b) TRIZ for business and management, c) TRIZ Pedagogy. Respectively, all three directions must be properly supported by such MATRIZ

units as Council for Expertise and Methodology (CEM) and TRIZ Research and Development Council (TRDC).

6. **Increasing the role of MATRIZ as a leading TRIZ knowledge and competence center.** Established to define and prioritize strategic directions of TRIZ research and development, MATRIZ TRIZ Research and Development Council (TRDC) unites representatives of various TRIZ schools. It is supposed to support growth of TRIZ-related research work and high-quality publications conforming to modern R&D and scientific requirements. TRDC must closely cooperate with Council for Expertise and Methodology (CEM), provide interaction with TRIZ Master Certification Council (TMCC) and act as a TRIZ knowledge competence center to react to professional inquiries emerging within the TRIZ community.
7. **Developing training and educational standards.** One of the core functions of MATRIZ is to help disseminating high quality professional TRIZ education and training in both academic and professional environments. Although MATRIZ itself does not provide training, it sees its role in developing the training curricula and establishing training standards to ensure that TRIZ trainers accredited by MATRIZ would be capable of delivering high-quality training and certification services. MATRIZ Council for Expertise and Methodology (CEM) responsible for developing educational and certification standards and regulations must constantly improve and update TRIZ reference training materials and help accredited trainers with getting access to any information and competence they need.
8. **Perfection of a system of TRIZ Masters (Level 5) preparation and certification.** Historically, the title of TRIZ Master has been awarded to those who not only prove their top level of knowledge and skills with TRIZ but also who are at the same time actively engaged to development and further promotion of TRIZ. It is well known that the current system of TRIZ Masters certification has certain drawbacks which cause numerous discussions. It means that further improvement of a system of preparing and certifying specialists of Level 5 (TRIZ Master) by TRIZ Master Certification Council (TMCC) must be undertaken in order to improve certification criteria and attract and encourage TRIZ specialists to be certified as TRIZ Masters.
9. **Publications venue.** Launched in 2019, TRIZ Review journal targets at providing an open platform for quality publications of technical and scientific achievements as well as summarize and publish information about recent and planned events, as well as news from MATRIZ such as TRDC, CEM, Presidium, and so forth. TRIZ Review welcomes all TRIZ researchers, developers and practitioners share their results independently if they belong to MATRIZ or not.

*Valeri Souchkov, Vice President of MATRIZ Development and Communications*  
*Oleg Feygenson, President of MATRIZ*



# TRIZ ROADMAP FOR IDENTIFYING ADJACENT MARKETS

Oleg Abramov, Simon Litvin, Alexander Medvedev, Natalia Tomashevskaya

## Abstract

Entering adjacent markets is a well-recognized and effective way of expanding a business without its dramatic transformation. Therefore, the identification of adjacent markets is a very popular service from TRIZ consultants. Modern TRIZ recommends using the Reversed Function-Oriented Search (RFOS) as a major tool for identifying adjacent markets for existing products. In practice, however, using RFOS is not always particularly straightforward, because (1) it is often necessary to find new markets / applications for technology and equipment involved in the production of a product, rather than for an existing product, and (2) the product itself may not be a separate product intended for the end user, but a component for some other product. However, RFOS is not the only useful TRIZ tool that can be used to identify new markets for existing products and technologies. Based on their practical experience in TRIZ consulting, the authors have developed a roadmap for identifying adjacent markets, which includes the analysis of Main Parameters of Value, Voice of the Product, screening based on the Quantum-Economic Analysis (QEA-screening) and other TRIZ tools, in addition to RFOS. The roadmap is applicable for all kind of products as well as for technologies involved in their production. Four brief case studies are presented to illustrate the use of the roadmap.

*Keywords: adjacent markets, Adjacent Markets Identification (AMI), Main Parameters of Value (MPV), MPV analysis, QEA-screening, Reversed Function-Oriented Search (RFOS), Voice of the Product (VOP)*

## 1 Introduction

Entering adjacent markets is a widely accepted marketing strategy for developing business without venturing too far from the core competence of the company [1, 2]. Therefore, the demand for the services of TRIZ consultants in Adjacent Markets Identification (AMI) is growing rapidly.

In the marketing literature, however, it is difficult to find specific recommendations or a sufficiently detailed algorithm for identifying the adjacent markets. For example, VisionEdge Marketing [3] recommends performing the following steps:

1. List adjacent markets you are already serving.
2. List agencies your organization has previously considered or rejected.
3. Identify other existing agencies you know.
4. Consider what potential agencies might emerge due to a technology advancement.

These recommendations are too general to be instrumental and rely too much on the personal skills and experience of the implementer, which makes them difficult to use in practice and does not guarantee success.

TRIZ practitioners have developed more specific approaches to identify and address adjacent markets, but in most cases, this is associated with developing a new product to serve adjacent customers who are not served by the core product of the company. Frequently, TRIZ consultants suggest doing the following: (1) generate ideas for new products, and (2) see if these products can serve some adjacent markets. For instance, Ball et al. [4] recommend using Systematic Inventive Thinking (SIT) tools proposed by Boyd and Goldenberg [5] in order to generate ideas for new products and then to identify others who may need these new products, apart from existing customers.

This method is in fact a type of trial and error approach, which requires a good deal of time and labor, but does not guarantee that adjacent markets will be found. Additionally, most companies would prefer not to develop new products, but to enter adjacent markets with their existing product and assets.

This demand is partially addressed by GEN TRIZ methodology for AMI [6,7] that represents a Reversed Function-Oriented Search (RFOS) [8]. RFOS generally includes the following main steps:

1. Select an object for RFOS, which could be the entire product/technology or one of its components.
2. Formulate all properties of the object (physical, chemical, geometrical, etc.) and select one of the properties.
3. Convert the selected property to a set of functions and select one of the functions.
4. Generalize the selected function and identify a leading area in which similar functions and properties are very important and that has the biggest business potential.
5. Identify in the selected area a specific function similar to the generalized function and use the identified function as a new main function of the initial object.
6. Identify and solve adaptation problems to make the object perform the new main function.

Although RFOS does provide a systematic approach to identifying adjacent markets, its application is not always straightforward.

First, the leading areas that RFOS suggests to identify at Stage 4 (see step 4 in the list above) are not defined for the case when AMI is performed for a consumer product. The term “leading areas” used in RFOS came from classical Function-Oriented Search

(FOS) introduced by Litvin [9], which is designed for industry and science, and is hardly applicable to the consumer market.

This means that RFOS can only be applied to AMI for business-to-business (B2B) products, but even in this case it does not give specific recommendations on selecting the leading areas, nor on assessing which of the leading areas offer maximum business potential to the client. In practice, this results in considering more leading areas than necessary, spending extra time and resources.

Second, RFOS does not provide specific recommendations on how to select one of the properties of the object for RFOS to convert it to a set of functions, which often results in the necessity to repeat the entire procedure several times in order to consider several different properties.

Finally, RFOS does not specify how to convert the properties of the objects into functions, which may be a difficult task, for example, if the object of RFOS is a chemical substance/ingredient.

In a recent conference paper [10], the authors have summarized their experience in identifying adjacent markets for different clients and devised an RFOS-based roadmap for AMI that is easier to use than the original RFOS [8].

In this paper, the authors describe this roadmap in more detail. The focus of the paper is shown below on the Innovation Ambition Matrix [1], see Fig. 1.

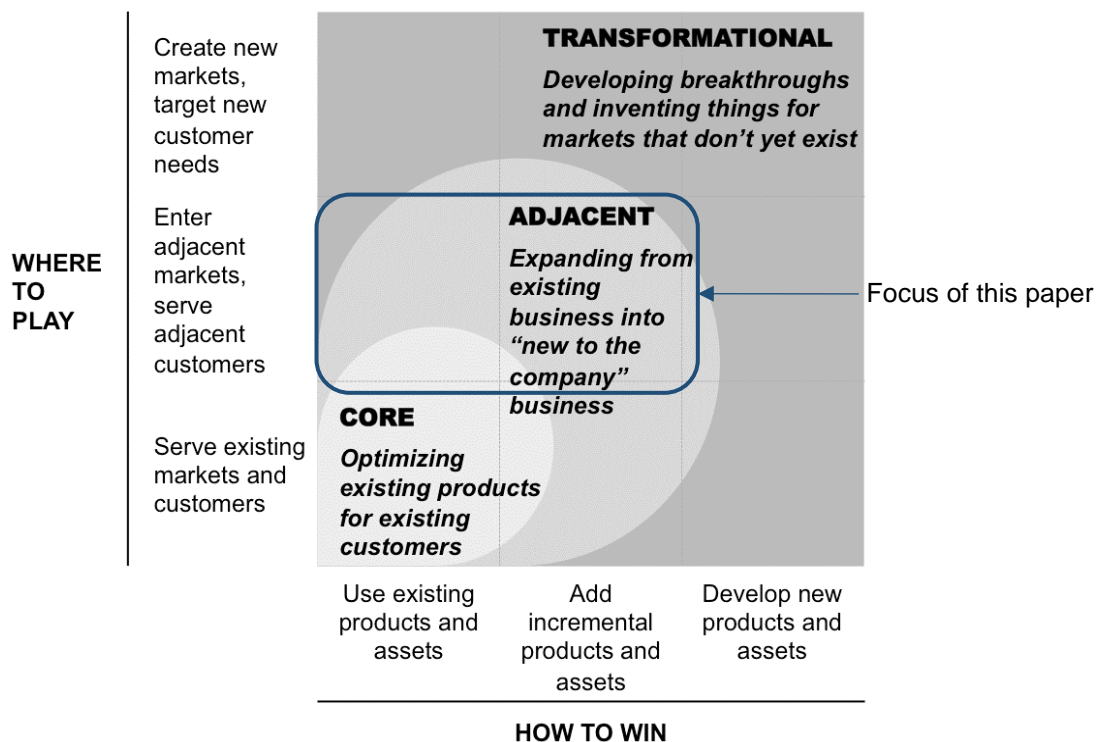


Fig. 1. Innovation Ambition Matrix [1] and the focus of this paper

As can be seen from Fig. 1, the paper mainly covers the identification of those adjacent markets into which you can enter with existing products and assets (such as technology and equipment) or with only incremental modification of existing products and assets. MBA Knowledge Base [1] indicates that resources are very unevenly allocated for different types of innovations, and their returns dramatically differ depending on innovation type (see Fig. 2).

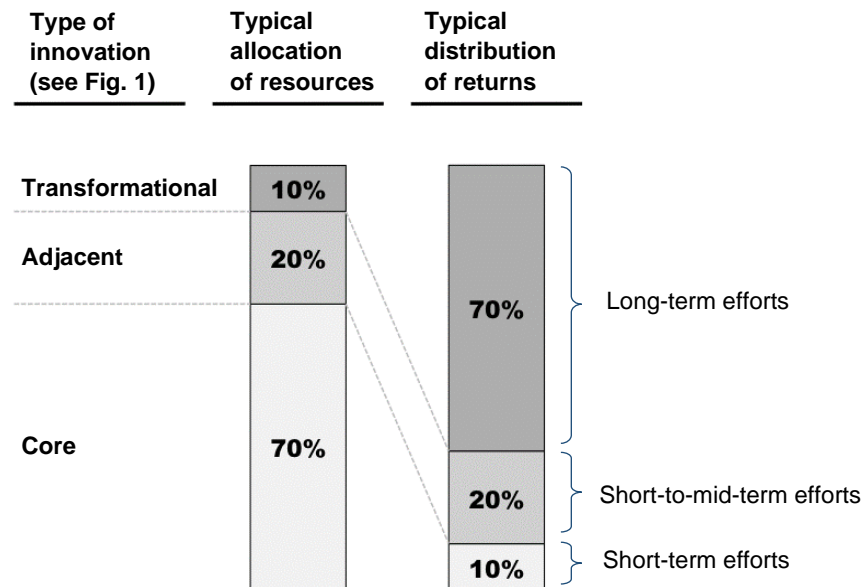


Fig. 2. Typical allocation of resources and distribution of returns for different types of innovations [1]

As shown in Fig. 2, “adjacent innovations” that include entering adjacent markets yield, on average, a decent 20% of the company’s total innovation portfolio returns while expending 20% of the resources allocated for the portfolio. This is a very good result compared to innovations aimed at improving the core product, which usually consume 70% of resources while yielding only 10% of returns.

At the same time, adjacent innovations typically provide their returns in short-to-mid-term, which is almost as fast as core innovations aimed at optimizing existing products. This explains why identifying adjacent markets is one of the most frequent requests in TRIZ consulting practice.

Although it might seem that transformational innovations consuming on average only about 10% of resources while generating 70% of returns (see Fig. 2) are much better than other types of innovations, these innovations are usually very risky and normally yield returns only in the long-term, which is often unacceptable to business.

## **2 Method: TRIZ tools utilized**

In order to make the roadmap for AMI as specific as possible, we used existing tools of modern TRIZ in order to enhance RFOS. These tools are:

- Main Parameters of Value (MPV) analysis, as summarized by Litvin [11], which helps to identify “leading areas” (that is leading demands) of the consumer market. This includes the approach for identifying latent customer needs described by Ikovenko [12].
- Voice of the product (VOP), as described by Abramov [13], that identifies the most promising MPVs (properties and functions) that the product may offer to consumers, including the product’s latent MPV, as shown by Abramov [14].
- Screening tool utilizing Quantum Economic Analysis (QEA), introduced by Abramov et al. [15-16] (further in this paper referred to as QEA-screening). This tool identifies leading areas that are unpromising for the client’s business, and should be rejected.

## **3 Results: suggested roadmap for AMI**

The resulting roadmap that the authors suggest for AMI projects is shown in Fig. 3.

It should be noted that this roadmap assumes that the object for which it is necessary to find adjacent markets has already been selected, which is, in fact, almost always the case in the practice of TRIZ consulting.

Indeed, the roadmap in Fig. 3 does not cover all cases when it is necessary to utilize adjacent markets. For example, it does not include the use of, as suggested by Hagel et al. [19], assets available on adjacent markets, e.g., Uber’s use of automobiles that are owned by others.

The authors, however, have successfully applied all parts of this roadmap in several actual AMI projects. The highlights of four projects are given in the brief cases studies below.



**Step 1:** Identify whether the Object for AMI (further – Object) is

1. Intended for business or for a consumer (**B2B or B2C product**)
2. A **finished product or a component/material/ingredient** for some other product

**Step 2:** Use product-oriented MPV analysis [13] to **identify all appropriate properties of the Object and related assets** (technologies and equipment) that are used to produce the Object:

- For a **finished product** – its **technical parameters** (performance, etc.)
- For a **component or material** – its **physical properties** [17]
- For an **ingredient** (sometimes for a material too) – its **chemical properties** [18]; if needed – **biological properties** (e.g. microbial properties), etc.
- For the **assets** – **their technical parameters, materials** that the assets can process and **operations** that the assets can perform with the materials

**Step 3:** If applicable, **convert these properties into a set of functions** as in the original RFOS [8]; otherwise, keep the properties unconverted

**Step 4:** Identify VOP [13, 14] for the Object and related assets; **reject all functions and properties that do not meet the VOP**

**Step 5:** **Generalize remaining functions and properties** as in the original FOS [9]

**Step 6:** Find **where these functions and/or properties are needed** most of all:

- For **B2B products** - identify **the leading areas of industry and science** for which these features are critical - just like in the original RFOS [8]
- For **B2C products** - use MPV analysis [11-13] in order to find **“leading groups of consumers”**, including latent ones, that need these features most of all

**Step 7:** **Identify specific applications or products** that may utilize these functions and/or properties:

- For **B2B products** – identify such applications or products **in the leading areas of industry** identified in Step 6
- For **B2C products** – identify **existing or new products** with these features that the **“leading groups of consumers”** identified in Step 6 will appreciate

**Step 8:** **Reject those applications and products that**

1. **Cannot be addressed without serious modification of the assets** that are currently used for producing the Object, and
2. **Do not pass QEA-screening** [15-16], and, therefore, are unpromising for the client in terms of business potential

**Step 9:** If necessary, **identify and solve adaptation problems** for the remaining applications and products as in the original RFOS [8]

Fig. 3. TRIZ roadmap for identifying adjacent markets

### 3.1 Case studies

The overview of the four case studies presented in this paper is shown in Fig. 3.

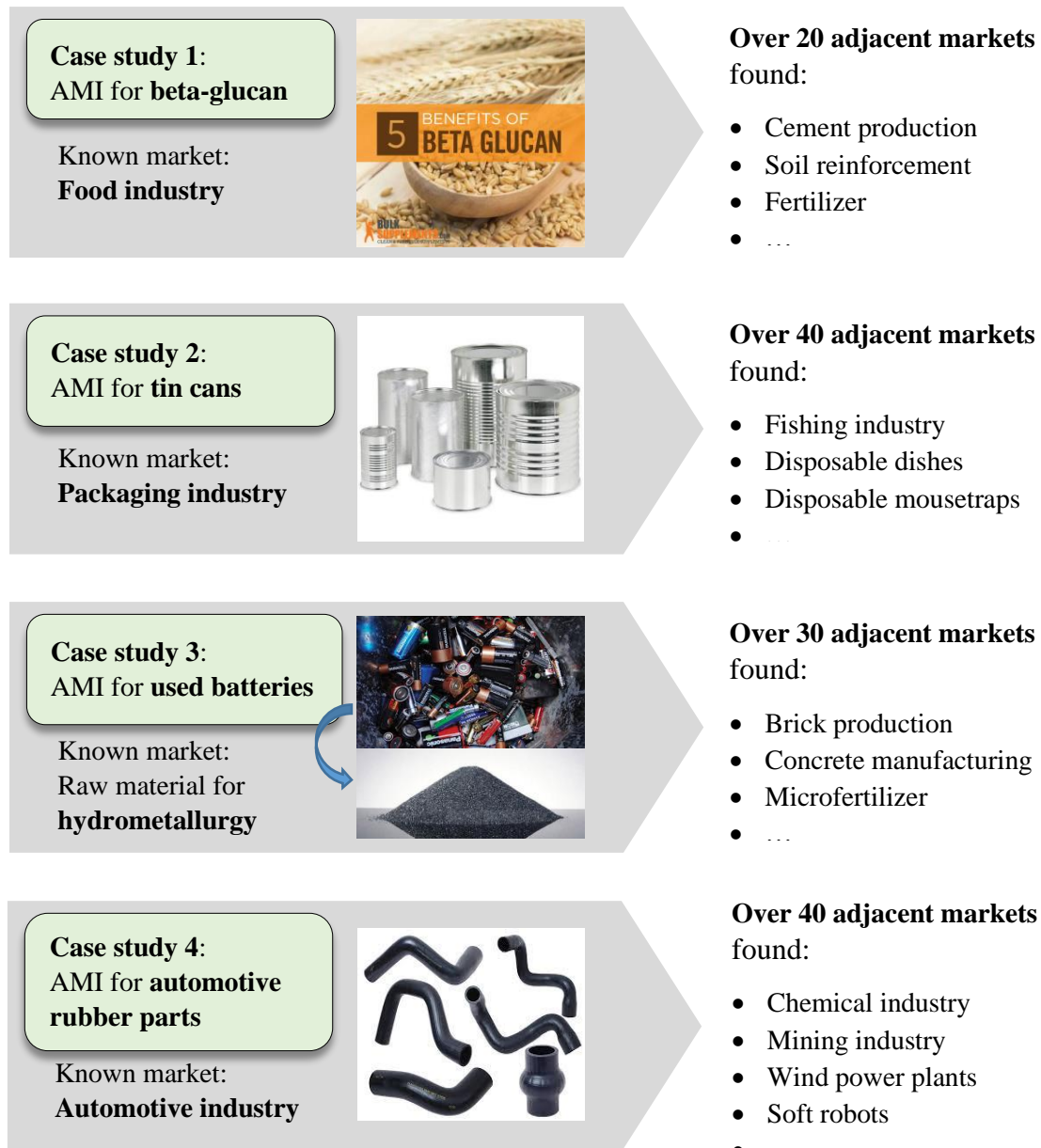


Fig. 4. Case studies at a glance

Some details of each case study shown in Fig. 4 are provided below.

### 3.2 Case study 1: AMI for beta-glucan

In this project, the client was a medium-sized company producing baking yeast. As a by-product, the company obtains beta-glucan, a biopolymer with high nutritional value, which is a popular food additive. However, the amount of beta-glucan produced

by the company exceeded demand in the local food industry and, so, the company was looking for adjacent non-food markets for this by-product.

The product-oriented MPV analysis [14], which we performed at the molecular level, showed that beta-glucan molecules have, the following features:

- They are able to promote gelling, and
- They have an internal cavity in which they are able to trap and hold foreign molecules.

These features can be translated into generalized functions “to thicken” liquids, and “to absorb” liquid or gas.

Examples of leading areas that need these functions most are: the concrete industry, geo-engineering, and the pharmaceutical industry.

Therefore, the new applications for beta-glucan that we recommended to the client included:

- Using beta-glucan as a viscosity agent in concrete that allows improving important properties of concrete without adding more cement as confirmed by Nara et al. [20];
- Using beta-glucan as a soil-strengthening component that, when sprayed over the soil, makes the soil stronger, thereby preventing its erosion, as researched by Chang and Cho [21];
- Using beta-glucan in the pharmaceutical industry as a drug encapsulation agent that is able to efficiently hold and deliver molecules of medications into the human body as indicated by Venkatachalam et al. [22].

QEA-screening revealed that for a medium-sized company, which our client is, all three of these applications are promising in terms of commercialization potential, while a few other applications that we found (not mentioned here) are much less promising for the client’s business.

### **3.3 Case study 2: AMI for tin cans**

The client in this case was a medium-sized producer of tin cans for the food and paint industries. Unfortunately, the local food and paint markets were not large enough, while the international market for tin cans was becoming more and more competitive, and therefore difficult for the client to penetrate and hold onto. For these reasons, the client wanted to discover adjacent markets for tin cans.

The product-oriented MPV analysis and the VOP [13, 14] for tin cans showed that

- Cans have some properties, for example, buoyancy, that are not utilized in their current application as a container for protecting products during storage and transportation.
- Consumers have latent MPVs that are not addressed by existing cans, for example, consumers would like the contents of the tin can not to stick to the can’s walls in order to use 100% of the product. Currently, large amounts of the contents (especially paint) remain on the can’s walls.

These two properties can be converted into the following generalized functions: “to float in the liquid” and “to repel substances,” respectively.

One of the leading areas for floating objects is the fishing industry, where large amount of floats are used for fishing nets; the leading area for anti-stick cans is the paint industry, which the client currently underserves with its existing cans.

Based on this, among the over 40 new applications for tin cans that we recommended to the client were:

- Using tin cans as floats for fishing nets (adjacent market is fishing net industry), and
- Making oleophobic cans, for example, by treating them with an omniphobic coating by UltraTech [23]. This may allow the client to win a good piece of the paint market currently served by competitors.

QEA-screening revealed that for a medium-sized company both of these applications are promising in short to mid-term prospective.

### **3.4 Case study 3: AMI for used batteries**

We performed this project for a large company that produces zinc-carbon battery cells for portable electronics. In order to protect the environment, the company accepts used batteries and, after crushing these batteries, obtains a black powder containing a mixture of carbon and metal oxides particles (mostly zinc and manganese oxides). Then, the company just stores the powder in special warehouses. There are two reasons for this: 1) the government forbids disposing the powder into the environment and 2) there are no known methods for recovering valuable metals (zinc and manganese) from the powder that are economically feasible. So, the company was looking for useful applications for the black powder as it is or for its components that can be separated without involving expensive technologies.

Examples of the black powder properties revealed by our MPV analysis are:

- Black color, and
- Electric conductivity.

We converted these properties into the following generalized functions: “to make black” and “to conduct electric current”, respectively.

These functions are needed in the following applications that we recommended to the client:

- Using in the manufacture of black bricks as suggested by Hyong Hag Im [24], in which black powder is used as a coloring agent for clay bricks, and
- Using black powder as a conductive additive for different materials.

QEA-screening revealed that for a medium-sized company these applications are promising in short to mid-term prospective.

### 3.5 Case study 4: AML for automotive rubber parts

In this project, the client was a medium-sized company that produces different types of molded and extruded rubber parts for the automotive industry: hoses, bellow, seals, gaskets, etc. The local market for these parts had become saturated and the company wanted to identify adjacent markets and the products for these markets that it could produce using its existing assets, which included technologies and equipment for molding and extruding items out of different elastomer compounds.

Our MPV analysis showed that elastomers have some properties that the products currently produced by the client did not utilize, for instance:

- High dielectric strength;
- High thermal conductivity;
- High damping ability, etc.

We converted these properties into the following generalized functions: “to stop electric current”, “to conduct heat” and to “absorb shock and vibration”, respectively.

These functions are critical for the following applications/products, among numerous other new applications that we had found, that we recommended to the client:

- Various insulators for medium- and high-voltage electrical grids;
- Heat conductive pads for electronic components, such as processors, power transistors;
- Vibration dampers for wind turbines, etc.

QEA-screening revealed that these applications are promising for the client in short to mid-term prospective, while some of the other new applications that we had found were not so promising for a medium-sized company like our client.

## 4 Conclusions

This paper describes research in progress and, so, the roadmap for identifying adjacent markets presented here, although it was very useful in actual TRIZ-consulting projects performed by the authors, cannot be considered as a universal roadmap that works equally well in all practical cases.

The roadmap does, however, cover the most frequent practical cases when the client wants to introduce its current product to adjacent markets or to use its existing assets to serve these markets.

As compared to the original RFOS [6], the proposed roadmap provides

1. Much more specific and detailed recommendations for most steps, which saves time and resources in the project;
2. Higher value results because it rejects unpromising products/applications for adjacent markets that either do not meet VOP or are unlikely to be commercialized by the client.



## Acknowledgements

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# ABOUT DEVELOPMENT DIRECTIONS OF TRIZ TOOLS FOUNDATIONS

Elena Redkolis

## Abstract

The paper considers the areas that are absent or poorly developed in TRIZ and serves to create a landscape for future system research in terms of expanding and improving the quality of the TRIZ tools functionality.

*Keywords: evolution, organizational and managerial problems, principle of action, secondary problems, synthesis tasks, TRIZ tool.*

## 1 Area of Interest

Discussions about TRIZ development can be organized from different viewpoints. For conceptual simplicity, we will focus on two of them: theory and practice.

Theoretical research is useful for turning the array of statistical regularities and confirmed hypotheses which form the basis for the development of TRIZ to science. While the analysis of practical experience of TRIZ applications helps to reveal "blank space" (the areas of the subjects and objects behavior that currently cannot be modeled using TRIZ), it also helps to formulate requirements for integrating TRIZ with other areas of system research.

From the theory viewpoint, before modifying existing or developing new TRIZ tools, it is necessary to develop criteria for evaluating the existing tools. The tools themselves can be evaluated, for example, by: 1) compliance with the requirements for the functions of the tools in a project, scope of their application, procedural and visual clarity; 2) unambiguity of the "output" indications from each tool (the criterion for stopping the use of the tool during the project), and so on.

Note that, working with criteria for evaluating existing TRIZ tools is not the subject of this article. Areas of improvement and evaluation of the existing tools were previously revealed and presented in [1-4].



We will focus on those areas of the TRIZ theory where instrumental study can reduce the number of "white spots" (those that a TRIZ professional is capable of identifying in practice but cannot eliminate by using known tools).

These "spots" usually appear on the stages of a project due to:

- inconsistencies in the used terminology (it is not detailed, incoherent);
- weak formalization of individual operational stages with TRIZ tools;
- opacity of transformation of "outputs" resulting from one tool to "inputs" for another;
- domination of such entities (subjects, flows) in a problem situation that have a low degree of determinism in their behavior and, therefore, are in principle poorly amenable to formal modeling;
- variability during the interpretation of results of using TRIZ tools for organizational and managerial tasks with a high degree of uncertainty.

The author confirms the need for the development of the discussed areas on the basis of experience with 109 TRIZ project reports that are currently being implemented at large and medium-sized companies, both in engineering and organizational and managerial spheres ([5], [8]). The identified directions do not claim to be unique and, of course, can be implemented not only with the help of TRIZ, but also with the support of other system research methods.

## **2 Analysis of Possible Development Directions**

The following discussion format is suggested below:

N. Directions for expansion of functionality and improvement of the TRIZ tools quality;

N.1. Need;

N.2. What will the implementation of this direction provide;

N.3. Problems related to the implementation of the direction;

N.4. Used tools (the lists of TRIZ tools that can be used to develop a separate research direction);

N.5. Winning tools (those TRIZ tools that will be significantly strengthened and will benefit if a particular research direction is successfully implemented).

TRIZ tools appearing in the further discussion are explained in [9], [10]. The following tools are mentioned:

- AP – Action Principle (performing the sequence of certain actions based on certain physical, biological, chemical, social and other phenomena that provide the required functioning of a technical system);
- BF – Basic Function (a useful function directed toward a target of the technical system analyzed);
- CECA – Cause-Effect Chains Analysis;
- FA – Function Analysis;

- FIM – Function-Ideal Modeling;
- FLA – Flow Analysis;
- FOS – Function-Oriented Search;
- IFR – Ideal Final Result;
- ITS – Ideal Technical System (Ideal Machine);
- LC – Life Cycle;
- MF – Main Function (a function for which a technical system is designed);
- MPV – Main Parameters of Value (parameters that a stakeholder evaluates when deciding to interact with the technical system);
- MPVA – MPV analysis;
- PC – Physical Contradiction;
- LTSC – the Law of Technical System Completeness;
- SA – Subversion Analysis (Diversion Analysis);
- SFA – Su-Field Analysis (vepol analysis);
- TC – Technical Contradiction;
- TS – Technical System;
- VA – Value Analysis (Function-Cost Analysis);
- 40P – 40 Inventive Principles;
- 4P – 4 Principles for Resolving Physical Contradictions (the typical approach for resolving a physical contradiction);
- 76S – 76 Standard Solutions to solving inventive problems (Inventive Standards).

Let us start discussing the tools in the format proposed above. We will also use abbreviation “TS” for Technical System.

### **1. Direction: Development of new idealization forms.**

1.1. *Need. **The answer to the questions:** “What requirements should be presented to the designed functions and flows?”, “When is it necessary to stop the design?”*

Currently, the "idealization" as a technique in TRIZ is applied to structures. General idealization is reflected in the concept of "Ideal Technical System" which is the formulation of what a TS should be, taking into account the static context of the purpose of its creation. Local idealization is implemented through the concept of "Ideal Final Result" which is the formulation of how individual elements of the TS should behave at the end, taking into account the active context of the requirements for TS change).

In order to finalize such tools as Function Analysis, Flow Analysis, Main Parameters of Value Analysis (see it. 9, below), it is promising to consider the concepts of “ideal function”, “ideal flow”, the elaboration of which will improve the detail and completeness of the modeling stage in a TRIZ project (table 1 in [5]).

The idealization of the proposed concepts can also serve as the formation of lists of typical requirements, which have to be taken into account when designing new functions and flows.

1.2. *Result. Management of the evolution variability* (search for the alternative interpretations and ways to improve the Technical System ideality).

1.3. *Gap of realization.* 1) No significant problems were identified. 2) The weakness of the formal analytical procedures.

1.4. *Used tools:* Function Analysis, Flow Analysis, Main Parameters of Value Analysis.

1.5. *Winning tools:* 4 Principles for Resolving Physical Contradictions, 40 Inventive Principles, Function-Oriented Search, 76 Standard Solutions.

## **2. Direction: Identification of new idealization directions.**

2.1. *Need. The answer to the question:* "What are the typical requirements of the TS at each stage of its life cycle?"

The classical interpretation of the Ideal Technical System affects aspects of interaction with the TS mainly at the stage of its functioning. It involves the assessment of ideality as the ratio of the sum of useful functions performed by the TS (the quantity and quality of the functions performed) to the sum of the factors of requital (costs, harmful functions, payment for the existence of the Technical System).

It is also promising to revise the concept taking into account the stages of the TS life cycle. Special attention should be given to identifying typical requirements of stakeholders in the context for each stage of the TS life cycle (differentiated for cases where the TS is considered as an object or a technological process).

2.2. *Result. Management of the evolution variability* (search for the alternative interpretations and ways to improve the TS ideality).

2.3. *Gap of realization.* 1) The weakness of formal procedures for working with the law of increasing ideality. 2) The weakness of the integration with methodologies of process modeling. 3) The weakness of the integration with socio-economic modeling methodologies.

2.4. *Used tools:* Life Cycle, Main Parameters of Value Analysis.

2.5. *Winning tools:* 4 Principles for Resolving Physical Contradictions, 40 Inventive Principles, Function-Oriented Search, 76 Standard Solutions.

## **3. Direction: Development of an approach to assessing the exhaustion of the existing principle of action.**

3.1. *Need. The answer to the questions:* "Have all the resources of the current Action Principle been used?", "Is there really no way to solve the problem while maintaining the structural and functional integrity of the TS, without translating it into a new Action Principle?"

It is not always a good thing for a customer to transfer a system to a new Action Principle although it is certainly a benefit from the viewpoint of scientific and technological progress. However, from the viewpoint of the company's profitability and maximum use of all available resources, transferring to a different Action Principle can lead to the destruction of the old business model and the need to develop and implement a new one.

This direction, if it successfully implemented, will allow formalizing recommendations for the development of the TS within the existing Action Principle without the need for a radical change in the TS, and will enable: a) improving the efficiency of the TS using on the current Action Principle; b) identifying indications for the transfer of the TS to a new Action Principle.

3.2. *Result.* 1) Management of *the evolution rate*. 2) A step towards eliminating the contradiction between the power of a solution and the simplicity of its implementation (it. 3 [3]).

3.3. *Gap of realization.* The weakness of formal procedures for working with the Action Principle, due to its structural and functional lack of elaboration.

3.4. *Used tools:* the Law of Technical System Completeness.

3.5. *Winning tools:* the Law of Technical System Completeness, Main Parameters of Value Analysis, Function Analysis.

#### **4. Direction: Development of an approach to assessing the completeness of functions.**

4.1. *Need. The answer to the questions:* “How to create a product that best meets the requirements of stakeholders?”, “When is it necessary to stop the design of new functions in the product?”, “How to reduce the likelihood of emergence of secondary problems?”

In the case of improving existing TS, work with the Basic Function is initially carried out starting from the current situation – some functions can already be implemented in the TS and the effectiveness of their implementation, at least, clearly increases within the existing Action Principle. Usually in practice, a solution to a problem is limited to such actions (due to the time limits imposed on solving the problem).

In the case of designing a new TS, the basis for creating the Basic Function is to define (or create "all-new") Action Principle. Further, the work can follow the path of designing a minimally complete TS that implements the actions needed on the basis of a certain Action Principle.

However, a procedure for determining a set of Basic Functions that will make the proper finishing "efforts" with respect to the product of TS is not defined. In some cases, the appearance of the BFs is caused by the peculiarities of the implementation of a particular Action Principle. In others, it is related to meeting the requirements of stakeholders who are in contact with the TS.

4.2. *Result.* 1) Management of *the evolution quality*. 2) Increasing the statistical confidence of the TRIZ theoretical basis by increasing the transparency of the transition from business problems to technical solutions (the need for which was repeatedly noted, including in it. 1 in [3]).

4.3. *Gap of realization.* 1) The weakness of formal procedures for working with the Action Principle, due to its structural and functional lack of elaboration. 2) The absence of criteria for the completeness of a set of Main Parameters of Value for a single stakeholder (for example, such criteria can be formulated, including in the course of elaborating a hierarchical model of human needs).

4.4. *Used tools:* the Law of Technical System Completeness.

4.5. *Winning tools:* Function Analysis, Main Parameters of Value Analysis.

## **5. Direction: Development of new procedures for constructing contradictions.**

5.1. *Need. **The answer to the questions:*** "How to identify all the contradictions that have to be resolved in the context of a problem situation?", "How to reduce the likelihood of emergence of secondary problems?"

We are talking about elaborating transparent procedures for resolving contradictions (both Technical Contradiction and Physical Contradiction) from the existing TRIZ analytical tools (table 1 in [8]).

It is not the purpose of using TRIZ analytical tools to analyze the process, of course. The implementation of each TRIZ analytical tool is currently being completed by updating the list of shortcomings and formulating tasks for further completion. However, the procedures for moving from analytical conclusions to contradictions are informal and poorly defined, even in cases of Function Analysis and Cause-Effect Chains Analysis. The most "transparent" now seems to be a link between Main Parameters of Value Analysis and Technical Contradiction.

5.2. *Result.* 1) Management of *the evolution quality*. 2) Increasing the statistical confidence of the TRIZ theoretical basis by increasing the transparency of the transition from business problems to technical solutions (the need for which was repeatedly noted, including in it.1 in [3]).

5.3. *Gap of realization:* —.

5.4. *Used tools:* Main Parameters of Value Analysis, Cause-Effect Chains Analysis, Function Analysis, Value Analysis, Flow Analysis, Subversion Analysis, Su-Field Analysis.

5.5. *Winning tools:* 4 Principles for Resolving Physical Contradictions, 40 Inventive Principles, Function-Oriented Search.

## **6. Direction: Development of new ways of formulating contradictions.**

6.1. *Need. **The answer to the question:*** "What problems may appear on the way to the implementation of fully functional TS?"



Special attention deserves the study of the contradiction modeling through the functions. This is necessary for establishing transition from Technical Contradiction, which is expressed through the values of stakeholders (or Technical Contradiction, which is expressed through the Main Parameters of Value), to Physical Contradiction, which is expressed through the elements of the TS, to which conflicting demands are applied.

6.2. *Result.* 1) Management of *the solution power*, incl. by improving the accuracy of the modelling. 2) Elimination of the TRIZ product virtuality and impracticality problem (it. 4 in [3]).

6.3. *Gap of realization:* —.

6.4. *Used tools:* Function Analysis, Function-Ideal Modeling, Function-Oriented Search.

6.5. *Winning tools:* 4 Principles for Resolving Physical Contradictions, 40 Inventive Principles, Function-Oriented Search, 76 Standard Solutions.

## 7. **Direction: Search for new principles.**

7.1. *Need. **The answer to the question:*** "How to increase the effectiveness (accuracy) of recommendations for resolving contradictions?"

4 Principles for Resolving Physical Contradictions (in terms of separation, circumvention, and satisfaction of requirements) appear to be implicitly distinguishable from the 40 Inventive Principles. Moreover, the GEN3 methodology suggests their direct relationship.

Further work is needed to identify the essential differences in the elimination of Technical Contradiction and Physical Contradiction including:

technological process;

organizational and managerial problem statements.

7.2. *Result.* 1) Management of *the solution power*, incl. by improving the accuracy of the modelling. 2) Elimination of the TRIZ product virtuality and impracticality problem (it. 4 in [3]).

7.3. *Gap of realization.* 1) A small volume of the source data array due to the need for preliminary formalization of the material in a natural language. 2) The weakness of the integration with methodologies of process modeling. 3) The weakness of the integration with socio-economic modeling methodologies.

7.4. *Used tools:* Main Parameters of Value Analysis, Cause-Effect Chains Analysis, Function Analysis, Value Analysis, Flow Analysis, Subversion Analysis, Su-Field Analysis, Technical Contradiction, and Physical Contradiction

7.5. *Winning tools:* 4 Principles for Resolving Physical Contradictions, 40 Inventive Principles, Function-Oriented Search, 76 Standard Solutions.

## 8. Direction: Classification and revision of known principles.

8.1. *Need. The answer to the questions: "How to increase the efficiency (accuracy) of recommendations for eliminating contradictions (including for TSs with the high degree of uncertainty in its behavior)?"*

It is promising to work with active use of approaches and technologies based on neural networks and Big Data.

8.2. *Result.* 1) Management of *the solution power*, incl. by improving the accuracy of the modelling. 2) Elimination of the TRIZ product virtuality and impracticality problem (it. 4 in [3]).

8.3. *Gap of realization.* 1) A limited number of facts available about implementation of TRIZ tools in regular business processes of companies to capture detailed statistical information. 2) A small volume of the source data array due to the need for preliminary formalization of the material in a natural language.

8.4. *Used tools:* Main Parameters of Value Analysis, Function Analysis, Flow Analysis, Technical Contradiction, and Physical Contradiction.

8.5. *Winning tools:* 4 Principles for Resolving Physical Contradictions, 40 Inventive Principles.

## 9. Direction: Improving the effectiveness of known tools.

9.1. *Need. The answer to the questions: "How to avoid mistakes when using TRIZ tools?", "How to organize teamwork?"*

The practice of using TRIZ tools demonstrates the imperfection of the latter in terms of working with:

synthesis tasks (meeting new values by creating new functions or new structures);  
tasks in which the vehicle is a technological process and (or) a set of technological operations;  
organizational and management tasks.

9.2. *Result.* 1) Management of *the evolution rate*: a) the speed of transition towards a new Action Principle; b) within the existing Action Principle. 2) Management of *the evolution quality* (focus accuracy, elaboration depth, conflict exhaustion). 3) Management of *the teamwork* (it. 6 [3]). 4) Elimination of the TRIZ product virtuality and impracticality problem (it. 4 [3]). 5) Elimination of problems arising due to the wrong choice of tasks to solve (it. 2 [3]). 6) Improving the instrumentality of the existing TRIZ tools (it. 5 in [3]).

9.3. *Gap of realization.* 1) The weakness of formal procedures for working with the AP, due to its structural and functional lack of elaboration. 2) The weakness of the integration with methodologies of process modeling. 3) The weakness of the integration with socio-economic modeling methodologies.

9.4. *Used tools:* All tools.

9.5. *Winning tools:* In the accepted logic of roadmaps.

## 10. Direction: Creation of new tools.

10.1. *Need. The answer to the question: "How to be sure that a solution will always be found?"*

In the course of working on a problem, a factual description of the existing situation usually occurs first. For this purpose, such TRIZ tools as Main Parameters of Value Analysis, Cause-Effect Chains Analysis, Function Analysis and Flow Analysis are actively used. As a result, the "task model" is formed (with Su-Field Analysis, Technical Contradiction, etc.) and a "solution model" (with Physical Contradiction, Ideal Final Result, Function-Ideal Modeling, etc.), which explains exactly what should be done to fix the problem. Only then the developed solution concept is implemented in real processes.

This logic fits into the general sequence: 1) Analysis (subject) → 2) Analysis (abstraction) → 3) Synthesis (abstraction) → 4) Synthesis (subject).

Of interest is the procedural description of a subject- and abstract-, structural and functional transitions between the TRIZ tools that are applied inside of the roadmaps by type: 1) Functions (subject) → 2) Functions (abstraction) → 3) Structure (abstraction) → 4) Structure (subject).

At the same time, the study of "1 → 2" transition requires the integration of TRIZ with other system methodologies, while the study of "3 → 4" transition is context-dependent and requires statistical accumulation of some significant experience.

10.2. *Result.* 1) Management of *the evolution rate*: a) the speed of transition towards a new AP; b) within the existing Action Principle. 2) Management of *the evolution quality* (focus accuracy, elaboration depth, conflict exhaustion). 3) Management of *the teamwork* (it. 6 [3]). 4) Elimination of the TRIZ product virtuality and impracticality problem (it. 4 [3]). 5) Elimination of problems arising due to the wrong choice of tasks to solve (it. 2 [3]). 6) Improving the instrumentality of the existing TRIZ tools (it. 5 in [3]).

10.3. *Gap of realization.* 1) The weakness of formal procedures for working with the Action Principle, due to its structural and functional lack of elaboration. 2) The weakness of the integration with methodologies of process modeling. 3) The weakness of the integration with socio-economic modeling methodologies.

10.4. *Used tools:* All tools.

10.5. *Winning tools:* In the accepted logic of roadmaps.

The sequence of directions shown in the list does not perform the function of ranking by importance. The question of setting priorities among the development directions highlighted in this article remains open and, of course, depends on the application frame and purpose of the use of TRIZ tools – whether it's a local project, some business process, or an organizational hierarchy.

It should be noted that the development of most mentioned directions will mainly contribute to the development of "synthetic" procedures and individual tools that allow creating qualitatively new systems.

The directions (items 1–10 above) discussed in this article do not address problems of integrating TRIZ tools with a single language for formalizing knowledge [4] and developing software for TRIZ, which are partially covered in [6], [7] and other publications. It is the author's opinion, these problems are certainly significant. Solving them will allow more specialists to master the TRIZ tools and will make TRIZ more computerized, and therefore – more mass knowledge and skill, which in the expected future will provide sufficient statistics for the fundamental development of the theory. However, the direction of increasing the knowledge formalization and work automation with some TRIZ tools is more applied and should go in parallel with the rethinking and development of fundamental postulates.

### 3 Conclusion

This paper summarizes results of the author's work on the analysis of TRIZ tools which are actively used in her corporate branched projects at the present time. The analysis of the functions of the TRIZ tools in such projects, and the nuances of applying their logical sets (road maps stereotyped fragments) allowed formulating key directions of work with technical systems that are absent or poorly developed in TRIZ.

Of course, targeted efforts should be focused on the development of each individual direction, the results of which should be covered in regular thematic publications in order to get a response from the TRIZ community. At least, it is the author's plan.

It will be particularly valuable if the “TRIZ Review” readers are interested in joining their efforts with the efforts of the paper's author to work out some directions described in items 1–10.

Note that you do not have to be actively engaged in TRIZ projects to develop one of such directions. The experience gained from working with other system methodologies, research experience, and capabilities to collect, process, and access a significant amount of statistical data are welcome.

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# VALUE ANALYSIS AS PRACTICED IN TRIZ-BASED FUNCTION ANALYSIS WITH TIME STEPS

Jochen Wessner

## Abstract

The paper proposes an enhancement of value analysis by integrating a time context to the known tool value analysis as practiced in TRIZ-based function analysis. This approach is shown for an electric machine - a system, which could contain the two important states of a motor mode and a generator mode. The proposed way of modelling reveals significant changes for the position of some of the machine components in the value diagram. Therefore, the recommended actions which are associated with certain areas of the value diagram differ as well and lead to an optimization of the system as a whole.

*Keywords: value analysis, time steps, function model*

## 1 Introduction

Technical systems develop in the direction of increased ideality [1]. Instead of the classical TRIZ term ideality, modern TRIZ uses value. Judging the value of a system, the known TRIZ tool value analysis as practiced in TRIZ-based function analysis can be applied. First, a graphical function model is built. This could be done as a last step in function analysis or directly from the system under evaluation, followed by the value analysis. Value analysis contains the steps of functional ranking, ranking of the determined costs and setting-up of a value diagram. The value diagram displays a relation of components and their associated relative functional values to the relative costs [2, 3]. These relations are defined as individual cost of a component over the maximum cost of one of the components and individual functional value over the maximum functional value of one of the components.

This is carried out for one specific time, usually the time when the main function is performed. For a common electric machine, this can present a problem because an electric machine could always be used in two modes. One mode is the motor mode and the other is the generator mode. Both modes could be important or even necessary. If



only one-time step is looked at this focus might lead to an optimisation to this one step only and therefore represents a strong limitation. The following paper deals with the enhancement of value analysis to address many time steps and the display of these steps within a value diagram and a graphical representation of the value analysis in a function model.

## 2 Value Analysis and Time with Function Analysis

The application of time stamps within a function model in form of a table was presented in [4]. A graphical model with three time steps was shown in [5] in which the shapes of the components were modified to the form of an hourglass and the times beginning, middle and post were introduced. In [6], an example is shown to use the graphical function model in combination with a greater number of time steps. The technical system of a tea press assembly is used to illustrate this (see figure 1).

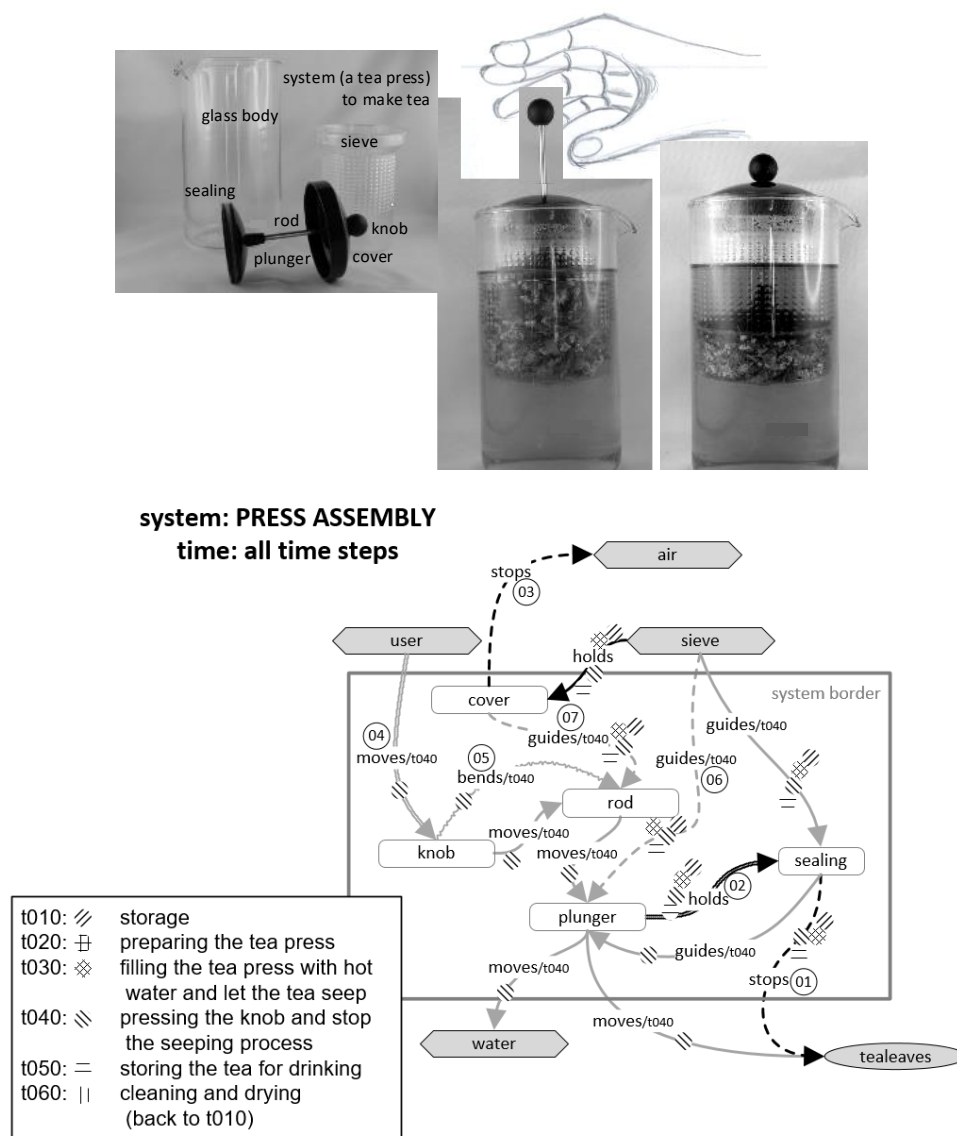


Fig. 2. Graphical function model of the tea press assembly at different times

Figure 2 presents a graphical function model of the tea press at six different times.

function model									
function carrier	action	object of the function	category	performance level	fct-rank B – Ad – Ax	fct. points	sum fct-points	normalized fct-points	cost
cover	guides	rod	U – H U	I – N – E I	A3	1	4	0,36	
	stops	air	U	I	Ad	3			
rod	moves	plunger	U		A2	2	2	0,18	
knob	moves	rod	U		A3	1	1	0,09	
	bends	rod	H		-				
plunger	moves	water	U		Ad	3	11	1,00	
	holds	sealing	U	E	A1	3			
	moves	tealeaves	U		B	5			
sealing	stops	tealeaves	U	I	B	5	8	0,73	
	guides	plunger	U		A1	3			
user	moves	knob	U	E	-				
sieve	holds	cover	U		-				
	guides	plunger	U	I	-				
	guides	sealing	U		-				

Fig. 3. Function model of the tea press assembly at different times (table)

Figure 3 displays the tea press assembly, which consists of the components cover, rod, knob, plunger and sealing, and the press assembly functions in more detail.

This figure also shows the functional values for the press assembly components. The costs of the components are omitted, and the perceptions of the function importance represent a personal view to show the process. Figure 8 shows a table of the tea press components with the evaluation of the function perceptions associated with them. The value analysis, together with this table, could also help finding possible ways to improve the system. This improvement is outlined later on.

The proposed improvement of value analysis is now illustrated with a different system, which has two different main functions. An electric machine with permanent magnets is chosen (see figure 4 for system description) because this type of machine could have two main states during the operation by turning the shaft in opposite directions. One main function or state is the motor mode t10, in which the machine drives a powertrain shaft (target during t10) and the second one is the generator mode t20 for recuperating electrical energy at the inverter (target during t20). This state takes place for example during a braking process.

t10: operation as motor - create torque

t20: operation as generator - create electrical energy

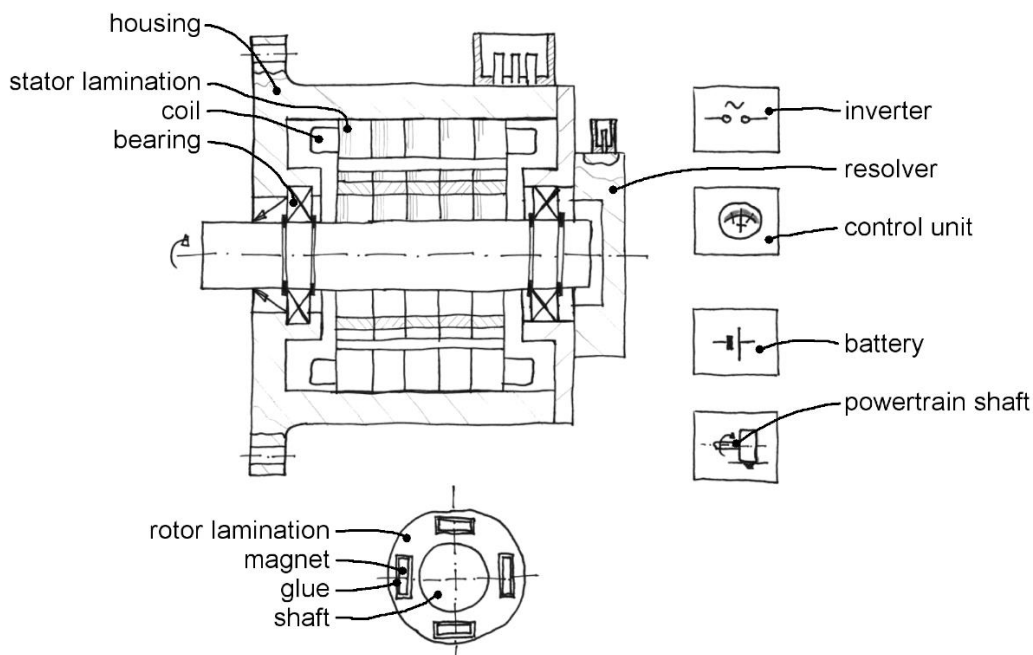


Fig. 4. Components of an electric machine (selection)

Figure 5 shows the function model, the ranking from which the functional value was derived and the costs for these time steps in form of a table. The durations of the modes are estimated to 75% motor mode and 20% generator mode. The remaining 5% refer to additional modes, e.g. different safety modes. These were omitted in the analysis.

One can see at once that due to the two modes and targets the direction of the ranking arrows point in opposite directions. This has a great influence on the value of the different system components because one component at the end of one function ranking is at the beginning of the other. The value of the function "bearing guides shaft" is A1 at the time step t10 (motor drives powertrain shaft) and is A4 at the time step t20 (motor energises inverter). The durations of the two ranked functions are significantly different. This could be taken into account by introducing a weighing factor  $g_i$ . The value of  $g_i$  is the relation of the time  $t_i$  of one time step to the total time  $t_{ges}$  taken into account -  $g_i = t_i/t_{ges}$ . The value of one function of a component is then given to  $val_i = g_i \cdot fct\text{-points}$ . Summing up all individual function values  $val_i$  gives the function value of the component, i.e.  $val = \sum val_i$ . In addition to weighing in respect to time, it is possible to use another weighing factor  $g_j$  for highlighting the relative importance of the time steps, e.g. higher  $g_j$  for safety relevance.

function model												
function carrier	action	object of the function	category	performance level	fct-rank	fct. points	step	time	fct-points	sum	normalized	
												U – H
shaft	drives	powertrain shaft	U	N	B	7	10	0,75	5,25	17,4	1,00	
	informs	resolver	U	N	A1	5	10	0,75	3,75			
			U	N	A1	5	20	0,20	1			
	holds	rotor laminations	U	N	A2	4	10	0,75	3			
			U	N	A3	3	20	0,20	0,6			
	holds	bearing	U	N	A2	4	10	0,75	3			
			U	N	A5	1	20	0,20	0,2			
	drives	rotor lamination	U	N	A3	3	20	0,20	0,6			
bearing	guides	shaft	U	N	A1	5	10	0,75	3,75	4,15	0,24	
			U	N	A4	2	20	0,20	0,4			
magnet	excites	rotor lamination	U	N	A2	4	10	0,75	3	3,6	0,21	
			U	N	A3	3	20	0,20	0,6			
stator lamination	moves	rotor lamination	U	N	A2	4	10	0,75	3	4	0,23	
	powers	coil	U	N	A1	5	20	0,20	1			
rotor lamination	holds	magnet	U	N	A3	3	10	0,75	2,25	6,15	0,35	
					A4	2	20	0,20	0,4			
	moves	shaft	U	N	A1	5	20	0,20	1			
	holds	glue	U	N	A4	2	10	0,75	1,5			
					A5	1	20	0,20	0,2			
	excites	stator lamination	U	N	A2	4	20	0,20	0,8			
resolver	informs	inverter	U	N	Ad	5	10	0,75	3,75	4,75	0,27	
			U	N	Ad	5	20	0,20	1			
housing	holds	stator lamination	U	N	A3	3	10	0,75	2,25	11	0,63	
			U	N	A2	4	20	0,20	0,8			
	holds	bearing	U	N	A2	4	10	0,75	3			
			U	N	A5	1	20	0,20	0,2			
	holds	resolver	U	N	A1	5	10	0,75	3,75			
			U	N	A1	5	20	0,20	1			
glue	holds	magnet	U	N	A3	3	10	0,75	2,25	2,65	0,15	
					A4	2	20	0,20	0,4			
coil	powers	inverter	U	N	B	7	20	0,20	1,4	3,65	0,21	
	excites	stator lamination	U	N	A3	3	10	0,75	2,25			
inverter	controls	resolver	U	N	-	-						
	controls	coil	U	N	-	-						
powertrain shaft	drives	shaft	U	N	-	-						

Fig. 5. Value analysis of the electric machine addressing two time steps (table)

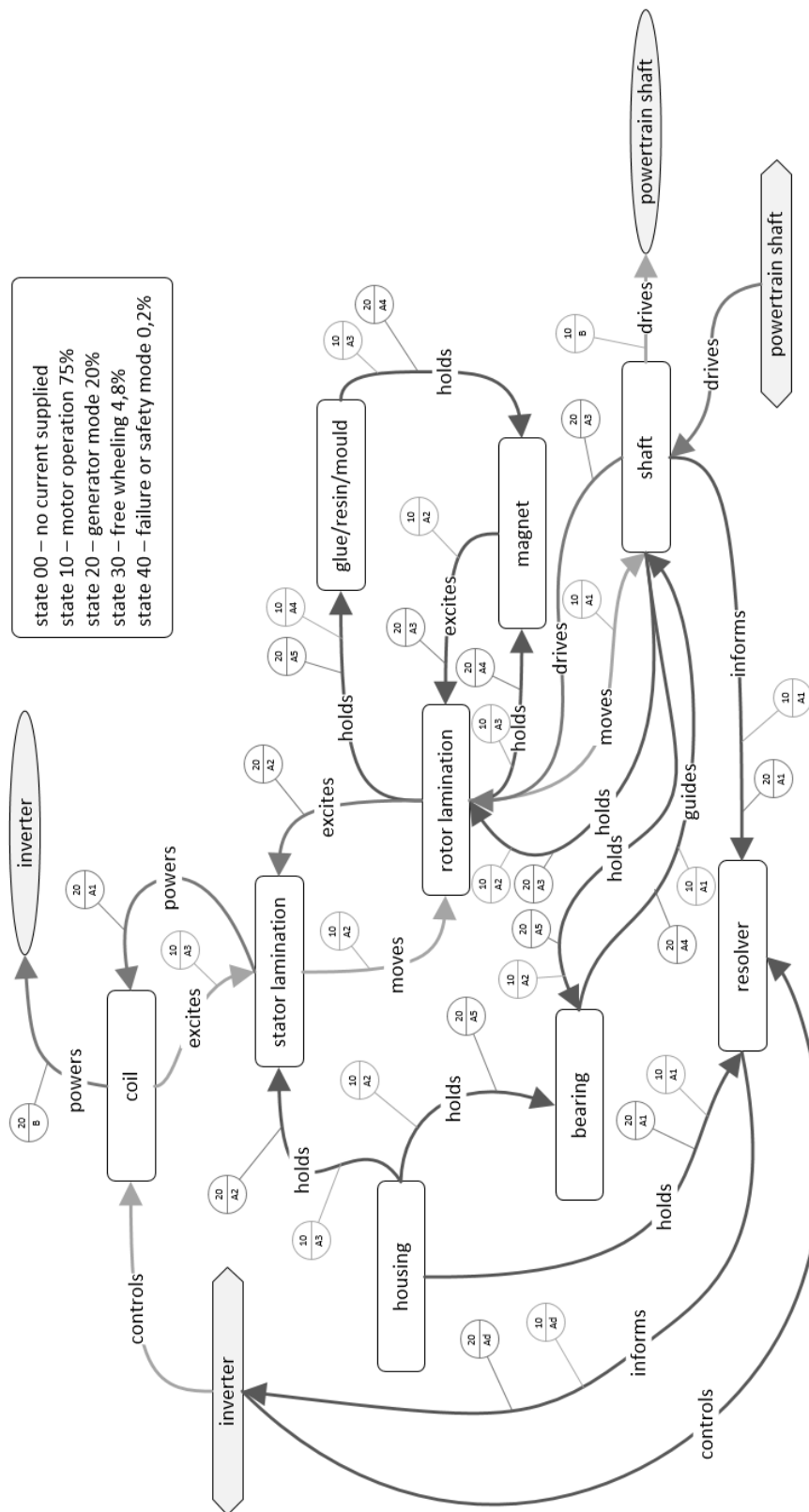


Fig. 6. Graphical model of the value analysis for two time steps



For example, the calculated functional value for the shaft and the time steps t10 and t20 is 17.4. This, being the highest value, is taken as the reference for normalising (see figure 5) the functional values. The costs are shown as well because the costs are necessary to set up the value diagram (see figure 7). Again, the used costs (fictitious values) of the components and the perceptions of the function importance represent a personal view to illustrate the process.

As mentioned, figure 6 shows the value diagram. It contains the values diagrams for the two individual time steps t10 and t20 and the combined values for both steps. Printing the three results in one picture helps to compare the results. This comparison reveals a significant change of position of the components five (rotor lamination) and nine (coil). The combined value is much higher than the value for the single time steps. The reason for that is the close position to the changing targets. In this case, the reference for normalising stayed the same, in other cases this might change as well and increase the influence on the result. The components four and six display minor changes in position. Nevertheless, it might be interesting to consider these components as well. The position of the different parts in the value diagram are associated with recommendation or possible actions to take. For components five and nine, a combined analysis gives the result that no modification is necessary. The individual time steps would lead to the conclusion that an action might be necessary. Therefore, the time for optimising these two parts could be spent more efficiently instead of addressing for example the housing, the bearings or the magnets.

The proposed graphical representation shown in figure 6 is easy to grasp. On the other hand, even for small systems like the electric machine with two main functions, it requires quite some amount of work. The reward for this effort would be the more complete optimisation in respect to many different main functions of a system and not leaving an important one out. The electric machine was modelled with useful functions, which are perceived normal.

If the first example of the tea press is looked at again, this case reveals different function categories and perceptions. This could lead to another course of action, which is explained in the following paragraph.

Figure 8 shows a summary of these different function categories and perceptions of the function importance for the tea press assembly during the time of moving the knob down in a table. Some functions fulfilments are perceived normal, some insufficient, excessive or harmful. If the goal is normal function fulfilment, then one could try to trim components fulfilling harmful, inefficient or excessive functions. Again, looking at more than one time step for the summing up would lead to a more complete system understanding and avoid optimising for one mode only. Due to the different time steps and hierarchical levels, the targets in the tea press case do change. The targets are the air (storage), the water and the tealeaves (seeping and following time steps). In [6] this is explained in more details.

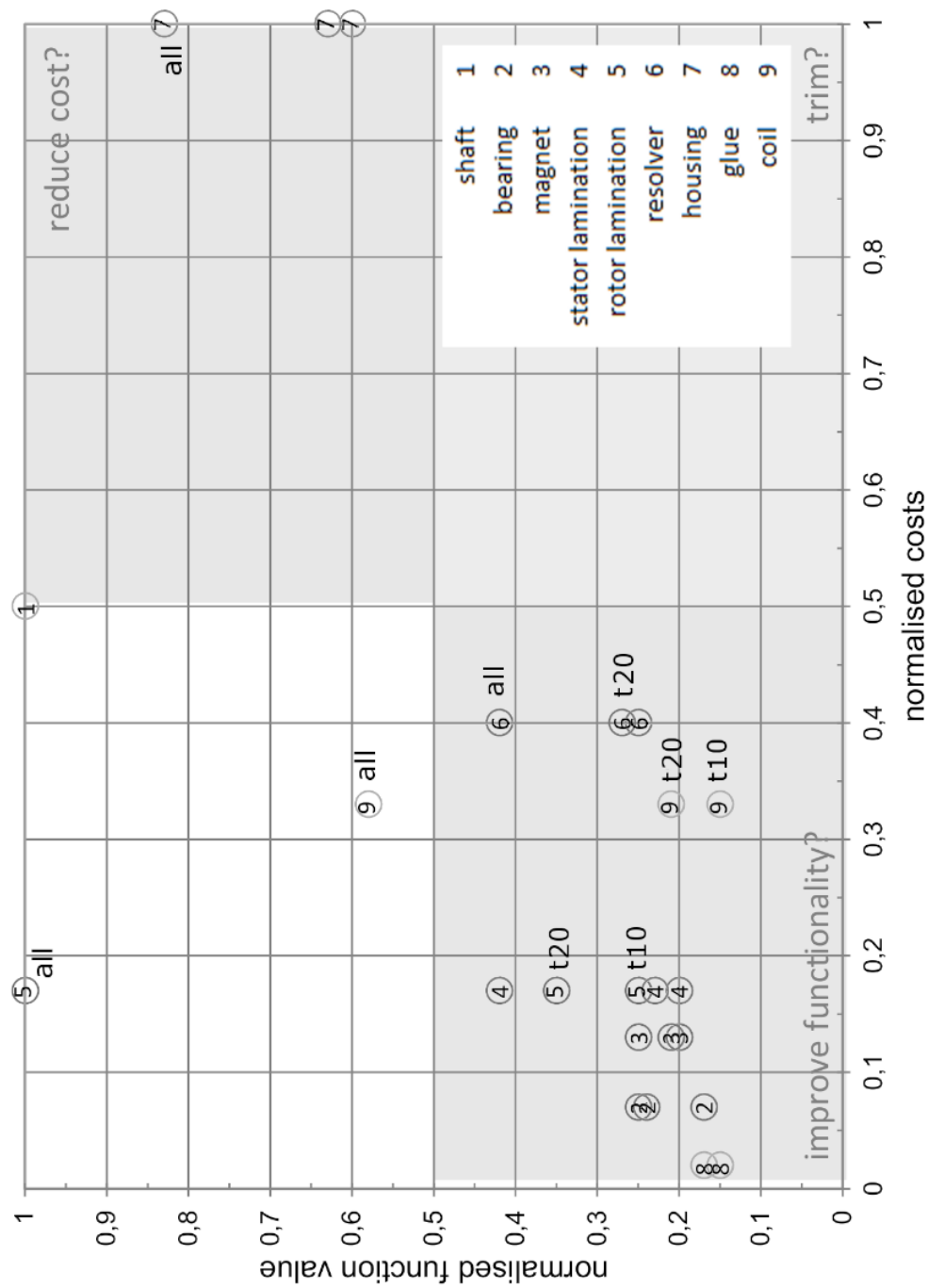


Fig. 7. Value diagram of the electric machine addressing two time steps

	functions			
	normal	inefficient	excessive	harmful
cover		2		
rod	1			
knob	1			1
plunger	1		1	
sealing	1	1		
user				
sieve				

Fig. 8. Function perception of the tea press assembly at different times (table)

### 3 Conclusions

The tea press was used for the graphical function model and time steps. For this kind of modelling an enhancement to value analysis as practiced in TRIZ-based function analysis is proposed. The extension is shown with the model of an electric machine, which has two main functions. The first one is creating torque to drive a powertrain and the second one is to create energy at the inverter during recuperation. The proceedings are equivalent to the ones known in the TRIZ tool value analysis, i.e., they contain ranking the functions, creating a table for value analysis, deriving the normalised function values, calculate the normalised costs and draw the value diagram. For the proposed enhancement to value analysis this has been illustrated for two main functions appearing at two different time steps. The first time step is the motor mode and the second one is the generator mode. Using a weighing factor, the durations of these two time steps could be related to each other. The functional value of the functions now contain all significant information, i.e. time steps, length of the time steps and the different ranking values due to the changing targets. This proposed enhancement therefore helps to optimise a system and its value in a more complete way than it would be done if only one time step is looked at. Another way of analysing the results is building up a table with the sums of the different kind of function categories and perceptions for the different time steps. Again, looking at all time steps is thought to make the analysis more general and complete.

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# TRIZ FOR PROCESS OPTIMIZATION

Stefan Schaper

## Abstract

*Several methods of the TRIZ toolbox are useful for optimizing industrial, administrative or service processes. However, in daily practice, TRIZ tools are rarely used for that purpose or only for isolated steps. Here, several TRIZ methods are used in a joined approach in order to achieve massive improvement of processes. Function Analysis for Processes, Trimming for Processes, CECA (Cause Effect Chain Analysis) and Trend of Flow Enhancement from TESE (Trends of Engineering System Evolution) were combined. A summarized case study about process optimization in a laboratory is presented.*

**Keywords:** *TRIZ, Function Analysis for Processes, Trend of Flow Enhancement, Trimming, Trends of Engineering System Evolution*

## 1 Introduction

Several methods of the TRIZ toolbox are useful for optimizing industrial, administrative or service processes. However, in daily practice, this activity is dominated by tools like Business Process Management, Value Stream Mapping, Makigami, Six Sigma, Kaizen, Lean and several others (pers.obs.). They support the transparency of activities and document the current situation, but apart from obvious solutions, they usually don't provide approaches for resolving the challenges of process optimization. See also [1]. However, these methods lack in creativity when solving problems [9].

When doing a literature search at Google Scholar, the biggest public search engine for literature search, the search for the keywords "value stream mapping" reveals 2.940.000 hits and for "Business Process Management" 3.230.000 hits. The same search for "function analysis for processes" delivers 7 (!) hits (observed 10.04.2020 by the author). This is an indicator of a low usage of this tool and maybe, a lack of knowledge in the community of process optimizers (TRIZ and "Process optimization" delivers 443 hits, for completeness).

Among the others, TRIZ provides several useful methods for analysis and solving of problems:

1. Flow Analysis: Analysis what type of flow is to be improved: information, substances or energy.
2. Function Analysis of Processes: Functions of the different process steps are defined and classified (productive, providing or corrective). This is a very effective tool for the analysis of the process as it provides initial problems for further processing. Function Analysis for Processes allows defining functional disadvantages and possibly cost, material or time saving or avoiding other disadvantages.
3. Cause-Effect-Chain-Analysis: the approach of asking several times “why?” is delivering root causes and valuable information for optimization.
4. Trimming for Processes: There are several trimming rules for productive, providing and corrective processes. In the authors opinion, these trimming rules are underused in optimization projects.
5. Trend of Flow Enhancement: This is one of the Trends of Engineering System Evolution. It shows probable lines of evolution of processes and gives valuable information on the future of a process. It can be used to trigger ideas for the improvement or redesign of a process.

Although TRIZ is being used to optimize industrial operations, it is mostly used to improve an isolated step. See [8] as an example.

In this case study, Function Analysis for Processes, Trends of Engineering Evolution (Trend of Flow Enhancement) and Trimming for Processes are joined to build a conclusive optimization tool for disruptive innovation of processes. The individual methods are obviously well known; however, they are not commonly used in combination and show results and synergies.

## 2 Methods

### 2.1 Flow Analysis

The first two steps (Flow Analysis and Function Analysis) serve as tools to gather initial disadvantages. In the case of flows it can include [2]:

- bottlenecks
- stagnant zones
- recirculation zones
- poorly transferable flow
- long flow channel
- high channel resistance
- low flow density
- large number of transformations
- grey zones
- channel damages flow
- flow damages itself
- flow damages channel
- flow damages other objects
- wasted flow



- inefficient use of flow

Some of these results can also be obtained with conventional business process mapping tools. Methods like six sigma or value stream emphasize the gathering of statistical or financial data for objective analysis. This enables the identification of bottlenecks or the elimination of non- or low-value-delivering steps. However, they usually stop their systematic approach after the analysis and leave improvements to the responsibility of creative skills of the project participants.

## 2.2 Function Analysis of Process and Trimming

In the opinion of the author, it should be possible to include data from such previous analysis and combine it with e.g. Function Analysis and/or CECA. Also, other authors [3] recommend using such information, for example, to derive technical or physical contradictions.

The above-mentioned classifications allow the characterization on a qualitative level if statistical data does not exist.

The Function Analysis of Processes classifies all functions as *productive* (if visible on the final product), *corrective* (if a defect from a previous step is corrected), *providing* (not visible on the product but necessary like transport tasks or support functions).

For these classifications, there are existing Trimming Rules [2] (Fig. 1):

An Operation with a Corrective Function can be Trimmed if:	An Operation with a Supporting Function can be Trimmed if:	An Operation with a Transport Function can be Trimmed if:	An Operation with a Productive Function can be Trimmed if:
A. The Operation that generates the defect is eliminated	A. The Operation requiring the Supporting Function is trimmed	A. The object of the analyzed Function is eliminated from the System	A. The object of the analyzed Function is eliminated from a System
B. The Operation that generates the defect is changed in such a way that it does not generate the defect any longer	B. The Supported Operation is changed so that it does not require any support now	B. The components between which the object of an analyzed Function moves are eliminated from the System	B. The necessity to perform the analyzed Function is eliminated
C. The Operation that generates the defect is changed in such a way that it starts generating the defect with another (safe) set of parameters. In this case the defect ceases to be a defect and the need for performing a Corrective Function is eliminated	C. The Supported Operation performs the Supporting Function itself	C. The subsequent Operations are changed in such a way that the necessity to perform the analyzed Function is eliminated	C. The analyzed Function is transferred to the preceding or subsequent Operation
D. The Operations which are harmed by a defect are changed in such a way that they become insensitive to it. In this case the defect ceases to be a defect and the need for performing a Corrective Function is eliminated	D. The analyzed Supporting Function is transferred to the preceding or subsequent Operation	D. An analyzed Function is transferred to the preceding or subsequent Operation	
E. The Corrective Function is transferred from that Operation to the Operation producing the defect			
F. The analyzed Corrective Function is transferred to the preceding or subsequent Operation			

Figure 1. Table of Trimming Rules

### 2.3 Trend of Flow Enhancement

The Trends of Technology Evolution provides valuable information about future developments of systems. These future developments can also be used to gather ideas for improvement of processes of all kinds. Initially, they generate new problems, as all recommendations require adaptations. Nevertheless, these new problems lead to a generation of ideas for creating a newt-generation-process. This can work as follows:

- Use the recommended steps to gather ideas for a vision of the future system and potential technological requirements
- For that vision, solve the related key (and adaptation) problems

One of such trends, the Trend of Flow Enhancement introduces several steps to be considered to design a process in an optimal way [2] (Fig.2). In combination with the trimming rules and the individual recommendations for Flow Enhancement, there are 58 trigger points to improve a process.

Improve useful flows		Reduce negative effects of harmful/incidental flows	
<i>A. Increase conductivity of the flow</i>	<i>B. Improve flow utilization</i>	<i>A. Reduce the conductivity of the harmful/incidental flow</i>	<i>B. Reduce the impact of harmful flows</i>
Increase the density of the flow Apply the useful action of one flow to another Apply the useful action of one flow to the channel of another flow Arrange for one flow to carry another flow Allot many flows to one channel Modify the flow to increase conductivity Direct the flow through a Supersystem channel	Combine two different flows to obtain synergy Preset the necessary substance, energy, or information Eliminate a stagnant zone Utilize impulse action Utilize resonance Modulate the flow Redistribute the flow Combine homogeneous flows Utilize recirculation	Introduce stagnant zones Reduce the conductivity of part of the flow channel Utilize recirculation Increase the number of flow transformations Transition to a lowconductivity flow Increase the length of the flow Introduce bottlenecks	Preset the substance, energy, or data that will be required to neutralize the flow Bypass Transfer the flow to the Supersystem Recycle or recover incidental flows Introduce gray zones Reduce the density of the flow Eliminate resonance Redistribute the flow Combine a flow and an anti-flow Modify the flow Modify the damaged object
Reduce the number of flow transformations Transition to a more efficient flow type Reduce the length of the flow Eliminate "gray zones" Eliminate "bottlenecks" Create a bypass Increase the conductivity of the separate parts of the flow channel			

Figure 2. Steps for flow improvement according to the Trend of Flow Enhancement

## 2.4 Flow

In order to generate an optimal result in process optimization projects, it is proposed to combine the existing TRIZ methods instead of using them in an isolated way.

1. Flow Analysis and Function Analysis of Process: Identify initial disadvantages. Material from previous analysis can be included and be enhanced.
2. Apply CECA for key disadvantages.
3. Apply Trimming.
4. Apply improvements from the Trend of Flow Enhancement.
5. Verify result(s)

## 3 Case Study

Flows in healthcare are typically complex and involve biological, chemical, technical and human factors that influence the outcome e.g. of a medical decision making. As

many factors influence the outcome of a flow, the complexity is difficult to master. However, the need for increased efficiency and the competitive situation increase pressure to drive the demand for improved flow [4].

As in other industries, the human labour is a very relevant factor for costs. At the same time, qualified medical expertise is extremely valuable. For these reasons, the human resources must be used as effective as possible.

### **3.1 Example “Logistic flow in clinical laboratory” (Extract)**

Clinical laboratories provide analytical services for hospitals or physicians in private practices. Samples taken from patients are analysed here on clinical analysers, requiring reagents, consumables like plastic tubes, rinsing solutions, etc.

Today, technicians need to transport system reagents and samples to the analytical devices. Also, they need to remove waste in order to keep the system running. As the degree of logistic integration is currently low, the labs need to keep considerable stocks of reagents and consumables and spend effort for manual supply of the devices.

#### **Step 1 Get supply (Flow of Material)**

Functions:

Technician search reagent	<i>(providing)</i>
Technician search consumables	<i>(providing)</i>
Technician move reagent	<i>(providing)</i>
Technician move consumables	<i>(providing)</i>
Technician loads reagent (to analyser)	<i>(providing)</i>
Technician loads consumables (to analyser)	<i>(providing)</i>

#### **Step 2 Operate Analyzer (Material / Information)**

Functions:

Technician starts analyser	<i>(providing)</i>
Analyzer generates analytical result	<i>(productive)</i>
Analyzer creates waste	<i>(providing)</i>

#### **Step 3 Maintain Analyzer (Material / Information)**

Functions:

Technician removes waste	<i>(corrective)</i>
Technician calibrates analyser	<i>(providing)</i>
Technician cleans analyser	<i>(corrective)</i>

Especially the search and transport by the technician can be qualified as “inefficient use of flow” as the technician needs to walk to the storage, search often manually and take the requested reagent or consumable and walk back. Also, the technician can be

considered as a bottleneck, while the warehouse can often be considered a stagnant or grey zone for the supplies as very often no real transparency exists on the availability of critical supplies and e.g. their expiry date. There are also some corrective functions like cleaning and removing of waste (reagents, consumables and samples).

**CECA** has led to following results:

Search: lack of information of stock and location of products

Transport: interruption of other important tasks leads to late supply of analyser causing stand-still times.

### **Trimming:**

The transporting functions cannot be eliminated as the supplies and reagents are essential to the system and it also cannot be transferred to a previous function (Trimming rules A-D for transport).

However, the search function can be eliminated using warehouse management systems.

Trimming of the corrective functions is difficult: waste is generated due to the chemical reagents; the patient blood samples and one-way-use consumables (plastic tubes). The reagents and blood can't be replaced. The tubes containing them must today be treated as special waste as it contains potentially infectious material. Therefore, a use of multi-use tubes is currently not possible as it may lead to contamination.

Cleaning functions can be partly eliminated by an intelligent design of the device where critical components are completely closed from the environment. Also, surfaces with self-cleaning anti-bacterial properties can be used.

However, the result from trimming is not yet satisfactory. The elimination of search effort is a first step for improvement, but this was already derived from previous (conventional) analysis.

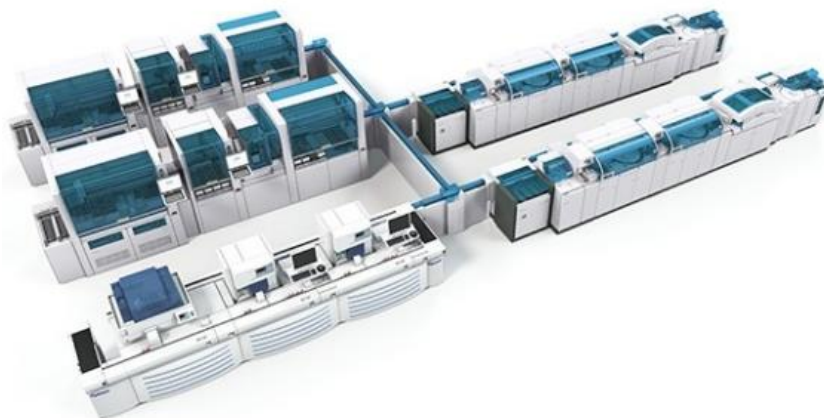


Fig. 3: Clinical Analyzer. Source : Roche.com



Fig. 4. Reagent cassettes for analyzers. They contain the reagents for performing biological assays. Source: Roche.com



Fig. 5. Barcoded sample tubes. Source: Medtech Insight

### **Trend of Flow Enhancement:**

#### **Increase conductivity of flow:**

To increase conductivity, automated warehouses like in other industries might play an important role in the future clinical laboratory. They can manage the placement of reagents to storage bins, manage inventories, do automated material movements including automatic scanning and related system booking.

Robots can also transport reagents to the analytical device [5]. Also, this is a way to save costs, as these tasks are performed by qualified lab technicians who should perform other tasks.

#### **Elimination of grey zones:**

Future systems will help to optimize stocks and automate flow of material and reagents to the analytical devices [6]. Warehouse management systems will automatically provide an overview on available stocks, order automatically or will alert staff on critical components out-of-stock situations.



### **Reduce number of flow transformations:**

Instead of delivering reagents and consumables to the warehouse of the clinical laboratory, the supplier could deliver them just-in-time to the analyser. Such approaches are already in place in many manufacturing companies.

Future contracts could oblige the supplier to guarantee a continuous supply in order to generate results without any interruption and even remove the waste afterwards.

## **4 Evaluation and Outlook**

TRIZ tools are gaining more importance in cost reduction efforts [1]. Also, the integration into value engineering tools is increasing [3]. The methods mentioned are very promising in a combined approach and can be used in a complimentary way with other process optimization tools. Very often, processes were already optimized before and the use of TRIZ tools can unlock additional potential for improvement. Some authors also propose the combination of TRIZ and methods such as Design for Cost, TOC (Theory of Constraints), DMAIC (Define, Measure, Analyse, Implement, Control) and others [7, 10]. In some studies, authors combine Lean or Six Sigma approaches with the 40 inventive principles for isolated tasks [9].

The listed example shows the value of using the Trend of Flow Enhancement, which has increased the quality and cost saving potential considerably and beyond the results of conventional process improvement work. This procedure is especially valuable when a complete renewal of the process is planned as the application of Function Analysis for Processes, CECA, Trimming and Trend of increasing Degree of Flow enables options beyond the approaches of e.g. Value Chain or Business Process Management. As mentioned before, these approaches deliver transparency but a limited creativity which can be significantly enhanced using TRIZ.

Apart from the mentioned methods, also other TRIZ trends or TRIZ tools could be employed.

Especially in digitization projects, the Trend of Increasing Degree of System Completeness should be studied further. This trend uses the paradigm that a system must be composed by tool, transmission, source of energy and a control. If one of these components does not exist, it is usually borrowed from the environment. In many processes, humans serve as a control instance and monitor machines or other functions. With the raising availability of sensors and computing power in industrial and other processes, it is more and more possible to replace the “control” function by machines. The Trend of Increasing Degree of System Completeness could systematically be used to enable digitization, as it helps to identify systems where the function of control is still exercised by humans. Such systems could be candidates for further digitization.

For industrial processes also the database of scientific effects or Function Oriented Search could be useful. In many cases, processes are performed since many years without major change and the base-principles were not modernized since then. The

use of alternative principles of execution could lead to new improvements, cost savings or innovations.

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# METHODS FOR RESOLVING OPTICAL CONTRADICTIONS IN TRIZ: AN OVERVIEW

Pavel Fimin

## Abstract

This paper suggests that it makes sense to consider physical contradictions in which two opposite optical properties are required from the same component as a separate type of physical contradiction, under the heading ‘optical contradiction’. This is justified by the wide variety of optical phenomena that relate to light propagation in space and time as well as to light interaction with matter, the rapid development of optical engineering and technologies, and the existence of special methods for solving optical contradictions, which take into account the wave nature of light. The paper reviews examples of optical contradictions from geometric, wave, laser, and other areas of optics. In addition, a few special methods for resolving optical contradictions are described. These methods are (1) separation in the radiation spectrum, (2) separation by intensity of radiation, (3) separation by polarization, and (4) separation in phases of the light wave. In optics, they can be more efficient than the general methods that TRIZ recommends for solving physical contradictions.

*Keywords: TRIZ, contradiction theory, physical contradiction, separation principle, optical properties and phenomena*

## 1 Introduction

The concept of physical contradiction, which is one of the key concepts in modern TRIZ, describes a situation, wherein the same parameter needs to exhibit opposite physical properties (e.g., it needs to be thin and thick, heavy and light, hot and cold, etc.). In terms of mathematics, the physical contradiction represents an equation of a technical problem [1].

Among the physical properties of material objects, optical properties, which relate to light propagation in space and time, as well as to the interaction of light with matter, hold a prominent place. More than one fourth of the approximately 250 physical effects collected by Denisov et al [2] represent optical phenomena. As noted by Jensen [3], from 80 to 90 percent of the information that humans receive from the outside world is visual perception.

In optics, the term ‘light’ normally refers not only to visible light, but also to infrared and ultraviolet radiation, as well as to X-rays. Overall, it covers the wavelength range from 0.01 nm to 1 mm.

Due to a wide variety of optical phenomena and the rapid development of optical engineering and technologies, it makes sense to consider ‘optical contradiction’ as a special type of physical contradiction in which two opposite optical properties are required from the same component of a technical system. Additionally, this separation is justified by the existence of special methods for resolving optical contradictions.

This paper is a review devoted to optical contradictions in TRIZ. Section 2 surveys examples of optical contradictions from geometric, wave, laser, and other areas of optics. Section 3 focuses on a few specific methods for resolving optical contradictions. These methods take into account the wave nature of light. In optics, they can be more efficient than the general methods that are recommended for solving physical contradictions by Litvin [1] and by Altshuller [4].

## **2 Optical Contradictions Solved Using General Methods for Resolving Physical Contradictions**

In this Section, examples of optical contradictions from different areas of optics are presented. It is shown how these contradictions can be solved using general methods for solving physical contradictions, namely by separation in space and time as well as at a system level.

### **2.1 Separation in Space**

The invention of the laser as a source of coherent optical radiation is, in itself, a result of overcoming the contradiction between quantum and classical physics. A necessary condition for laser generation utilizes an active medium with an inverse population of energy levels, which is known in quantum physics. In classical physics, though, the active medium cannot exist because at thermodynamic equilibrium, in accordance with Boltzmann distribution, the upper energy level population is always less than the lower energy level population<sup>1</sup>.

Nevertheless, an active medium is not enough to build a laser. All specific properties of laser radiation are formed by an optical resonator, inside which light wave travels back and forth through the active medium [6].

Optical resonators used in conventional methods of generating high-power diffraction-limited laser beams are unstable resonators. Such resonators are especially effective in

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<sup>1</sup> *The existence of non-equilibrium systems with population inversion was predicted in 1939 by Valentin Fabricant. Interestingly, in the 1920s Rudolf Ladenburg observed the so-called enhanced emission of gas discharges that corresponded to the non-equilibrium state of the system. Nevertheless, Ladenburg and his followers were too deeply steeped in Boltzmann’s idea of thermodynamic equilibrium to make anything of their observations. (See review [5] and references therein for details.)*

lasers with a high gain and a large cross-section of the active medium (e.g., in excimer and CO<sub>2</sub> lasers).

However, in order to ensure single-mode laser generation<sup>2</sup>, the edge diffraction on the output mirror must be eliminated. This is because a light beam diffracted off the edge of a mirror causes energy to scatter over a wide angular range, and a small amount of radiation is scattered back into the cavity as a converging wave, as shown in Fig. 1. Since it remains inside the resonator for a long time, such a wave affects the laser mode structure and deteriorates beam quality.

Thus, there is an optical contradiction: the reflectance of the output mirror of the unstable resonator should be high in order to maintain laser generation, but it should be low in order to minimize the diffractive effects at the mirror edge.

This contradiction is solved by a separation in space using the principle of a local quality. In substance, the mirror reflectance should be low only within a narrow operative zone wherein detrimental diffraction effects occur, namely, in the periphery region. Near the longitudinal axis of the resonator, the mirror reflectance can remain high.

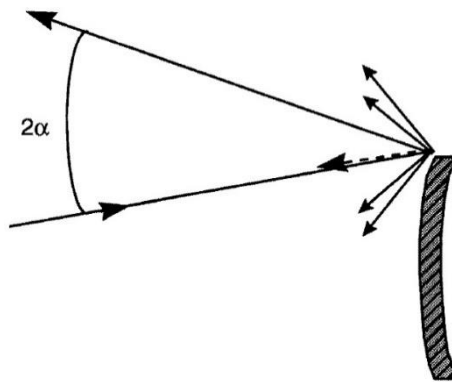


Fig. 1. Scattering of the diverging wave on the edge of the output mirror. Some radiation is scattered back into the resonator, yielding a converging wave [6]

The solution is a mirror, whose reflectance decreases smoothly from its maximum in the central zone to zero on the periphery. As an example, Fig. 2 shows a mirror with an ideally ‘smoothed’ edge, its reflectance distribution described by the Gaussian function.

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<sup>2</sup> A laser mode is defined as an electric field distribution, which reproduces itself (apart from a possible loss of power) after a full trip through the resonator. (See, for example, Ch. 1 in the fore-quoted monograph [6].)

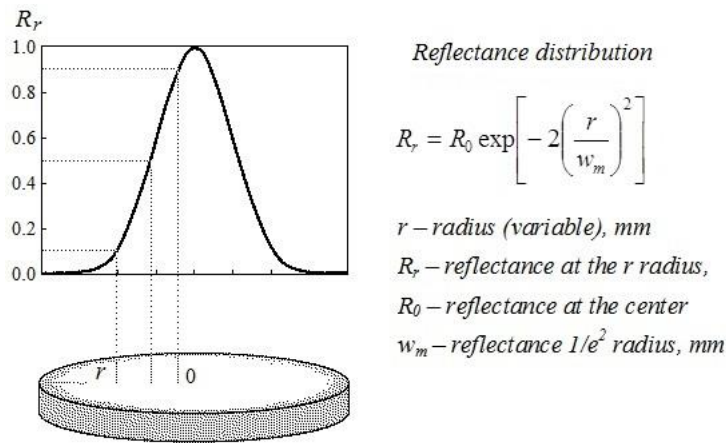


Fig. 2. Mirror with Gaussian distribution of reflectance [7]

There is, however, a secondary problem: how to make such a ‘gradient’ mirror? This can be solved by using multilayer dielectric coatings of variable thickness on a glass substrate. The reflectivity of components manufactured in this manner is determined by the effects of multi-path interference in multilayer thin-film systems [8]. Nowadays, gradient mirrors are commercially available and can be found in an increasingly large number of lasers [9].

## 2.2 Separation in Time

The main function of the automotive rear-view mirror is to inform a driver of the situation on the road. As every driver knows, being able to clearly see pedestrians, bicycle riders and other vehicles depends on the characteristics of the rear-view mirror. This mirror, however, also has a harmful function: to reflect bright light. The glare of bright lights from a following automobile, brilliant sunshine, and even the setting sun can blind the driver and cause a car accident.

Once again, there is an optical contradiction: the reflectance of the automotive mirror should be high in order to show the traffic situation clearly, but it should be low in order to prevent dazzling the driver.

This contradiction can be solved by separating the contradictory requirements in time because low reflectance is required only when there is glare from light reflected in the mirror.

One of the known solutions, suggested by Byker [10], involves temporarily changing the mirror’s optical characteristics by using chromogenic materials. Currently, there are two major categories of reversible chromogenic materials: transition metal oxides and organic compounds. The commercially available chromogenic switchable mirrors surveyed by Lampert [11] are based on a stack of solid inorganic of  $H_xWO_3/Ta_2O_5/NiO_y$ .

Another important application wherein optical contradictions are separated in time is an auto-dimming glass on a welding helmet. For instance, the safety welder’s glass, patented by Masses [12], comprises an interference filter that transmits visible light



and a combination of polarization filters and liquid crystal layers controlled by a light sensor to darken the glass quickly as soon as the welding arc is stricken.

### 2.3 Separation at a System Level

Observational astronomy started in 1610 when Galileo Galilei directed his lens telescope at the night sky. In 1668, Sir Isaac Newton suggested the mirror telescope wherein the light from a celestial object is received on a primary concave mirror and the real image of the object is formed in its focal plane. A secondary mirror directs the rays to the eyepiece on one side of the tube. In another arrangement, proposed by Laurent Cassegrain (Fig. 3), the secondary mirror reflects the beam back towards the primary, where rays pass through a hole bored in the centre of the mirror and come to a focus just behind it [13, 14].

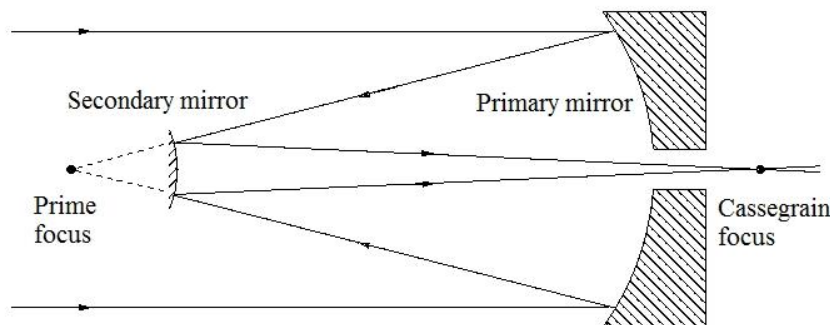


Fig. 3. The Cassegrain telescope [14]

Since mirrors use reflection rather than refraction to form an image, they are inherently free of the most destructive aberration – chromatism. However, they have monochromatic aberrations, which are caused by manufacturing imperfections in the optical components. For a long time, the only solution was to use aspheric mirrors, which are difficult and expensive to make.

The optical contradiction here is that the primary mirror of the telescope should be spherical in order to produce it easily and inexpensively, but it should be aspherical in order to eliminate spherical aberration.

Furthermore, the geometric properties of reflectors allow us to formulate another optical contradiction: the primary mirror of the telescope should be parabolic in order to eliminate spherical aberration, but it should be spherical in order to eliminate parabolic aberration, i.e., coma.

These contradictions cannot be solved by separating contradictory requirements in space or in time. Nevertheless, it is possible to use the system transition from a mono-system to a bi-system made from inverse components. This is what Dmitry Maksutov did in 1941<sup>3</sup>. By that time, aspherical Schmidt corrector plates were already well known

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<sup>3</sup> Some say that Maksutov did not resolve the above contradiction. This, however, refers to a technical contradiction for an inexpensive school telescope, as pointed out by Gerasimov [15]:

[13]. Maksutov, however, was looking for a spherical optical component with an aberration equal to but opposite that of the primary mirror. Thus, he suggested using a meniscus with spherical surfaces [16, 17] as the solution. Fig. 4 shows Maksutov's modification of the Cassegrain telescope. The inner face of the spherical meniscus corrector has a small aluminized spot on it, which acts as the secondary mirror, redirecting the light through a hole in the spherical primary mirror<sup>4</sup>.

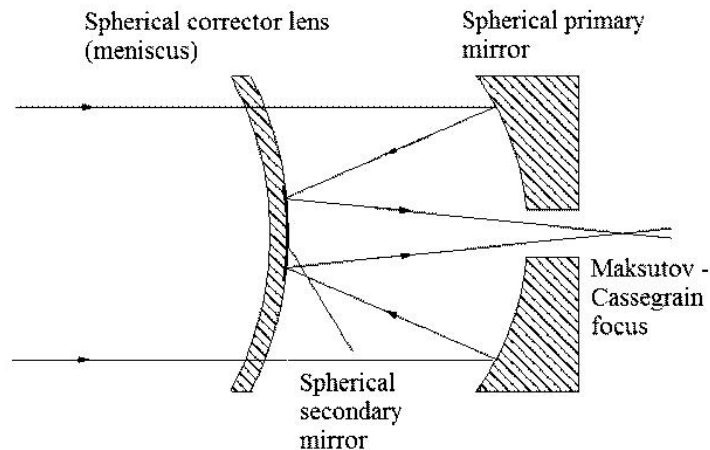


Fig. 4. The Maksutov – Cassegrain telescope [18]

This solution, however, does not involve specific methods for solving optical contradictions.

### 3 Special Methods for Resolving Optical Contradictions

Being a physical contradiction, any optical contradiction can be resolved by canonical methods that TRIZ recommends for solving physical contradictions: by separation, satisfaction and bypass. However, in optics, an approach that takes into account the wave nature of light may be more effective. It is based on the separation of the conflicting properties of the light wave by wavelength, intensity of radiation, polarization and phase shift.

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*(1) if a telescope tube is not covered with protective glass, the telescope will be inexpensive, but the primary mirror is unserviceable; (2) if a telescope tube is covered with protective glass, the telescope will serve for a long time, but it will be expensive. In our example, however, we are talking about the physical contradiction relating to the geometric form of the telescope's primary mirror.*

<sup>4</sup> It was also found that achromatic menisci with  $\Delta R/d \approx 0.7$ , where  $\Delta R$  is the difference of radii of curvature, and  $d$  is the thickness of the meniscus, introduce the same spherical aberration regardless of the refractive index of the glass from which menisci are made. This allows us to substitute one type of glass with another, leaving all structural components of the system unchanged.

### 3.1 Separation in Spectrum

Let us return to the optical contradiction posed for the automotive rear-view mirror: the reflectance of the automotive mirror should be high in order to show the traffic situation clearly, but it should be low in order to prevent dazzling the driver.

Application of the reversible chromogenic materials discussed in Subsection 2.2 solves the contradiction in time, but this solution has a certain disadvantage: the switching time required to obtain the low reflectance can be rather long. Is there any solution with a 'zero' switching time? In order to find out, the relationship between the spectral characteristics of automotive headlamps and the spectral reflectance of mirrors has to be considered.

For example, the maximum radiation intensity of halogen automotive headlamps lies in the red or yellow region of the spectrum (wavelength range of 620-700 nm and 570-590 nm, respectively). Therefore, by reflecting only blue and green spectral components (in the range of 450-590 nm) while inhibiting red and yellow light (Fig. 5), it is possible to achieve effective eye protection against this type of glare while providing enough detailed information on the traffic situation. This solution was proposed by Pein [19]. In order to prevent dazzling by xenon headlamps, which generate blue lines at 405, 435 and 475 nm, the mirror reflectance should be minimal in the blue spectral region, as suggested by Makhin et al [20].

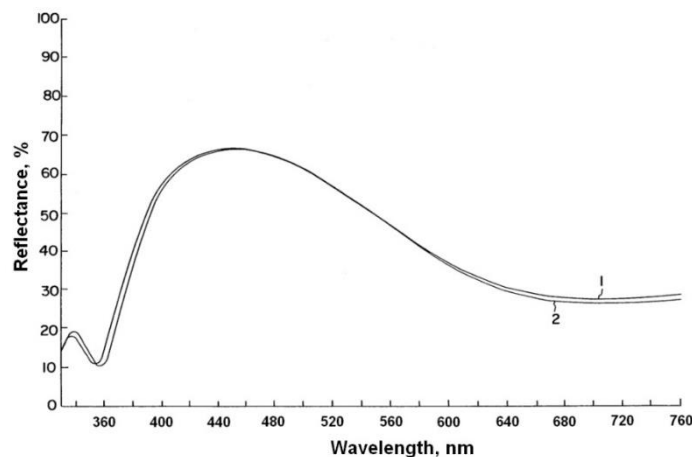


Fig. 5. Spectral reflectance of anti-glare automotive mirrors. 1 – plane mirror, 2 – spherical mirror [19]

In both cases, spectral variations of the mirror reflectance are provided by multilayer interference coatings on a glass substrate. The coatings are made from materials with alternating high and low refractive indices.

These examples demonstrate a powerful method for resolving optical contradictions: separation in spectrum.

Another example of using separation in spectrum relates to improving the energy efficiency of conventional incandescent light bulbs. Here, the optical contradiction is that the colour temperature of a bulb filament should be high in order to increase the fraction of energy emitted as visible light, but it should be low in order to decrease the amount of electrical energy required to heat the filament. The solution presented by

Bergman and Parham [21], involves depositing multilayer optical coatings on the outer surface of a light bulb. These coatings do not affect the visible light emitted by the filament, but reflect the infrared radiation back to the filament, thereby recycling its energy.

Multilayer interference coatings described here are also called ‘dichroic filters’ because they allow light of certain wavelengths to pass through while the light of other wavelengths is reflected.

Besides dichroic filters, there are other components that can be used in solutions that involve separation in spectrum, e.g.:

- absorptive and band-pass filters [22, 23]
- prisms [24]
- diffraction gratings [25]
- Fabry-Perot interferometers [26]
- other optical components [27, 28]

### 3.2 Separation by Intensity of Radiation

In Subsection 2.2, we dealt with the auto-dimming welding filter. In the considered problem, a combination of polarization filters and liquid crystal layers allowed us to resolve the following optical contradiction: light transmittance of the welding filter should be high so that the welder can observe the welding area, but it should be low in order to prevent eye injuries to the welder from the welding arc.

This example shows that the light transmittance of a system can depend not only on the optical properties of individual intrasystem components, but also on the radiation intensity interacting with the system. Under certain conditions, in which nonlinear optical effects (light self-action, nonlinear absorption, etc.) are manifested, an optical system is capable of strongly attenuating high-intensity radiation while exhibiting the transmittance for low-intensity light beams<sup>5</sup>.

This suggests that optical contradictions can also be solved using the separation by intensity of radiation. Devices that in practice realize this separation principle have a simple design, short switching time and high reliability [30].

Nonlinear optical phenomena were discovered with the advent of lasers. However, obtaining high-intensity radiation from a laser requires using the Q-switching technique, in which some sort of shutter is installed inside the laser resonator (Fig. 6).

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<sup>5</sup> Nonlinear optical effects are typically observed at very high light intensities when the electric field is no longer negligible in comparison with intra-atomic and intramolecular fields [29].

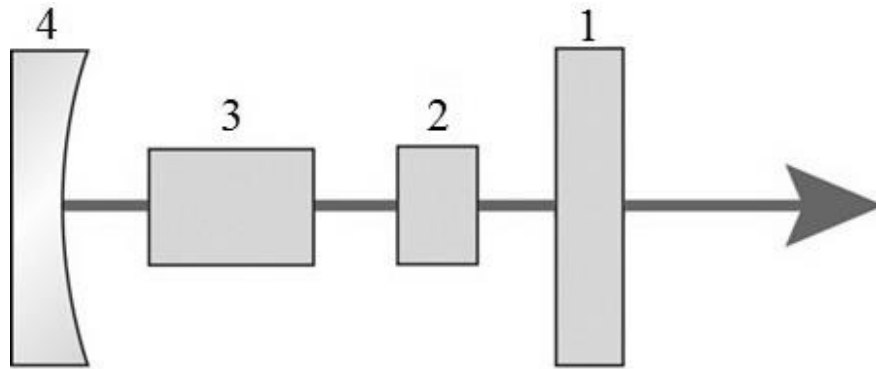


Fig.6. Simplified scheme of a Q-switched laser. 1 – output mirror, 2 – Q-switch (shutter), 3 – active medium, 4 – rear mirror [31]

When the shutter is closed, the laser is off and population inversion in the active medium increases to a value that far exceeds the threshold population when the shutter is absent. If the shutter is now opened suddenly, the laser will exhibit a gain that greatly exceeds losses and the stored energy will be released in the form of a short and intense light pulse [31, 32]. Therefore, an intra-resonator Q-switch resolves the following optical contradiction: light radiation should travel through the resonator in order for laser generation to occur, but it should not travel through the resonator in order to achieve high population inversion in the active medium.

Various mechanical and electro-optical shutters can serve as Q-switching elements. However, the former have a long switching time, and the latter cause considerable resonator losses, need high-precision adjustment and use high-voltage power sources.

The question, then, is: Is it possible to use the intra-resonator radiation itself to switch the shutter? In fact, let us imagine an optical element closed when low-intensity radiation travels within the resonator and opened only when the radiation intensity increases significantly. It turns out that such elements exist. They are often in the form of a cuvette containing a solution of a saturable dye in an appropriate solvent. Their action principle is based on the phenomenon of nonlinear light absorption. As the laser power increases, it saturates the absorber, thereby rapidly reducing the resonator loss so that the laser's power can increase even faster. Ideally, this brings the absorber into a state with low losses to allow efficient extraction of the stored energy by the laser pulse [31, 32].

Thus, the optical contradiction above is again resolved using the separation principle by radiation intensity.

### 3.3 Separation by Polarization

Traditionally, the process for manufacturing integrated microcircuits includes exposing light-sensitive material, called a photoresist, on a semiconductor substrate to ultraviolet radiation. The light beam passes through a lithographic mask with slits and reaches the photoresist through a lens. On the surface of the light-sensitive layer, the lens forms an image corresponding to the mask pattern [33].

In order to make integrated circuits more compact, individual circuit elements must be located as close to each other as possible. To accomplish this, the width of the slits in the mask should be decreased; however, the narrower slits allow less light to pass through the mask to the photoresist. Moreover, the narrower slits increase the detrimental effect of scattering and absorption of radiation manifested in the mask. This results in a low contrast image on the photoresist layer.

The optical contradiction relating to this situation could be formulated as follows: slits in the mask should be narrow in order to decrease the size of individual elements of the circuit, but they should be wide in order to form a high-contrast image on the photoresist layer.

There is no solution for this contradiction within geometric optics; however, in a wave-optical approach we can find it quite easily if we consider light polarization [34-36].

Unpolarized light, for which there is no preferred polarization angle, can be thought of as a superposition of two states of polarization: *s*-polarization and *p*-polarization that have, respectively, perpendicular and parallel directions of the electric field vibration relative to the plane of light incidence. (See Fig. 7 for details.)

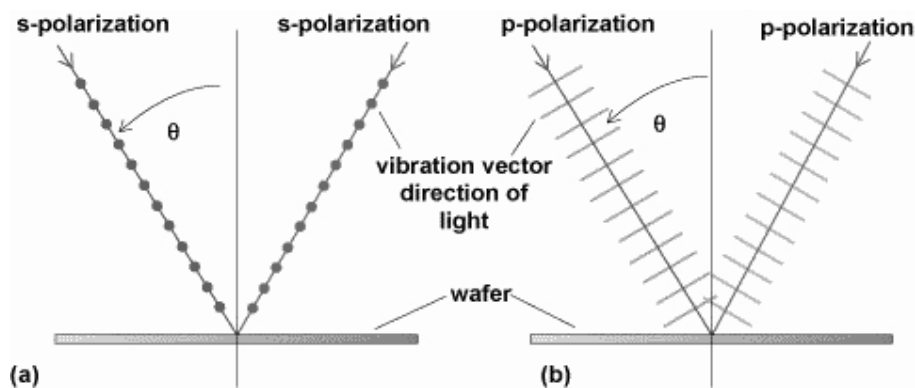


Fig. 7. Two states of polarization showing the vibration direction of the electric field for the two light rays incident on the wafer surface with an angle  $\theta$ . (a) *s*-polarization has the vibration direction perpendicular to the plane of the figure, (b) *p*-polarization has the vibration direction parallel to the plane of the figure [36]

Only the *p*-polarized component of the light deteriorates image quality on the photoresist layer. With a polarizer placed before the mask, only *s*-polarized light will penetrate, while the *p*-component of the polarization will be blocked. Such an arrangement minimizes scattering and absorption of light energy at the mask, and provides maximum contrast of the photolithographic image.

Another example of separating contradictory requirements by polarization relates to the personal hygiene mirror with a built-in light source. The problem is that the glare light reflected off the skin surface can impede the user from seeing his or her skin in detail.

Thus, there again is an optical contradiction relating to the suppression of light glare: the mirror reflectance should be high in order to let the user see his or her skin in detail, but it should be low to prevent glare reflected from the surface of the skin.



In order to find the solution, it is necessary to note the following effects:

1. Light reflection on the air-skin boundary. From 4 to 7 percent of incident light reflects back to the viewer at the boundary between air and skin. This specular reflected wave carries mostly information about the contour of the skin surface. For this light, wave the polarization does not change.
2. Light absorption and scattering in deeper skin layers. The majority of the light flux enters the skin and is absorbed or is scattered back as diffuse reflected wave, which makes it possible to see colour variations, pigmentation, hair follicles, blood vessels, and other details in deeper skin layers. As described by Anderson [37], when polarized light penetrates deeper into skin tissue, it is depolarized due to scattering.

The solution patented by Mullani [38], involves a polarizer in front of the mirror that blocks specular reflected radiation. At the same time, the diffuse reflected light passes through the polarization filter, thus producing an enhanced view of the skin surface.

It is worth pointing out that in non-optical applications polarization separation methods have also been used. For instance, in geophysics, the separation of wave field from crosswell seismic data into *s*-wave and *p*-wave for earthquake prediction has been suggested by Byerlee [39] and Liu et al [40].

### 3.4 Phase Separation

From ancient times, humans have wanted to see things far smaller than could be perceived with the naked eye. In conventional optical microscopes that magnify tiny objects, a contrasted image is formed when light is absorbed by the sample. However, many lightly stained, transparent or colourless objects (e.g., single-celled organisms, aquatic environment samples, etc.) do not absorb light and, therefore, cannot be seen with a traditional bright-field microscope.

Thus, we can formulate the following optical contradiction: light should pass through the object plate with the sample in order to make the details of the object visible, but light should not pass through the object plate with the sample in order to provide a high contrast image.

Another approach can be found in dark-field microscopes, which achieve enhanced contrast through light scattering rather than direct transmittance and absorptance. Yet these microscopes do not completely resolve the contradiction because dirt and dust located along the light pathway distort the sample's image. Furthermore, the low light level means the sample must be strongly illuminated, potentially damaging delicate samples.

In order to obtain a contrast image in the transmitted light, Frits Zernike suggested using minute variations in the phase of the light wave passing through the object [41]. Although the human eye does not perceive differences in light wave phases, these differences can be converted into corresponding changes in amplitude that the human

eye can distinguish. In microscopy, such a separation in light wave phases is called the phase contrast method<sup>6</sup>.

Phase contrast makes it possible to visualize internal cellular components, such as membrane, nuclei, mitochondria, chromosomes, etc. Nevertheless, if the absorption is non-uniform within the sample cross-section, then the image observed with a phase-contrast microscope will be distorted. In recent years, several methods known as methods of quantitative phase-contrast have been proposed to overcome this limitation by separating the phase images from the absorption images [42, 43].

In Subsection 2.1, we discussed the advantages and drawbacks of unstable optical resonators for single-mode lasers with high power or energy. Owing to large diffraction losses, such resonators do not suit active media with low gain or small cross-sections. In contrast, in stable resonators the radiation is concentrated near the resonator axis, which allows for using active media with low gain or small cross-sections. Unfortunately, diffraction losses in stable resonators are small not only for the fundamental mode, but also for higher laser modes, which increases beam divergence.

In order to suppress higher laser modes in the stable resonator, a series of intracavity apertures arranged in a certain order have been suggested by Pax and Weston [44]. In this invention, the amplitude of the fundamental mode has a bell-shaped profile with smoothly tapered ‘wings’ that are partly cut by aperture edges. The disadvantage of this solution is that large losses are introduced by the intracavity apertures.

Thus, for the laser resonator, we can formulate the following optical contradiction. Intracavity losses should be small to assure laser generation in low-gain active medium, but they should be large to suppress higher laser modes in the resonator and, therefore, to provide low beam divergence.

In our publication [45], it was shown how to resolve the above contradiction using the phase separation principle. The proposed approach avoids the trial-and-error method used earlier in such cases. If the phase responses of both mirrors in a two-mirror resonator coincide with light wave phase distribution as shown in Fig. 8, then the light wave will represent the fundamental mode of the resonator. Thus, its diffraction losses will be close to zero. Moreover, as a fundamental mode, we can choose a beam with the prescribed amplitude-phase distribution. For any other beam, diffraction losses will be significant. This laser resonator assures that, in a certain range of amplification gain factors of the active medium, (1) a single-mode laser radiation is generated and (2) energy accumulated within the active medium is efficiently converted into the fundamental laser mode.

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<sup>6</sup> For this invention, in 1953 Frits Zernike received the Nobel Prize in physics

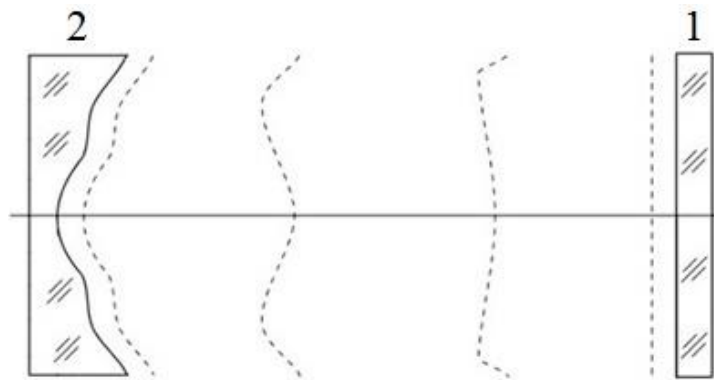


Fig. 8. Laser resonator designed for single mode laser operation. 1 – output mirror, 2 – rear mirror. Dashed lines show wave fronts of the beam corresponding to the fundamental transverse mode of the resonator [45]

Thus, separation by phases of fundamental modes makes it possible to overcome one of the major challenges of conventional resonators that use spherical mirrors and to effectively suppress the higher laser modes at a low level of diffraction losses for the fundamental mode.

## 4 Conclusions

This paper introduces a definition of the optical contradiction as a physical contradiction in which two opposite optical properties are required from the same component of the engineering system. A review of optical contradictions from geometric, wave, laser, and other areas of optics has been presented. It is shown that the wave nature of light allows us to use four special methods for resolving optical contradictions. These methods are (1) separation in the radiation spectrum, (2) separation by intensity of radiation, (3) separation by polarization, and (4) separation in phases of the light wave. We suppose that they can be a good in solving inventive problems in the field of optics.

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Pavel Fimin earned his Ph.D. degree in optical engineering from National Research University of Information Technologies, Mechanics and Optics, St. Petersburg, Russia in 2001.

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# FUNCTION ANALYSIS FOR ORGANIZATIONAL AND MANAGEMENT PROBLEMS. A REVERSE APPROACH

Nikolay Saunin

*How to find an entry point to a problem?*

*“Don't get involved in partial problems, but always take flight to where there is a free view over the whole single great problem, even if this view is still not a clear one.”*

*Ludwig Wittgenstein (1889–1951)*

## Abstract

The paper presents a novel approach to deal with an entry phase of a problem solving process dealing with complex management and organizational problems. Rather than using a traditional random approach to gathering and structuring problem information, it is proposed to use a systematic approach on the basis of inverse Function Analysis. The approach proposed is illustrated by a real case performed by the authors at a large industrial corporation.

*Keywords: TRIZ, Function Analysis, Problem Solving*

## 1 Chemical Corporation: a Problem

The management of one of the Russia's largest chemical companies have set an ambitious task of bringing internal corporate communications to a completely new level. The case of solving this problem allowed us to formulate and propose a new approach to the entry phase of problem-solving process when dealing with multi-parameter organizational and management problems.

**Objective:** *To bring corporate communications of a large chemical company to a new level.*

### **Inputs:**

*“We understand that internal corporate communications cannot cope with intensive changes occurring in the company. Communications are the hampering factor for company’s development. There is not enough communication between the manager and the team. We need to teach the manager to communicate with the team.”*

*"Annual research of employees' attitude towards the company is conducted (detailed report is attached) – the loyalty level is high, but we want higher."*

*“To be: Business Function (BF) sends request to the Internal Communications (IC) department, IC provides several solution options for each case.*

*As Is: BF sends a strict order to IC, e.g. “publish this specific article here and there”; no expertise is needed from BF’s point”.*

*“What is a problem solver's action plan?”* We addressed this question to more than 20 managers of different levels.

A wide range of actions were proposed from “create regulation policy on interaction with Internal Communications department” to “organize regular meetings between managers and staff to discuss company values”. Options vary: from conservative to provocatively radical, from short-term projects to long-term ones requiring several years of implementation. Obviously, if such an extensive problem is discussed, a solution cannot be provided with a single event or an action. Therefore, a solution to the request of the problem owner will be some project program.

However, what is an algorithm for its formulation? Where to start? Typically, one can brainstorm the task, generate ideas (this is the way all interviewed managers went), and then try to combine all the ideas produced to conceptual streams and arrange them in a certain sequence. However, how to be sure that as a result of the implementation of all initiatives, we will definitely achieve the effect desired and avoid missing critical aspects?

In addition, what can be done when there is only one day to develop proposals? It is no secret that most problem-solving projects are carried out in the “Alarm! The decision needs to be urgent!” mode. On top of that, when it comes to strategic tasks (as described above), and the team includes corporation's top managers, the problem solver will not have a second chance to bring them together. At least, not in a case if no worthy result was shown during the first day.

As a conclusion, we need a well-managed approach that would allow us to identify reliably all key aspects of the task, to structure the search field, and to show possible directions for a solution.

The basis for this approach was the idea that as a result of our work we should get an image of a system that solves a problem faced (but almost never articulated) by the problem owner. Having determined and documented such a system, we can then “push” it to ideality, increasing the problem owner’s level of satisfaction. Therefore, we target answering three questions:

- *What should be the outcome?*
- *What should the problem-solving system look like?*
- *What does it look like now?*

## 2 Function Analysis

Function Analysis is a technique which is used in TRIZ to describe and model operations (functions) within a system.

Classical Function Analysis [1] suggests the following procedure to construct a function model (see Fig. 1):

1. List system components (Component Model).
2. Build the structure of their interactions (Structural Model).
3. Document functional interactions of the components, separate useful, harmful and inadequately performed functions.

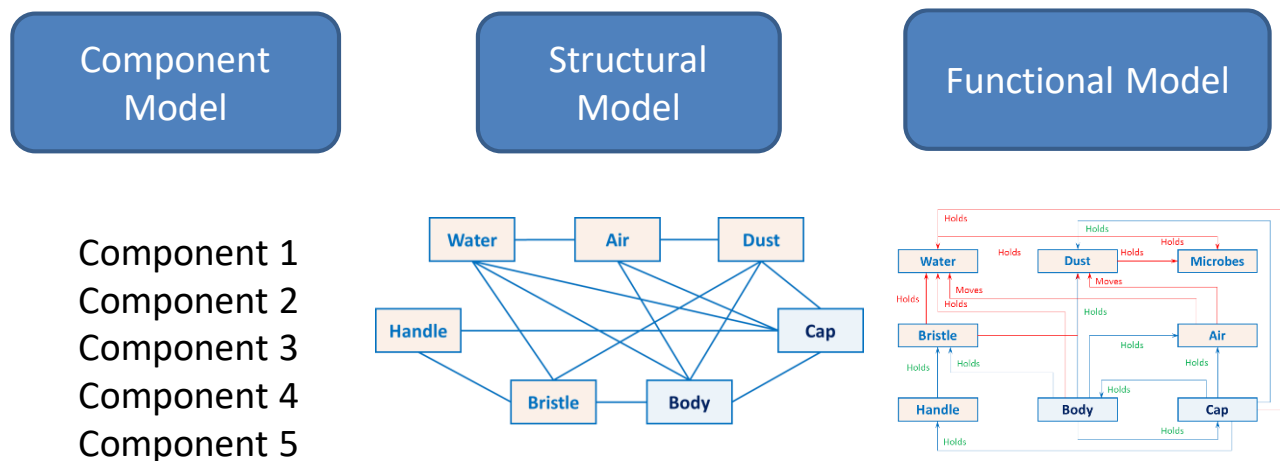
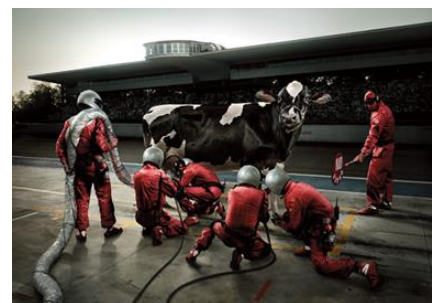


Fig.1 Steps of Classical Function Analysis

## 3 Components

This approach has been proven to work great with engineering (technical) systems that have tangible boundaries. However, an attempt to list the components included in the “internal corporate communications” system immediately baffles: what has to be included in this particular system? Daily briefings of shop supervisor? Corporate magazine? A banner with company's mission on a factory bus? Corporate New Year's party? CEO's annual address?

Of course, all of them and many other components that ultimately provide the function of internal corporate communications.



The prospect of combining these infinite components into some kind of the interactions structure is even more confusing. At the same time, we understand that there is a system and it is functioning. However, we "do not see" it in its integrity. We see a vague outline and pull out some parts of it.

#### **4 Schematization**

One of the possible options to deal with the issue mentioned above is to use the "Schematization" tool developed by the School of Systematic Thought Activity (STA) methodology founded by G. P. Shchedrovitsky [2].

This tool is supposed to be used while having internal team discussion to identify the primary (only those that are substantial for a problem being solved) entities and construct a scheme of their interaction, thus identifying problem points that inhibit the solution of the problem [3].

This approach is indeed efficient in solving some of the organizational and management problems. However, its efficiency drops sharply when applied to "strategic level" problems where these same "key entities" are not obvious. This tool does not offer any clear criteria for determining which entities are key-ones and which are not, and, therefore is highly dependent on the experience, intuition and luck of a problem solver. Consequently, the results of the exercise might appear to be "unstable": the number of different scheme variants will roughly be equal to the number of people developing them. Thus, we have to admit poor manageability of the result-oriented process and its low predictability. Again, there is no guarantee that we did not miss anything.

A problem emerges: how to identify all the key components of a complex organizational system distributed across the entire company's body, and separate them from many non-key ones?

#### **5 Function Analysis: Reverse Approach.**

An idea of an answer to the question above was born during working on the task indicated at the beginning of the paper: "*Bring internal corporate communications to a whole new level*". The logic of the idea that helped "identify" the target system is as follows:

1. It is necessary to bring internal communications to a new level. It means that the problem owner expects a radical increase in the result of the work of a certain system. Let us call this system "Internal Corporate Communications" (IC).
2. "IC" system performs some functions aimed towards processing of some object(s).
3. We need to ensure an substantial increase of the effectiveness of current functions, otherwise create new functions.
4. The functions are performed by some components.

5. The components are mandatory if the required functions cannot be performed without them. We must identify them in order to get an image of a minimally viable system - a framework that we can further improve on.

These objections allowed us to construct the following algorithm to solve the above-mentioned problem.

**Algorithm:**

1. Identify object(s) that are being processed and identify the Main Parameters of Value (MPV(s)) [4, 5] of a system analyzed aimed towards it (them).

*What has been the purpose of a system created? What parameters of an object(s) processed it is supposed to change or preserve?*

**As a result** of this step, we obtain a list of main functions and objects to be processed. The system was designed to change those.

2. Identify stages of system operation.

*Over its lifecycle, each system goes through a sequence of operation stages: a car is not only limited to carrying us but also stays in the garage, gets refueled, undergoes repairs... Similarly, a sales department not only closes a deal, but also prospects potential customers, retains them after a deal, encourages to leave positive reviews. In order to not miss any important aspects of the system's operation, we need to make sure that all such stages are documented.*

**As a result** of this step, we obtain a list of the system operation stages that it must successfully undergo in order to realize the MPV(s) identified.

3. Identify functions that must be performed at each stage so that it is successfully completed.

*What functions should the system realize to complete successfully each stage? E.g., during a customer prospect, sales unit staff collects information, analyzes and structures it, then carries out initial interaction, so forth; while at the stage of deal closure they formalize certain conditions, prepare an agreement and then sign it, and so forth.*

**As a result** of this step, we obtain a list of functions that must be performed at each stage.

4. Identify components necessary to perform the functions at each stage.

*What components are required to perform each function identified at the previous step?*

*For example, to collect some information you need a manager (how many?), databases (which?), rules and metrics for screening, etc.*

**As a result** of this step, we obtain a set of components necessary for the implementation of the functions identified at the previous step.

- Build a structural, and then functional (if required) interaction model of the identified components.

*How do the identified components interact?*

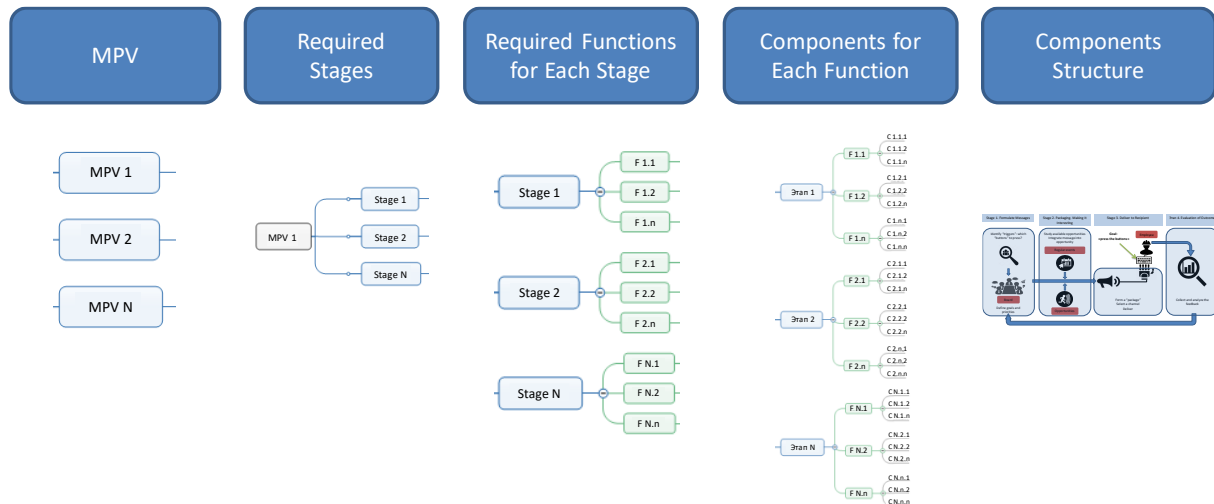


Fig. 2. Steps of Reverse Function Analysis

As one can see, such algorithm suggests changing the steps presented in the Classical Functional Analysis: start by identifying the necessary functions, and only afterwards identify the components necessary for their realization.

As a result of this approach, we obtain a structural model of a “minimally viable” system. This way we only identify the components that are *necessary* for the realization of the *necessary* functions only (without which it would be impossible to achieve a goal).

If we get back to the analogy with a car: after we have applied the algorithm presented above, we obtained a description of the car which only consists of the components necessary to move from A to B (if such an MPV was originally announced): frame, wheels, driver's seat, steering wheel, pedals, engine, braking system. It will exclude body, silencer, air conditioner, radio etc., because it is possible to move (and to make it) without them.

To complete our “car” with air conditioners and radios, we will use MPV analysis [6, 7, 8], which becomes appropriate after identifying the structure of the system.

Let us illustrate application of this approach and the algorithm proposed using the case mentioned at the beginning of the article.

## 6 Chemical Corporation: Solution Case

The description of the case was presented in Section 1. The goal was formulated as “*To bring internal corporate communications of a large chemical company to a new level.*”



***Step 1. Identify the object(s) being processed; formulate the MPV.***

At this step, the project team was asked the following questions: *Why do we need Internal Corporate Communications system? What do we demand from it? What is its operation directed at?*

As a result of the time-consuming discussions, the following answers were documented, which were downright counter-intuitive initially:

1. Create intrinsic motivation for company employees (A):
  - Convert.
  - Transform.
2. Create extrinsic motivation for company employees (B):
  - Inspire.
  - Retain.
3. Gather information from company employees for decision-making (C):
  - Perform the role of the "nervous system" of the company.

Next, we show the components identification for delivery of the first function "Create intrinsic motivation".

***Step 2 (A). Identify the stages of system operation.***

- MPV "Creation of intrinsic motivation":
  - Stage 1. Messages formulation.
  - Stage 2. Packaging. Making it interesting.
  - Stage 3. Delivery to the recipient.
  - Stage 4. Evaluation of the outcome (measurement).

***Step 3 (A). Identify the functions***

- MPV "Creation of intrinsic motivation":
  - Stage 1. Messages Formulation
    - Identify "triggers": which "buttons" to press?
      - Study the object.
      - Define a list of motivational requests that we will work on.
      - Define goals and priorities that we will concentrate on.
  - Stage 2. Packaging. Making it interesting:
    - Study available opportunities.
    - Integrate message into opportunity.
  - Stage 3. Delivery to the recipient:
    - Form a "package" (article, address, rumor):
    - Select a channel.
    - Deliver.
  - Stage 4. Evaluation of the outcome (measurements):
    - Collect and analyze the feedback.
    - Make adjustments.

### **Step 4 (A). Identify components and their structure**

At this stage, the team was offered to document top-level (critical) components necessary to perform the functions at each stage. The work resulted in the following scheme (see Fig. 3).

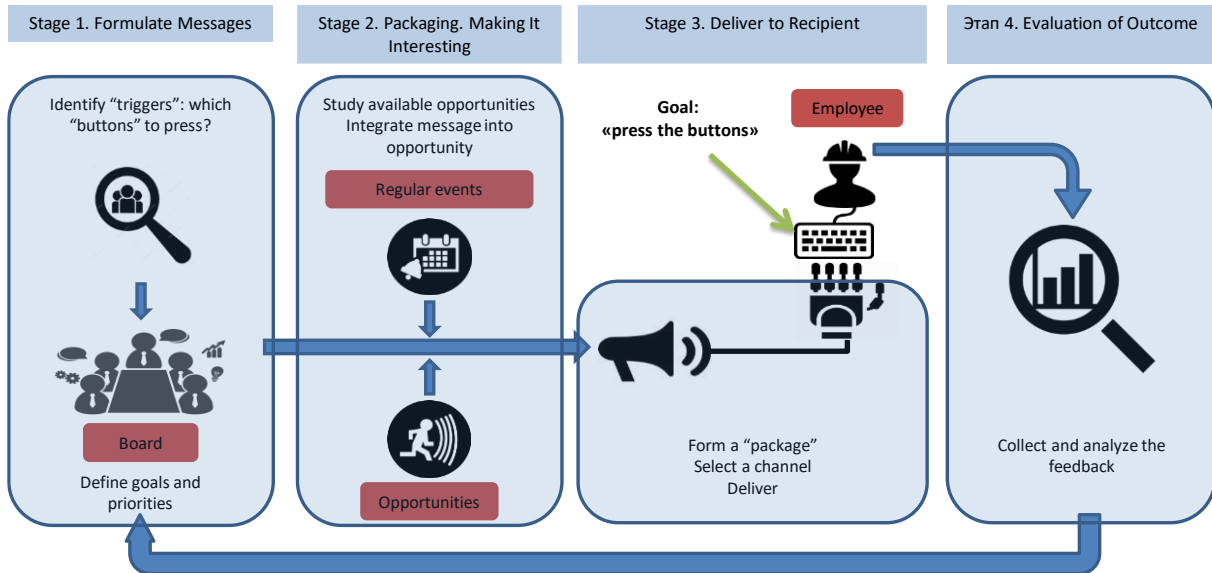


Fig. 3. Application of Reverse Approach to Function Analysis

After all leaders have agreed upon what the overall scheme of operation is, it became possible to develop assessment criteria for the performance of the identified components, to divide areas of responsibility and to develop a program to improve the underperforming components, i.e. weak spots.

The next step in this example would be producing a detailed description of the necessary components that realize the functions and sub-functions required at each stage. Commercial nature of the described project makes us skip its specific content and continue description of this example in general terms.

Having said that, we will proceed to a more detailed analysis of the second stage as an example. As described above, for its successful realization we will need to implement the following functions:

1. Study available opportunities.
2. Integrate a message into opportunity.

We can offer the following as their further decomposition:

1. Study available opportunities:
  - a. Organize tracking of significant / important events in the media (significant and extraordinary events, emergencies, "hype", important professional community events etc.)
  - b. Identify regular events that are suitable for news delivery opportunity (holidays, memorable dates, corporate events etc.)

2. Integrate message into opportunity

- a. Organize creative matching of current employees' demands (triggers) with suitable (identified) news opportunities and informational addresses (messages) (see Fig. 3).

To realize function 1, it's required to develop criteria for the selection of news opportunities; to prepare a list of media sources and a work plan; to estimate the number of employees and their load to implement the plan.

To realize function 2, it's required to develop a media plan, to identify regular “routine” messages, and to organize regular preparation of ad-hoc (one-off) informational addresses for the next sprint.

From this level of detail, the following can be seen already:

- Realization of these functions will provide a 2-3 FTE (full-time equivalent).
- The team needs to be staffed with the roles of i) analyst able to analyze and organize information, ii) administrator able to plan and to organize consistent work, as well as iii) creative professional able to come up with original ideas across diverse informational entities.

For further work, we can assume the need to appoint a person tasked with developing a plan to organize the activities listed, to estimate the unit's target indicators, to calculate staff load, to select candidates, and so forth.

## 7 Conclusions

As a conclusion, it should be noted that the schemes similar to the described above add considerable practical value, despite apparent simplicity. It is ensured by two factors. First, our experience shows that initially such scheme of work equally acknowledged by everyone is not always obvious, whereas the resulting simplicity arises from identifying and from discussing many of the complex ambiguous aspects of the problem and long vigorous synchronization. Secondly, such a scheme becomes a solid starting point for further problem solving, simplifies its planning, distribution of tasks between project participants etc.

We should note the similarity of the proposed approach with the Failure Analysis approach, where a problem solver is also invited to identify the system (that creates an undesirable effect), and then the components and the resources that ensure its operation. The differences are apparently as follows: with the reverse approach, it is not necessary to invent masking effects. Then, we don't need to identify all possible options for functions realization at each stage - our task is to identify and document the existing system “on paper”, to “develop” its so-called “photograph”. Afterwards, we proceed with its improvement.

Using the reverse approach, we should keep in mind that the practical implementation revealed its counter-intuitiveness and vulnerability in terms of the influence of psychological inertia of practitioners: under the pressure of their own experience, members of the problem solving team give hasty familiar replies within the mental

model they're used to. From this perspective, it is useful for the team to have a participant who has not been deeply immersed in the problem being solved and who can therefore ask “naïve” questions. The tool itself likewise should be presented to the team gradually, meanwhile controlling the quality of the outcomes of each step, refining them before proceeding to the next step.

After this work has been completed, the author discovered that a similar approach to systems analysis and design is known in German engineering school [9]. However, the paper presented is still relevant since it deals with organizational and management problems.

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# COMPARISON OF THREE DIFFERENT TRIZ TOOLS FOR A BUSINESS PROBLEM ANALYSIS CONSIDERING THE EXAMPLE OF THE MENTORING PROBLEM IN A SALES DEPARTMENT

Anton Kozhemyako

## Abstract

Managers are used to solving sales management problems by using their own experience. In the extreme cases, if the decision is ambiguous, there is always an opportunity to discuss with colleagues or invite consultants. As a result, most of the problems in the field of management are solved.

But not all problems are solved easily. What to do in such cases? If one must solve a difficult managerial problem, one should use the system analysis methods. In this article, the author will show how it is possible to "decompose to details" almost any problem with the use of TRIZ.

In addition, the author compares different methods used in TRIZ for solving organizational and managerial problems on the basis of analyzing the same problem and providing solutions that emerged in each case.

Keynotes: *TRIZ, Root Conflict Analysis, Functional Analysis, Schematization, Contradictions.*

## 1 A Problem

Let us consider a case. In the sales department of a company engaged in the sale of rolled steel (B2B market), the process of skill transfer from more experienced employees to newcomers suffered. Therefore, the head of the sales department decided to intensify the mentoring process.



However, the problem appeared: if inexperienced employees conduct mentoring, then the newcomers learn slowly and reach the planned indicators within long time, because they make a large number of mistakes, which have to be corrected by the manager.

On the other hand, if mentoring is conducted by experienced employees, the process runs significantly faster and provides a higher quality, but experienced employees spend their valuable time with the newcomers rather than spending it with clients they are responsible for working with (the most experienced employees are in charge of key accounts, e.g. clients of category “A”). Their resource is much wasted... What to do?

We have a contradictory problem: mentoring should be conducted by the experienced employees in order to bring the newcomers to the result required (achievement of the sales plan) relatively quickly, and mentoring should be done by less experienced employees to avoid distracting the experienced ones from their primary functions - working with the most important clients.

Thus, we can draw up a model of technical contradiction:

***Mentoring should be conducted by the experienced employees in order to quickly bring the newcomers to the result, but at the same time the experienced employees reduce the time of interaction with key accounts, which is not acceptable.***

As seen this contradiction, one attribute refers to the new employees (students), the other corresponds to the experienced employees (if they are involved as mentors), but both are important properties of the system under study from the point of view of the KPI implementation by the sales department. It is important to note that it is the sales department of the trading company.

It is crucial that the contradiction shown above can be identified as “an upper level contradiction”, which means that this contradiction is defined on the basis of the initial conditions of the problem and requires further detailed analysis. If we try to resolve this contradiction by using standard TRIZ tools [1], for example, with well-known 40 Inventive Principles, then we will certainly come up with some solutions, but there is a high probability that such solutions will be rather weak.

Therefore, let us try to perform analysis of the problem in three different ways: with RCA+, Function Analysis, and Schematization.

## **2 Application of Root Conflict Analysis (RCA+)**

If we decide to analyze the problem deeper by using RCA+ [2], first we would need to formulate the target negative effect, for which we determine the working technical contradiction from the pair of the technical contradiction model shown above.

Correspondingly, we have two contradictions to choose from:

- Mentoring should be conducted by the experienced employees in order to quickly bring the newcomers to the result, but at the same time the experienced employees reduce the time of interaction with key accounts, which is not acceptable.

- Mentoring should be conducted by less experienced employees (usual employees), because they are not in charge of working with key accounts, but at the same time the quality of training of the newcomers is lower than by the experienced employee and the newcomers mentored take a long time to achieve their results, which is not acceptable.

Which contradiction we must choose?

From the point of view of business goals, it is more important for us that new employees quickly reach planned targets and work reliably in the interests of business; therefore, we accept the working contradiction 1:

*Mentoring should be conducted by the experienced employees in order to quickly bring the newcomers to the result, **but at the same time the experienced employees reduce the time of interaction with key accounts**, which is not acceptable.*

Now we determine the problem which we have to analyze in depth, but we set up the conclusion of mentoring should be conducted by the experienced employees. Such a problem would be:

**The mentoring process absorbs time of the experienced employees** (which they could spend on working with key accounts otherwise).

After we have selected the target problem, we build a cause-effect chain (Fig. 1).

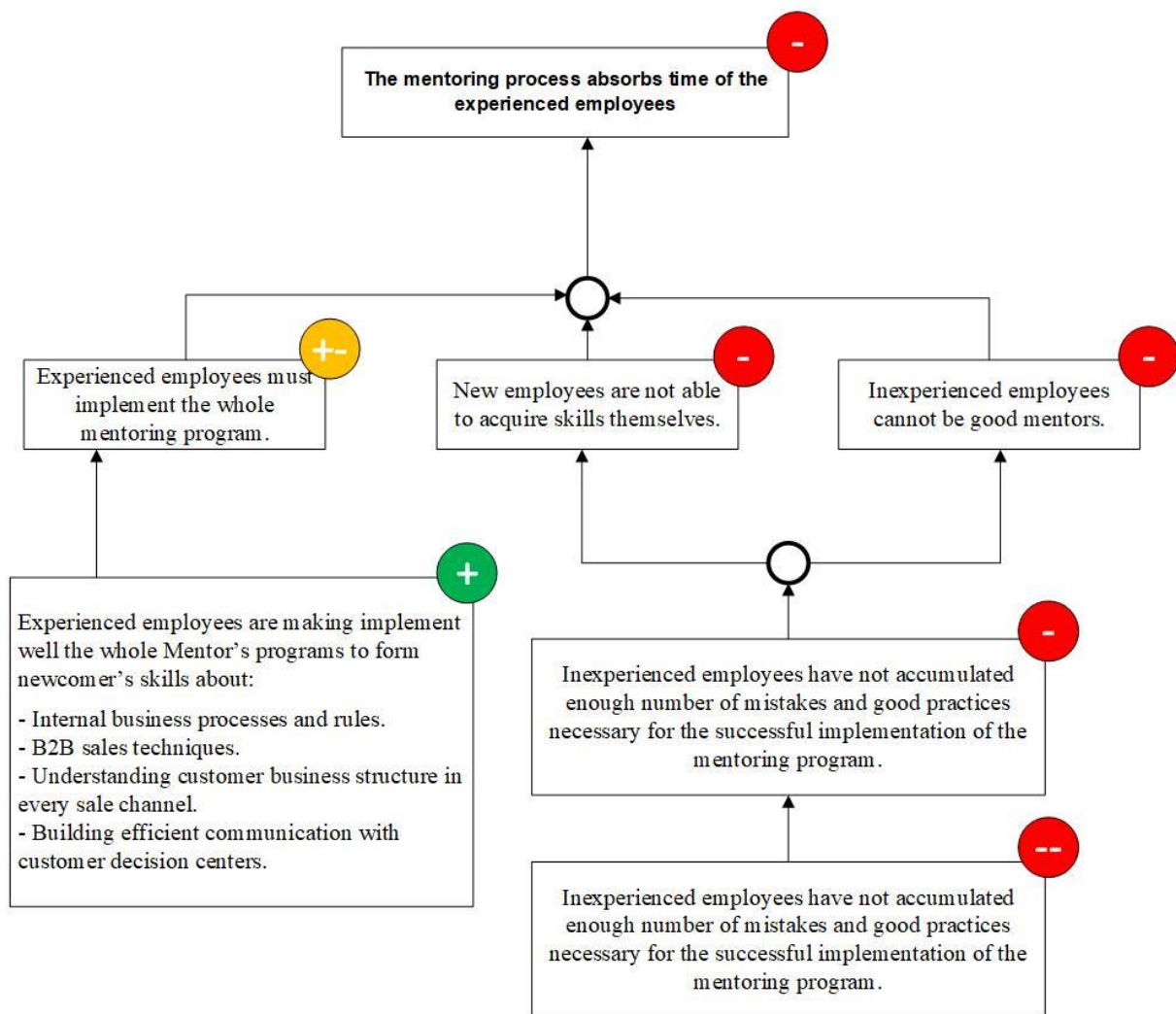


Fig. 1. Application of RCA+

In principle, we do not have to go on the deeper analysis of the chain resulted. A solution becomes obvious: you need to disassemble the mentoring program into components for each of the listed blocks:

- Internal business processes and rules.
- B2B sales techniques.
- Understanding customer business structure in every sale channel [3].
- Building efficient communication with customer decision centers.

Next, we will need to determine which blocks of the mentoring processes can be converted to the online format so that the participants can study them on their own; which ones have to be supported by less experienced employees (for example, some nuances of filling in the fields of CRM system, reports in the CRM system, warehouse inventory database, general approaches to communication with clients, work with a matrix of commercial advantages, etc.), and which ones have to be supported by the most experienced mentors, for example, developing a transaction strategy, the nuances of effective communication with decision centers of company's clients.

Now let us try to identify additional tasks (added to the list below) with respect to the obtained cause-effect chain by using the operator of negation (using the negation operator provides to pose problems on the causal chain implies that we do not accept the consequence, while accepting its cause, thus forming a paradox):

1. How to make it possible that inexperienced employees COULD implement the mentoring program in a quality manner, even if they have not accumulated sufficient list of mistakes and good practices necessary for the successful implementation of the mentoring program?

**Solution:** typical errors can be identified and described in advance, including in the form of interactive simulators or tests in the LMS-system, which will reduce time spent by experienced employees on working on typical errors.

2. How to make it possible that experienced employees IMPLEMENT the whole mentoring program, even if the mentoring program does not include essential subjects of theory and practice?

**Solution:** it is also about the transition to digital learning with interactive simulators. Moreover, we have to foresee some sessions with experienced employees too.

3. How to make it possible that the mentoring program does NOT include an essential block of theory and practice, but new employees will successfully study all 4 blocks of the program?

**Solution:** part of the blocks of mentoring program must come from outside. For example, to change the conditions for the reception of employees and to give priority to the hunting of employees from competitors with similar processes (this solution has significant limitations, although it is quite useful).

**Conclusion:** RCA+ is a useful and effective tool for primary processing of a business problem, which can be successfully used to solve organizational and managerial tasks. It is confirmed by our experience with using this tool. In addition, RCA+ can show clearly hidden contradictions in investigated business system.

Through the use of the negation operator, the list of solutions according to the results of applying RCA+ can be identified. An operator of negation could help to draw up some useful additional problems to work out (types of paradox).

Unfortunately, this TRIZ tool has a significant drawback because it does not have internal means for working with the structure of a system. Therefore, when conducting RCA+, it is easy to miss elements of the system and supersystem that are essential from the point of view of a problem. It is why in TRIZ, RCA+ is often used after the application of other tools, e.g. Function Analysis in order to clarify causes of a particular function.

RCA+ can be used as a standalone tool, but there is a risk of missing a significant element of a system, it is why there is a risk of narrowing the potential solutions space.

### 3 Application of Function Analysis

The problem is drawn from the main contradiction drawn up above: **the mentoring process absorbs time of the experienced employees** (which they could spend on working with key accounts instead).

An example of the detailed functional analysis using organizational and management tasks is described in the author's book "TRIZ. Solving Business Problems" [4]. In this article, the solutions are presented without explanation of how exactly they were generated.

**Note:** If to apply Extended Function Analysis for business systems to this problem in the version proposed by V. Souchkov [6] instead "classical" TRIZ-based Function Analysis" [7], the results could be much better than in the case of applying the "classical" Function Analysis.

#### Component Analysis:

Table 1. Component Analysis (previously).

Investigated system	Subsystems	Supersystems
Mentoring system	1. Mentor 2. Mentoring program	1. New fellow workers 2. Market environment: a. Clients. b. Rivals.

#### Function modeling and ranking of functions (with final definition of system elements):

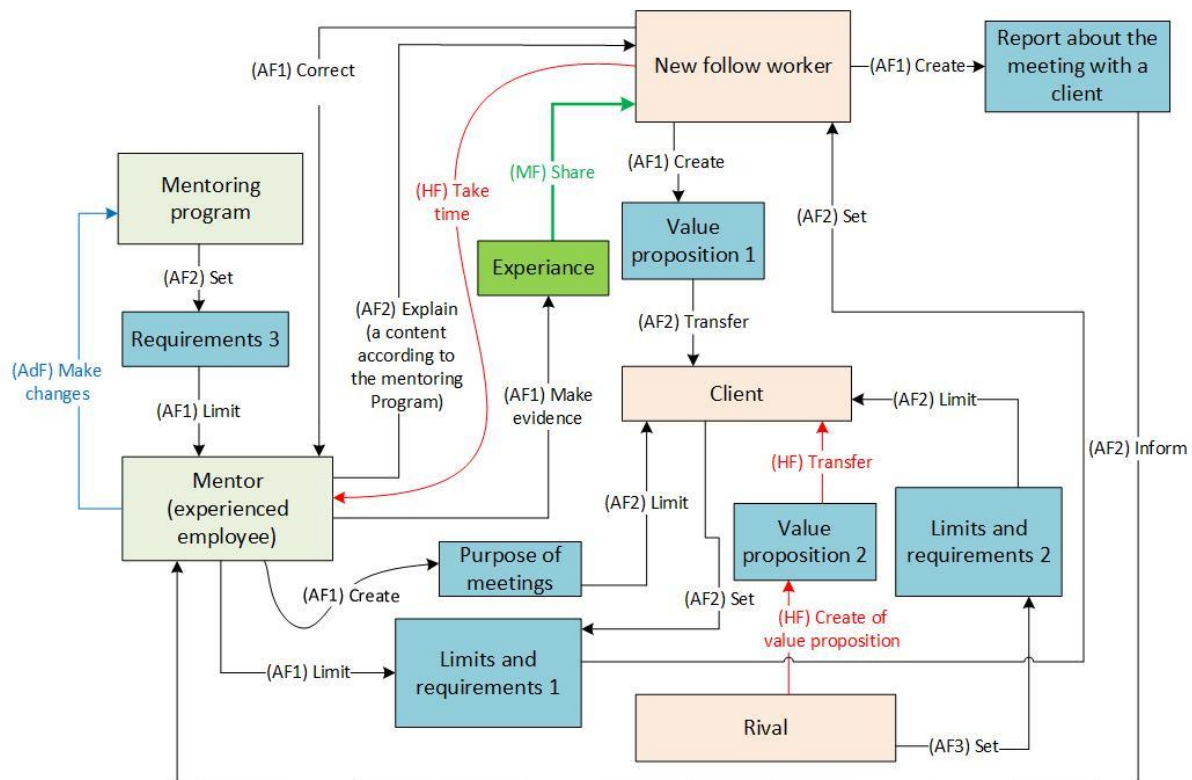


Fig. 2. Functional model of the mentoring problem.

Where:

- Green rectangle: an element carrying a main mentoring function.
- Pink rectangle: elements of supersystems from table 1.
- Grey rectangle: elements of supersystems from table 1.
- Blue rectangle: elements which are created due to analysis during drawing up the functional model, fig.2

### Function model in the matrix form:

Table 2. Functional model in the matrix

Nº	Function description	Type/rank	Function performance	Notes
<b>1. Mentoring program</b>				
F1.1	Sets requirements to the experienced employee	AF2*	N*	
<b>2. Mentor (experienced employee)</b>				
F2.1	Makes evidence of his experience	AF1	E	Many not useful details
F2.2	Explains the content to new employee according to the mentoring program	AF2	E	This activity does not require high mentor's qualifications
F2.3	Creates purpose of the meeting	AF1	E	This activity does not require high mentor's qualifications
F2.4	Set limits and requirements according mentoring goals	AF1	N	
F2.5	Makes updates to the mentoring program	AdF	I	Mentor often forgets it
<b>3. New employee</b>				
F3.1	Creates value proposition through mentoring process	AF1	I	Lack of experience → new employee has a mentoring process
F3.2	Prepares a meeting report due to special formes	AF2	I	Himself / herself. Lack of experience → new employee has a mentoring process
F3.3	Corrects the transfer of experience by an experienced employee	AF3	N	new employee corrects the work of a mentor



				according to his activities
<b>F3.4</b>	<b>Spends mentor's time</b>	HF		It's our goal.
<b>4. Client</b>				
F4.1	Sets limits to an experienced employee	AF1	N	Client sets the scope within which mentor's actions are possible.
F4.1	Sets limits to a new employee	AF1	N	Client sets the scope within which new employee's actions are possible.
<b>5. Rival</b>				
<b>F5.1</b>	<b>Creates value own value proposition</b>	HFp		A rival is trying to provide its proposition.
F5.2	Sets limits to the client	AF1	N	A rival creates additional restrictions in which the client acts.
<b>6. Mentor's experience</b>				
<b>F6.1</b>	<b>Shares with a new employee</b>	MF	N	
<b>7. Value proposition 1</b>				
F7.1	Transfers to client	AF1	N	It's enough to mentoring process.
<b>8. After meeting report</b>				
F8.1	Informs mentor about particularities of meeting with a client	AF2	N	It's enough to mentoring process.
<b>9. Purpose of meetings by mentor</b>				
F9.1	Limits client's responses	AF2	N	
<b>10. Limits and requirements 1</b>				
F10.1	Sets requirements to the new employee within the meeting time	AF2	N	
<b>11. Limits and requirements 2</b>				

F11.1	Sets rival's requirements to the client within the meeting time	AF2	N	We can only respond to them
<b>12. Limits and requirements 3</b>				
F12.1	Sets program's requirements to the mentor	AF1	N	
<b>13. Value proposition 2</b>				
<b>F13.1</b>	<b>Transferring of rival's value proposition to the client</b>	HF		

Where:

- MF – main function.
- AF – auxiliary function with rank 1...n.
- AdF – additional function.
- HF – harmful function.
- I – insufficient function implementation.
- E – excess of function implementation.
- N – normal (sufficient) function implementation.

The system of tasks which resulted from the assessment of the function model:

1. How to make it possible that the mentor does not broadcast the content of the program to the new employee?

**Solution:** E-learning; a new employee plans a lesson with a mentor, guided by a well-known mentoring program.

2. How to make it possible that the mentor does not spend time explaining the purpose of the meeting to the client?

**Solution:** the employee does it on his own, when the mentoring program includes a block for explaining the purpose of the meeting with the client (the new employee draws up the explanation according to the given complementary materials).

3. How to make it possible that the mentor does not forget to make updates to the program, while not wasting time making them? This is an important task, as the company loses important information that is the property of the mentor. **It is a separate task that needs to be solved additionally.**

4. The mentor spends the main time (F3.4) to help the employee to implement the F3.1 function in a high-quality manner. This is the main purpose of mentoring!

**Solution 1:** to integrate as much as possible the implementation of the F3.1 function into F3.2, that is, in the process of preparing for the meeting and preparing reports to the mentor, the new employee plans his dialogue with the client in the direction of creating value by points. These subjects are

defined as a meeting preparation and report template. During further discussion with the new employee, the mentor checks those points of the new employee's report where the new employee achieved success and those points that need to be improved.

**Solution 2:** an electronic "journal" of mentoring, which allows you to see the subjects of creating value in which the new employee achieved success and the points in which the progress of the new employee is visible. The mentoring journal needs to be harmonized with the sales funnel and KPI accepted in the sales department.

5. Setting up tasks from the position of element elimination (trimming). We try to remove the element "mentor".
6. The mentor overcharges the new employee with many details which are not useful.

**Solution:** mentor has to transfer own experience according the checklist with titles of key notes due to such forms of activity that they are training now.

Table 3. Remove an item from the system.

Rule	Rule description	Task after element elimination
Rule A	If there are no new employees, then a mentor in the system is not needed.	1. How to eliminate the staff turnover in the sales department? 2. How to do that when expanding the business of the company, the sales department does not become enormous?
Rule B	New employee educates himself.	How make it possible that a new employee quickly achieves KPIs in the allotted time for this without mentor assistance?
Rule C	Other elements of the system train a new employee, namely: a. mentoring program. b. client. c. competitors. d. other new employees. e. more experienced colleagues.	1. How to organize correct feedback from clients on the quality of employees' work with experience up to one year to correct their skills quickly? 2. How to get feedback from competitors on the work done by new employees with clients? 3. How to organize mutual training of new employees? 4. How to involve more experienced colleagues (not mentors) in the training process so that they do not spend time on mentoring?

### **Solutions:**

Rule C, p. 2: it is easy to get feedback from competitors through interaction with them within the framework of entrepreneurial social communities; or within the framework of accelerators, if joint participation is planned, etc. The exchange of experience must be included in the agenda of several events.

Rule C, p. 3: organize periodic meetings of new employees to exchange experiences (one time per month) under the supervision of a mentor (the mentor's time is won because he spends time not on a single person but immediately on a group). The secondary task: how to organize a high-quality reflection of experience at such meetings to use it in your company?

Rule C, paragraph 4: you need to organize a convenient removal of statistics from the CRM-system so that new employees can see:

- a. The dynamics of the development of the client (project), which the more experienced colleagues see too.
- b. A summary report which shows the dynamics of the development of clients (projects) in the context of their management by several employees, as a result of which the actions leading to the progress of the sales funnel (visible in comparison) immediately on the CRM system [4].

### **Conclusion:**

In this example, Function Analysis made it possible to uncover significantly more particular problems in the system under study, and therefore, allowed more interesting solutions to be found than with causal analysis. It is worth noting that when conducting RCA+ while realizing several projects, we built much more detailed cause-and-effect chains. Respectively, with the help of such cause-effect chains a significant amount of determined problems provided many tasks and found a lot of interesting solutions, so the comparison of the number of tasks does not seem to be correct.

But one thing is clear: RCA+ sometimes requires construction of huge cause-and-effect chains when solving business problems. On the one hand, it is not convenient and on the other hand, it is quite difficult to determine the elements of an organized social system which represent the starting points to carry out research through RCA+. That is why there is a strong recommendation to use RCA+ when you analyze the ordinaire problem only. Using the RCA+ with a functional analysis would be conveniently, either using CECA with FA.

It is worth paying special attention to the degree of quality of the problems found by using Function Analysis. Solving a system of problems obtained as a result of Function Analysis allows us to obtain solutions with a high degree of detail. It is very important when solving organizational and managerial problems because when having deal with problems similar to these, we often get the directions of transformation at the output only, but not specific ideas that can be implemented in the company without long discussions to elaborate these ideas.

### **Advantages:**

Function Analysis is a powerful TRIZ tool for analyzing organizational and managerial tasks. The advantages of this method from the point of view of solving organizational and managerial problems include a significant depth of problem analysis and obtaining a system of particular problems, solving which allows us to obtain solutions with a high degree of readiness to use, solutions that are sufficiently cleared of “information noise” (there is a lot of information noise in business tasks), and therefore, more powerful solutions.

### **Disadvantages:**

The disadvantages of Function Analysis include the high complexity of the method, which complicates its application to organizational and managerial tasks, characterized by many factors affecting each of the elements of a business system under consideration. Many factors complicate definition of functions in business system. The author estimates that the use of this method for analysis of organizational and managerial tasks is a very promising approach, but is recommended either for small business systems or for individual sections of more complex organized social systems (in particular, business systems), where a time-consuming analysis is justified in terms of the impact on final result.

## **4 Application of Schematization**

Schematization is a method similar to Function Analysis which has one significant difference. Schematization allows us studying elements of a business system according to the logic of management hierarchy in the business system. The method was proposed by the author based on the previous works of G. Shchedrovitsky. This method is described in detail in [5].

Before applying this method, we recall the task once again: **the mentoring process absorbs time of the experienced employees** (which they could spend on working with key accounts instead).

We construct the model of the problem in accordance with the concepts of systems (Fig. 3).

The concepts of systems were defined by G. Shchedrovitsky in [8]:

- Elements of the system (subsystems, supersystems) - subjects and objects.
- Layers on the schema.
- Types of relationships between elements:
  - Connections.
  - Processes.
  - Functions.
- Generalized objects.
- Content of generalized objects.
- System framework.

### Principle of problem statement as a result of schema's analysis:

1. Tasks at the contact points of a system and its supersystem.
2. **Tasks set by layers** (this paragraph explains the main feature of the schematization and its significant difference from functional analysis. You can see 5 layers on the fig. 3). **Common approach: how to improve the management of object A (located on a higher layer) by object B (located on a layer below)?**
3. Tasks set inside aggregated elements.
4. Tasks assigned to processes, functions and relationships not investigated in paragraphs from 1 to 3.
5. Tasks set at the junction of a generalized object / content of a generalized object.

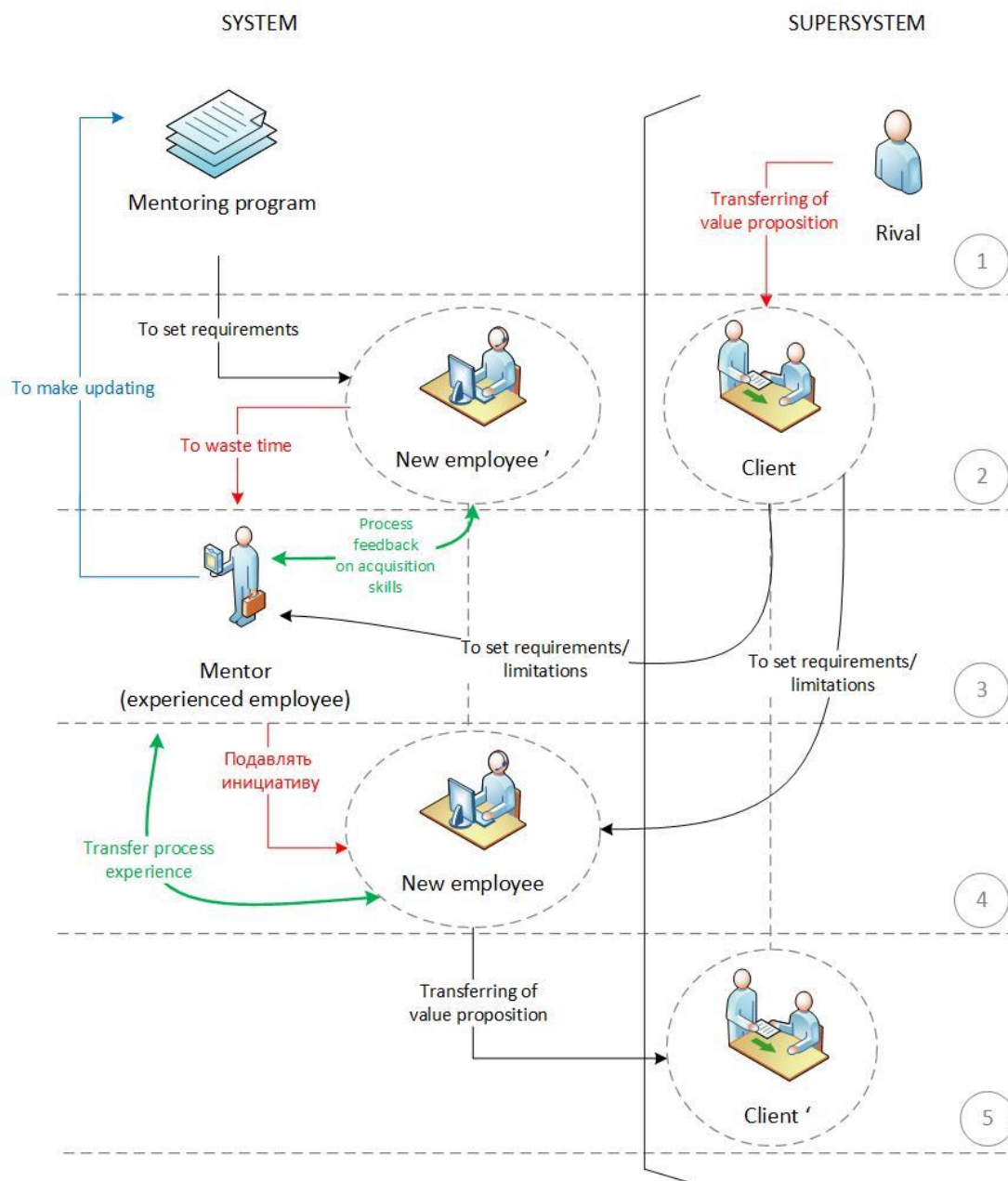


Fig. 3. Schema of problem situation.



A detailed description of system concepts and how to set tasks within the schema see in the author's book [4].

The tasks posed by the results of the analysis of the circuit in fig. 3 (the matrix of tasks according the schema):

Table 4. Tasks according to schema of problem situation (Fig. 3). Table of tasks.

Type of task	Nº	Task description
1. Tasks at the contact points of the system and the supersystem.	1.1.	How to make it possible that the client requirements reduce time spent by an experienced employee in the process while maintaining the quality of training new employees?
	1.2.	How to make it possible that a new employee creates a value proposition for a client without the participation of a mentor? <i>(the mentoring is eliminated from the new employees professional growing process).</i>
2. Tasks set by layers	2.1.	How to make it possible that the mentoring program corrects the activities of a new employee in such a way that an experienced employee would spend little of his time?
	2.2.	How to make it possible that in the process of providing feedback to the experienced employee a new employee affects the activities of the experienced employee so that the experienced employee spends as little time as possible?
	2.3.	How to set up the process of transferring experience from an experienced employee to a new one so that an experienced employee does not waste his time on it?
	2.4.	How to eliminate the suppression of the initiative of a new employee in the process of transferring experience from an experienced employee to a new one?
	2.5.	How to make it possible that the competitor's value proposition manages the client's activities in such a way so that the transferring of experience from an experienced employee to a new one will be faster than what is happening now?
3. Tasks set inside aggregated elements.	3.1.	<p><i>Since the task is set in the field of B2B-sales, the client should be considered the most important aggregated element.</i></p> <p>How to make it possible that the various client's Decision Centers and their interaction contributes to the transfer of experience from an experienced employee to a new employee, while minimizing time spent by an experienced employee?</p>

4. Tasks assigned to processes, functions and relationships not investigated before.	4.1.	How to make it possible that the mentoring program updating is produced itself so that an experienced employee does not waste his time on it?
5. Tasks set at the junction of a generalized object / content of a generalized object	5.1.	How to make it possible that when the experienced employee is conducting mentoring, the personal characteristics of the new employee (strengths and weaknesses) are considered as much as possible so that an experienced employee does not waste his time on it?
	5.2.	How to make it possible that the existing competencies of a new employee minimize the participation of an experienced employee in the process of transferring his experience?

### Matrix of solutions:

Table 5. Matrix of solutions due to the table of tasks (Table 4).

Task's number	Solutions description
1.1.	<p>1.1.1. You need to know customer requirements in advance. It is achieved by ranking customers by customer's channels and categories (according to ABC-analysis [4]), with a detailed description of customer requirements in accordance with their typology (customer portraits, benefits matrix [4]).</p> <p>1.1.2. You need to explain the basic knowledge of a meeting with clients to a new employee. This issue can be successfully closed by less experienced employees instead of mentors (experienced employees).</p>
1.2.	To remove a mentor (experienced employee) is an enormous task. It is of a higher level than the rest of the tasks, which are set according to the scheme (Fig. 3), since it directly corresponds to the main goal defined in the initial conditions of the task.
2.1.	<p>2.1.1. Transfer of trainings online.</p> <p>2.1.2. Detailed explanations of the points of the mentoring program (the program is prepared in Google docs, the points of the program are made in the form of links [4], after which a new employee can receive a detailed comments and explanations); the use of infographics, pictograms (visualization to simplify the perception of this information).</p> <p>2.1.3. Introduce the principle of "inverted education": the employee studies the proposed materials, thus a usual transfer of the materials from the experienced employees is excluded. Next, the new employee presents his understanding to an experienced employee who draws up a corrective action plan in a pre-prepared template.</p>

2.2.	<p>2.2.1. <i>It is necessary to somehow provide feedback in a special way, and for this it needs to be set, structured.</i> Therefore, material should be integrated into the training modules to provide feedback on the completed tasks towards an experienced employee: the form of providing information, content requirements, the procedure for answering questions. Moreover, you need to create a whole “mentor kit”.</p> <p>2.2.2 It is necessary to exclude any duplication of feedback. Therefore, it is recommended that the mentoring process be divided to elementary forms of activity and feedback should only be received per one form of activity at the same time.</p> <p>2.2.3. <i>additionally:</i> if an employee cannot carry out initial form of activity in the course of one iteration, then other new employees should also be involved in the process of finalizing this form of activity (working in pre-prepared mini-groups, mutual improving of their activity).</p>
2.3.	<p>2.3.1. it is necessary to clearly separate the process of transferring knowledge from the process of transferring experience. This solution is a part of solutions 2.1.3, 2.2.1, 2.2.2. It is necessary that the new employee have possibility to receive the necessary information (2.1.1, 2.1.3), and then adjust his feedback (2.2.2) according to his experience.</p> <p>2.3.2. It is necessary to ask experienced employees to provide 3-5 typical cases for the most important subjects of sales activity with a detailed analysis of their solutions (e.g. record videos), and then present these cases to new employees. The second stage, when they start working out the office with their clients, they must demonstrate these forms of activity in contact with real customers, plan 2-3 sessions of improving their activity forms. Thus, we create a hierarchically organized system of mentoring, which depends on the degree of level of skills of new employees. It ensures that most of the transferred competencies will not disappear due to inability of a new employee to perceive practical particularities.</p> <p>2.3.3. It is necessary to delegate mentoring in part of activity forms to less experienced employees, and to transfer part of the simplest activity forms to new employees, while self-learning of those parts where is no difficulty in transferring experience must be done by new employees.</p>
2.4.	<p>Previous solutions lead us to a rather rigid mentoring structure, however, if you need to keep the maximum initiative for a new employee.</p> <p>2.4.1. To include a block in the mentoring process to explain one’s own vision of the process of tasks in the studied forms of behavior by new employees.</p> <p>2.4.2. To include the obligate work of new employees in the mentoring process to structure their activities, taking into account the comments of an experienced employee on important forms of activity, followed by the presentation of their vision to an experienced employee.</p>

2.5.	<p>It is necessary to know how to collect and systematize information on the value of competitors' proposals for the client, followed by using this information as a means of adjusting the forms of activity of a new employee. To do this:</p> <p>2.5.1. It is necessary to create a database of competitors' value propositions.</p> <p>2.5.2. It is necessary to periodically update the hypotheses of customer needs in <i>the matrix of benefits</i> depending on the information received by the competitors' value proposition database.</p> <p>2.5.3. It is necessary to prepare a new employee for a meeting with a client using <i>the matrix of advantages</i> and a database of competitors' value propositions. Besides, it is very useful to valuate new employees' activity with a specially developed <i>training card</i>, i.e. an experienced employee gives recommendations on the completed card by the new employee.</p>
3.1.	<p>3.1.1. Make preparations for a meeting with a client and the meeting with the decision makers by a separate process controlled by less experienced employees. An experienced employee only controls preparation for the meeting with a client and the meeting itself with the decision makers (the experienced employee helps prepare a business case only).</p>
4.1.	<p>4.1.1. A training manager (or an employee acting as a training manager in a small company) should make changes based on the results of periodic meetings with mentors and new employees who go through the mentoring process.</p>
5.1.	<p>5.1.1. HR is developing an <i>employee competency profile</i>. The mentoring program is adjusted depending on the <i>employee competency profile</i> - its theoretical and practical parts can be improved. If a profile shows high competencies for self-training, then the mentor sets control points of the mentoring process. The resource of an experienced employee is used at control points only! The rest of the entire process of mentoring the employee goes on their own according to the offline program or online training module (online training is preferable).</p>
5.2.	<p>5.2.1. see solution 5.1.1.</p>

### Conclusion:

As for author's opinion, the use of schematization made it possible to get a little more interesting solutions than functional analysis due to the *ability of schematization to study the layers of investigated business system*, and also consider a person in a business system *from two perspectives*: from the standpoint of its business function and from the standpoint of its personal capabilities.

## 5 Conclusions

**Important note:** *Decisions found as a result of FA application and schematization application are not final. Further, it is supposed to form a system of contradictions and their subsequent solution, which will significantly improve the preliminary solutions found. As the author's experience shows, this approach usually allows you to find solutions that satisfy the owner of the problem. The system of contradictions*

*is not given in this article, since only the tools for preliminary analysis of the problem are considered.*

Such tools as Function Analysis and Schematization provide the most in-depth analysis of the organizational and managerial problems and help to identify enough high-quality preliminary management solutions. Such solutions should be considered preliminary because many of them will need to be further improved by resolving contradictions.

In addition, due to the consideration of some features of organized business systems, the schematization allows one to find a larger number of preliminary useful solutions, as it allows one to consider the interaction of system elements from some important points of view, that are not visible after carrying out functional analysis, especially for **layers of control and not only generalized objects and content into ones, but also their relationships.**

During analyzing layers using Schematization, 12 solutions were found (2.1.1 – 2.5.3). When considering the generalized objects / content into generalized objects relationships, the most valuable and previously unobvious solution in this project was found (5.5.1).

As a conclusion, we can consider Schematization as a promising tool for a comprehensive analysis of organizational and managerial tasks. While Schematization looks as a tool very similar as Functional Analysis, it is not the same tool due to identification of layers of control in the schema. This feature significantly changes the general appearance of the graphic model and affects approaches to its subsequent analysis.

Finally, we can compare all three methods according a number of criteria (Table 6).

Table 6. Comparison Table

Nº	Measure	RCA+	FA	Schematization
1	Coverage surface (the tool allows you to cover the entire investigated system or part of it)	+	++	+++
2	Depth of the problem analyzing	+++	++	+
3	The number of identified tasks from the original problem	+	+++	+++
4	How much the identified tasks correspond to the models adopted in TRIZ	+++	++	++
5	How much time was spent analyzing ( <i>more signs «+» corresponds to less time</i> )	+++	+	+

6	Identification of hierarchical relationships between system elements (important for business tasks)	-	-	+
7	Dual consideration of a person: as an element of a business system and as a separate system with its own properties	-	-	+

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## About Author



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# TOWARDS AUTOMATION OF CAUSE-EFFECT ANALYSIS

Jerzy Chrząszcz

## Abstract

Creating, manipulating, analysing and presenting complex cause-effect diagrams are challenging tasks, and in times of Artificial Intelligence (AI) invading several areas of human activity the expectation of supporting cause-effect analysis process with automated tools seems reasonable. Perhaps in the near future fully-autonomous AI-based expert systems will be able to process cause-effect diagrams drawn by hand and formulate accurate recommendations for solutions. Meanwhile, this short paper reports on a work in progress, which is focused on building and using the *causality matrix* – a computer-friendly representation of models developed during Cause-Effect Chains Analysis (CECA). The paper briefly presents the implementation of the matrix in the MS Excel environment, together with a method of supporting selection of key disadvantages in an automated way using Boolean expressions.

*Keywords:* TRIZ, Cause-Effect Chains Analysis, Boolean expression, key disadvantage, key problem.

## 1 The need for computer-friendly cause-effect model

Cause-effect analysis requires the researchers to investigate and document relations between causes and their effects. The Cause-Effect Chains Analysis (CECA) method [1, 2], widespread in TRIZ community, starts with indicating *target disadvantages* that should be eliminated from the system. Then the chains of their subsequent causes are identified, called the *intermediate disadvantages*, until the *root causes* are found. Because in CECA the root causes refer to laws of nature or projects constraints, they usually cannot be eliminated and so the analysis focuses on finding *key disadvantages*, which reflect the most impactful causes. Then a subset of such disadvantages is selected, elimination of which is sufficient to eliminate target disadvantages.

A typical approach to cause-effect modelling is to draw diagrams with boxes reflecting disadvantages and arrows indicating flow of causality. Additional symbols illustrate if any of the input causes are able to trigger a given disadvantage (logical OR) or if all the input causes must be jointly active to trigger this disadvantage (logical AND). Drawing such diagrams manually on a whiteboard or flipchart is fast and convenient for creating

cause-effect models during analytical sessions, but does not allow for any computerized support.

Creating CECA diagrams with MS PowerPoint or similar general-purpose drawing tool adds the ability to manipulate graphical objects easily (e.g. move or resize them), and there are some templates offered for popular platforms to ease the modelling [3]. Unfortunately, these templates mainly support linear 5 Whys model or Ishikawa fishbone model. Predefined structure and lack of the logical operators make them inappropriate for documenting CECA models. There are also several tools supporting Fault Tree Analysis (FTA), such as [4], that uses logical operators like CECA, but it assumes tree-like topology of the diagram, which limits its usability for CECA-style modelling. On top of that, the probabilistic attributes used for quantitative FTA do not have interpretation in the CECA realm and only incur additional burden.

Another approach to supporting cause-effect analysis is described in [5]. The paper focuses on expanding a CECA diagram with several annotations increasing its usability beyond documenting causal relations and identifying key disadvantages. In addition, some considerations are also presented, regarding appropriate software tool to support CECA process. After comparing characteristics of several off-the-shelf programs the authors recommend yEd graph editor [6], equipped with CECA-specific templates. Although such solution fulfils indicated functional requirements, it only addresses manual use of the editor by making it more user-friendly, with basic analytics (counting nodes, edges, etc.) and data export using various file formats.

In case of large models, containing hundreds of nodes, even simple manipulations of PowerPoint diagrams are difficult. Such complex models are usually documented, analysed and presented in fragments, with some key nodes repeated in several slides as “visual links” between the fragments. Unfortunately, PowerPoint slides are just collections of objects, without any logic behind the scenes. As a consequence, it is pretty easy to copy a key object and put its duplicates on several slides, but in case of changing its description or other attributes, the only way to update the copies is to do it manually. So that the choice remains between a scrupulous propagation of changes and endangered coherence of the model. The yEd, in turn, offers several graph-oriented functions, such as grouping nodes into subgraphs, folding and unfolding groups, indicating successors or predecessors, etc., which make working with large diagrams easier.

If visual consistency of a model documented with a drawing tool is essential for professional look, then supporting automation in the analysis seems to be an appealing challenge, especially for complex CECA models. Therefore, in the advent of autonomous AI expert systems, let us consider an intermediate solution, using a computer-friendly CECA representation, which was originally proposed in [7]. It relies on a *causality matrix* that documents disadvantages, logical operators and connections between them, so that both the structure of a model (interconnection scheme) as well as the contents (descriptions of disadvantages) are properly reflected.

## 2 Building causality matrix from CECA diagram

The main part of a causality matrix is a square data area having rows and columns labelled with identifiers of the disadvantages set in the same order for both dimensions. The rows represent the effects and the columns represent the causes, so that the value in the cell  $[m, n]$  is positive if and only if the disadvantage  $n$  is a direct cause of the disadvantage  $m$ , and it is 0 otherwise. Causality may be modelled with equal values (just to indicate existence of the connections in the diagram), or the values may reflect expert estimations regarding importance of particular input causes, as it is explained in [7]. An additional column is used in each row for recording type of the logical operator combining the input causes – OR / AND, respectively, or empty – in case of a single predecessor (a link in a linear chain) or no predecessor.

Conversion of a CECA diagram into a causality matrix employs the following steps:

- assigning sequential numbers to all disadvantages,
- annotating matrix row and column labels according to the sequence,
- filling rows of the matrix according to the sequence – each disadvantage is represented by a row having non-zero values in the columns reflecting preceding disadvantages and indicated type of a logical operator (if any).

Such construction of the matrix implies that a root cause is represented with an empty data row (as a root cause does not have any predecessors in the diagram) and for a target disadvantage respective data column is empty (as a target disadvantage has no successors in the diagram). The size of the data structure grows with a squared number of the disadvantages, while its contents are very sparse, which justifies a compaction step to be performed prior to processing. It aims at extracting all non-zero items in order to avoid scanning sparse data set several times.

Compacting of a causality matrix involves building informationally equivalent data structure with a simpler and thus faster access to data items. Each matrix row is scanned and the indices (positions) of all non-zero elements are stored one by one into consecutive cells in a row of a secondary table, together with the number of such elements. Such list-like representation is much more convenient for algorithmic processing, because the number of iterations and the column numbers to iterate through are given explicitly in the compacted causality table.

## 3 Supporting selection of key disadvantages

The idea of using Boolean algebra to support CECA process was first introduced in [8] and further developed in [9, 10]. This approach employs Boolean expressions to describe the structure of a CECA model as a set of combinational functions which operate on logical variables evaluating to 1 and 0 for active and inactive disadvantages, respectively. Candidate key disadvantages may be automatically characterized by calculating logical expressions describing the impact of these candidates on the target disadvantages. Moreover, using De Morgan's Laws we can easily calculate negated expressions that characterize *key problems*, as described in [2]. The algorithm operating on causality table is given below in the form of a generic pseudo-code.

expression = logical function defined for a given variable // + stands for OR \* stands for AND ! stands for NOT

REPEAT

FOR EACH variable name in table

IF the name appears in the expression AND the name does not indicate root cause or key disadvantage THEN

replace all instances of the name in the expression with the logical function defined for this variable

END IF

END FOR

UNTIL there is no change in the expression

A sample CECA model inherited from [7] is depicted in Fig. 1a. It describes two target disadvantages ( $y_1, y_2$ ), four root causes ( $x_1 \div x_4$ ) and five intermediate causes ( $x_5 \div x_9$ ). Other parts of the figure present snapshots of implementation of the described method in MS Excel.

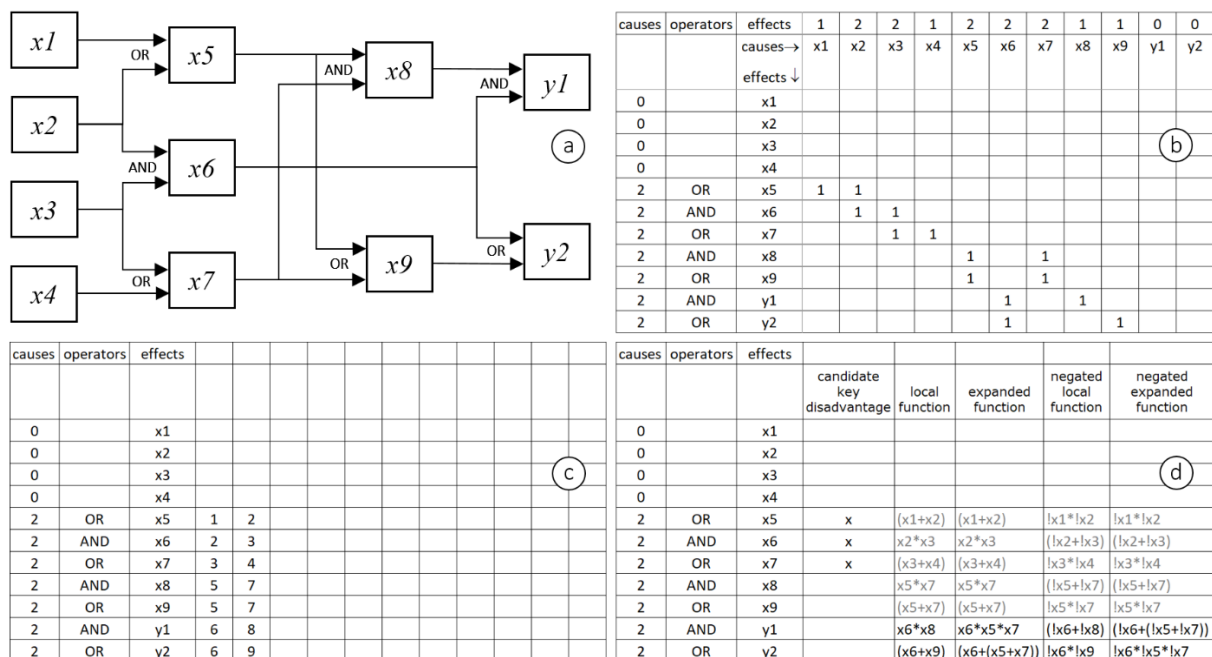


Fig. 1. Sample cause-effect diagram (a), its causality matrix (b), compacted causality table (c), local and expanded logical expressions for  $y_1, y_2$  with  $x_5, x_6, x_7$  as candidate key disadvantages (d); direct functions describe disadvantages, while negated functions describe conditions of their removal

#### 4 Summary and further work

The previous author's papers described logical CECA model [8, 9, 10] and quantitative CECA extensions [7, 9]. The causality matrix was used for computing *structural impact factors* [7], indicating how strongly particular disadvantages affect target disadvantages just because of the structure of the model, which may be used alone or in combination with experts' assessments.

This paper reports another step in the implementation of automated support in selecting key disadvantages from the CECA model. We have described the process of creating a causality matrix and transforming the matrix into a compacted causality table in order to avoid multiple search operations. Then the symbolic processing of logical expressions in MS Excel was described, aimed at describing target disadvantages as functions of candidate key disadvantages.

The next step should be merging qualitative (logical) and quantitative (numerical) representations for better support in the selection of sets of key disadvantages. On top of that, generated logical expressions appear to be a compact and precise representation of a CECA model, and therefore they may be used for e.g. automated diagram creation from a textual description.

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## About Author



Dr Jerzy Chrzęszcz works as Assistant Professor in the Institute of Computer Science, Warsaw University of Technology, since 1986. He authored/co-authored over 80 publications, including 7 patents, and supervised over 50 MSc/BSc theses. He cooperates with Pentacomp Systemy Informatyczne S.A. as a Project Manager, Quality Manager and Security Manager, since 2001. Certified Lead Auditor of QMS (ISO 9001), ISMS (ISO 27001) and BCMS (ISO 22301). He is TRIZ Practitioner (MATRIZ Level 3) and member of the European TRIZ Association (ETRIA).

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# A NEW OPERATOR IN CECA

Yongwei Sun

## Abstract

It is well known that there are two operators in Cause and Effect Chain Analysis (CECA). However, AND / OR operators are not good enough for a situation when all underlying disadvantages contribute certain percentage to achieve 100%. Therefore, we propose to add a “+” operator to two other operators used in CECA.

*Keywords: + operators, CECA, cause effect chain analysis, key disadvantages*

## 1 Background of CECA

CECA (Cause and Effect Chain Analysis) is a very strong analytical tool in modern TRIZ.

It plays an extremely important role in determining key problems which can further be resolved with TRIZ solving tools. In many cases, once we have determine a key problem with CECA, we can successfully apply the classical problem solving TRIZ tools to solve the problem. There are many discussions in TRIZ community. <sup>[1]</sup><sup>[2]</sup> Such as Mr. Valeri Souckov proposed RCA+, Mr. Aurthur Lok shared a case with CECA, Dr. Oleg Abramov compared CECA and RCA. On TRIZfest 2017, Dr. Jerzy Chrzęszcz proposed a qualitative approach to link all disadvantages with Operator AND and OR. <sup>[3]</sup>

## 2 Existing operators in CECA

It is well known that there are two operators in CECA <sup>[4]</sup>. These two operators are “AND” and “OR”. Operator “AND” is used in a situation when all underlying disadvantages must be present to create the upper layer disadvantage. (Fig. 1) “OR” operator means that there may be several disadvantages under the upper layer disadvantage, but each of them by itself can cause the upper layer disadvantage independently. (Fig. 2)

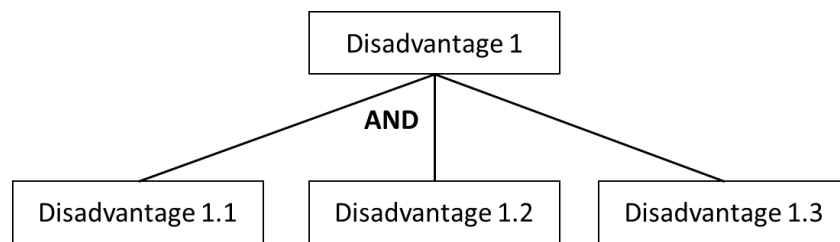


Fig. 1. AND Operators in CECA

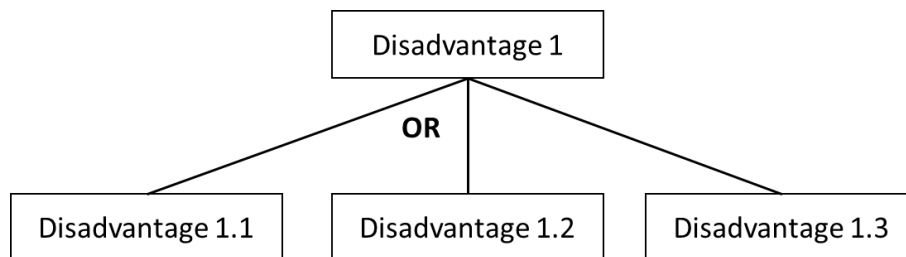


Fig. 2. OR Operators in CECA

In a situation with “AND” operator, if we want to remove the upper layer disadvantage, we need to remove only one of disadvantages and then the upper layer disadvantage will be removed. In Fig. 1, we can remove one of the three disadvantages and then we can remove Disadvantage 1. But in case with “OR” operator, in order to remove the upper layer disadvantage, we need to remove all underlying disadvantages. In Fig. 2, we need to remove all three disadvantages in order to remove Disadvantage 1.

For example, there is a problem of catching fire. There are three underlying disadvantages for fire: a) temperature exceeds point of ignition; b) there is flammable materials in the system; c) there is oxygen in the system. All these three disadvantages are connected with “AND” operator. We can remove one of the three disadvantages in order to avoid the fire. There may be 3 ways of achieving it: a) reduce the temperature; b) remove the flammable materials; c) remove oxygen. Another easy understanding example with “OR” operator, my computer can’t work. We can list all the disadvantages, such as the i) CPU is broken; ii) the memory is broken; iii) the battery is dead. In that case, all the three disadvantages are connected with “OR” operator. We need to remove all the disadvantages in order to make the computer work.

However, there may be another situation which is very similar to operator “OR”. Smog is a serious problem in big cities. Once we build a cause effect chain, we can identify many sources of smog. It seems they are connected with Operator “OR”.

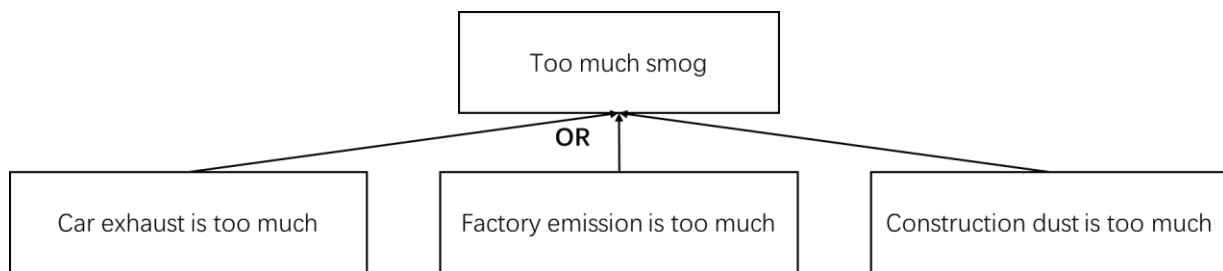


Fig. 3. Cause Effect Chain of Smog

Based on the rule above, we need to remove all the disadvantages that cause smog. But it is almost impossible to remove all the sources. Now, we are facing a serious challenge when we use the “OR” Operator.

### 3 Existing operators in CECA

There can be many real projects which have to be executed, especially when we are executing a very big project. Situations of this kind emerge often when we do Six Sigma projects. For example, there is too much energy consumption; there is too much noise; the aircraft engine is too heavy; there is too much heat generation...

We propose a new Operator to replace the “OR” Operator when we meet such situation.

The new operator we propose is “+” (the sign of plus). All the situations mentioned above have a common feature: each disadvantage contributes certain percentage to a disadvantage of an upper layer. If we add them altogether it will be 100%.

The Operator “+” means that each underlying disadvantage contributes certain percentage and the sum of contribution of all disadvantages will result in 100%. It is necessary to identify and put the contribution percentage for each disadvantage.

Now, the cause effect chain mentioned above will look like shown in Fig. 4.

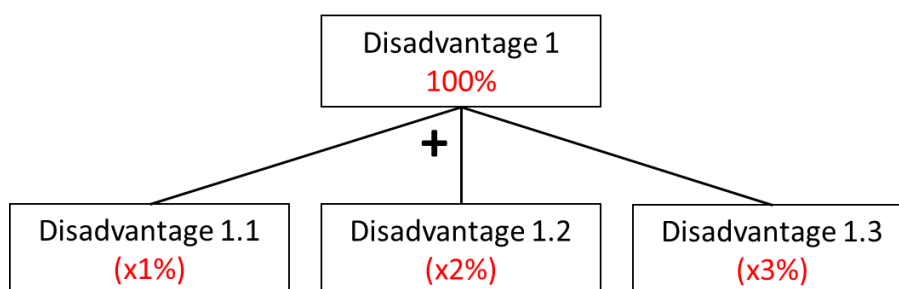


Fig. 4. Cause Effect Chain Connected with Operator “+”

In many projects there are many disadvantages which reside at different layers. In order to make the chain more complete, we need to investigate it deeper. The chain will be like shown in Fig. 5.

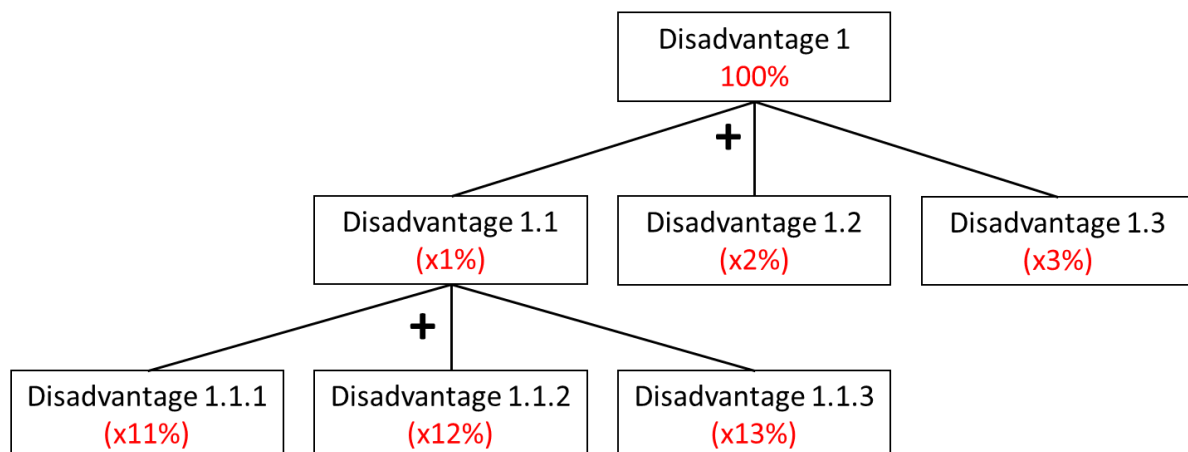


Fig. 5. Cause Effect Chain with more than one layers with Operator “+”

In Fig. 5,  $x_1 + x_2 + x_3 = 100$  and  $x_{11} + x_{12} + x_{13} = x_1$ . Of course, there still may be disadvantages connected with “AND” and “OR” operators. Therefore, there might be three types of operators coexisting in the same Cause Effect Chain.

The Cause Effect Chain of the smog emergence presented above is shown in Fig. 6.

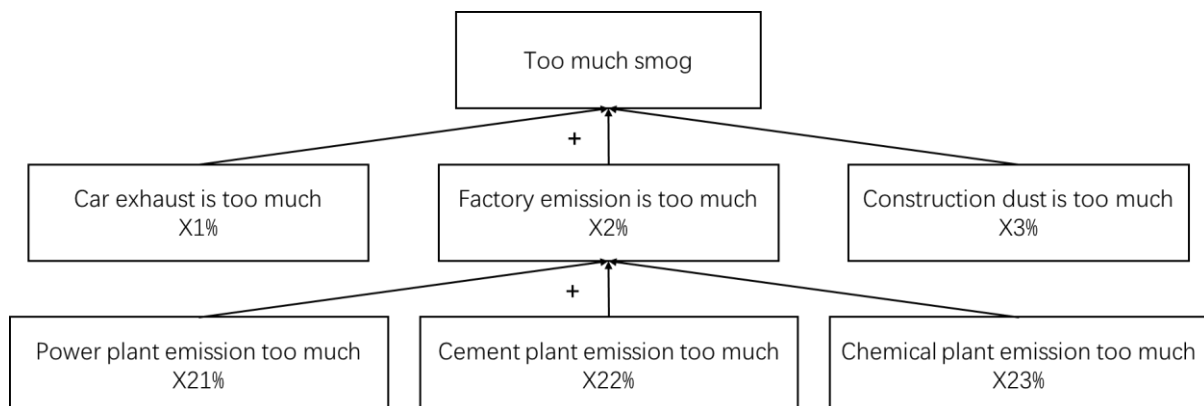


Fig. 6. Cause Effect Chain of smog

## 4 Key Disadvantages

A very important outcome of CECA are key disadvantages. If there is Operator “+”, how can we select the key disadvantages? The contribution is the most important point which should be considered. We need to select those disadvantages which contribute more and then prioritize them. If there is a disadvantage which contributes very little, we will definitely not select it as a key disadvantage, unless it is extremely easy to resolve. Thus, the priority will be given to those disadvantages which contribute the most. Sometimes, it is necessary to use Pareto Chart which is a very popular tool in Six Sigma and statistical field and is also known as “80-20 rule”.

Since it is often almost not possible to remove all the disadvantages, we can remove some disadvantages which contribute the most and see if a customer can accept it. If the customer is satisfied, the project goal is achieved. If not, we need to remove the other significant contributors. The best situation is when the disadvantage contributes the most and is also the easiest to remove. As a conclusion, we have to keep in mind

that we do not have to try to eliminate all disadvantages, but rather remove those which contribute the most.

## 5 Algorithm of CECA with Operator “+”

Similar to the other tools of TRIZ, we also propose an algorithm of CECA with Operator “+”:

- 1) Identify the initial disadvantages. Several years ago, we proposed an approach of how to identify the initial disadvantages [5].
- 2) Build the cause effect chain by identifying the underlying disadvantages layer by layer.
- 3) Connect the disadvantages with Operator AND, OR and +.
- 4) Select the key disadvantages.
- 5) Formulate the key problems and solve the problems with the problem-solving tools of TRIZ.

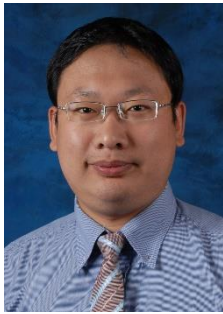
## 6 Conclusions

We propose to use a new operator “+” in CECA in addition to the “AND” and “OR” Operators. It is found to be very helpful to build a Cause Effect Chain and choose the right key disadvantage. An algorithm is also proposed to use the Operator “+”.

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## MATRIZ NEWS AND REPORTS

### Structure of MATRIZ

Currently, MATRIZ includes the following departments and appointments:

**MATRIZ Board** (elected at the MATRIZ Congress on September 14, 2019):

- Feygenson Oleg, Russia (President)
- Abramov Oleg, Russia
- Adunka Robert, Germany
- Ahn Hyunsoo, S. Korea
- Fomenko Aleksey, Russia
- Ikovenko Sergei, USA
- Mayer Oliver, Germany
- Souchkov Valeri, the Netherlands
- Yatsunenko Sergey, Poland

**MATRIZ Appointments:**

- Executive Director: Mark Barkan
- Vice President of Development and Communications: Valeri Souchkov
- Coordinator of MATRIZ Member Organizations: Yury Fedosov
- Chairman of TRIZ Master Certification Council (TMCC): Simon Litvin
- Chairman of the Council on Expertise and Methodology (CEM): Sergei Ikovenko
- Vice President, Chairman of TRIZ Research and Development Council (TRDC): Victor Fey
- Vice President of South Korea for Government and Higher Education Affairs: Yong Won Song
- Director of TRIZ Deployment of MATRIZ in South Korea: Huynsoo (Alex) Ahn
- Vice President of China for Government and Higher Education Affairs: Yue (Alp) Lin
- Marketing Director of China: Nan Han
- Vice President of China for Industry Affairs: Yongwei Sun
- Vice President of Marketing in Russia the CIS countries: Sergey Logvinov
- Vice President of Russia and the CIS countries for Industry Affairs: Alexey Fomenko
- Director of TRIZ Deployment of MATRIZ in India: P. V. Narayan
- Director of TRIZ Deployment of MATRIZ in India: Tito Kishan Vemuri
- Senior MATRIZ Adviser in Europe: Robert Adunka
- Vice President for TRIZ Deployment in Europe: Stephane Savelli
- Vice President for New Projects: Dmitry Bakhturin

- Editor in Chief, TRIZ Review journal: Valeri Souchkov
- Director of Developing TRIZ Applications for Business and Management: Anton Kozhemyako
- Coordinator for the development of Creative and Critical thinking skills: Mark Barkan

**TRIZ Research and Development Council (TRDC):**

- Victor Fey (Chairman)
- Alexander Kudryavtsev
- Simon Litvin
- Sergey Logvinov
- Alex Lyubomirskiy
- Victor Minaker
- Valeri Souchkov
- Alla Zusman

**TRIZ Master Certification Council (TMCC):**

- Simon Litvin (Chairman)
- Oleg Abramov

**Council on Expertise and Methodology (CEM):**

- Sergei Ikovenko (Chairman)
- Mark Barkan
- Christoph Dobrusskin
- Andrey Efimov
- Alex Lyubomirskiy
- Yong Won Song
- Sergey Yatsunenko

**Council on Expertise and Methodology (CEM) invited experts:**

- Oleg Abramov
- Robert Adunka
- Hyunsoo Ahn
- Tiziana Bertonecelli
- Alexey Fomenko
- Barbara Gronauer
- You-Shin Han
- Jung-Hyeon Kim
- Arthur Lok
- Oliver Mayer
- Heungyeol Na
- Tanasak Pheunghua
- Valeri Souchkov
- Yongwei Sun

## **MATRIZ NEWS AND REPORTS**

### ***NEWS FROM TRDC***

## **TRIZ Research and Development Council Regulations**

On April 16, 2020 an update of TRDC Regulations was suggested by TRDC and approved by MATRIZ Board:

### **Part I. General provisions and goals**

1. The TRIZ Research and Development Council (hereinafter TRDC) is an organizational unit of MATRIZ, which works out and implements MATRIZ policy in the field of further development of TRIZ.
2. The main goals of TRDC are the following:
  - a) Formation of a unified TRIZ terminology
  - b) Identification and expertise of new prospective TRIZ tools
  - c) Methodological expertise of TRIZ materials upon request of the MATRIZ President, the MATRIZ Board, and the Council on Expertise & Methodology (CEM)
  - d) Development and regular update of the MATRIZ-recommended document “TRIZ Body of Knowledge”
  - e) Development and regular update of the MATRIZ-recommended document “Main Directions of TRIZ Development”
  - f) Control of methodological accuracy of the CEM’s recommendations
  - g) Upgrading the methodological level and status of TRIZ developers

### **Part II. TRDC Membership and procedure for Council formation**

1. TRDC Chairman is appointed by MATRIZ President from among TRIZ Masters and is serving as the Council’s leader. The TRDC Chairman gains the status of MATRIZ Vice-President on Research and Developments in TRIZ (VP R&D).
2. The size and make-up of TRDC (no less than seven persons) are determined by TRDC Chairman and approved by MATRIZ President.
3. When necessary, TRDC invites consultants and establishes various temporary units/committees involving TRIZ specialists who are not TRDC members
4. TRDC has the right to coopt new or expel current members, presenting new members for approval to MATRIZ President.

### **Part III. Organization of TRDC work**

1. TRDC activity is carried out in accordance with a plan developed by TRDC and approved by MATRIZ President.
2. TRDC Chairman organizes and moderates the work of the Council
3. TRDC Chairman appoints the Academic Secretary of the Council and persons responsible for each direction of TRDC activity.

4. TRDC sessions are held regularly onsite or online (telephone, Skype, etc.) at least once a month.
5. Decisions of the TRDC are taken via voting in person or electronically by simple majority of votes – over 50% of the total number of TRDC members who take part in the voting procedure (with a quorum of at least 50% of the total number of the TRDC members). In the case of equal number of positive and negative votes, the vote of the TRDC Chairman represents a decisive vote.
6. Results of TRDC sessions are recorded in meeting minutes, which contain the following information: the members who participated in the session, date of the session, major issues discussed at the session, suggestions proposed during the discussion, and decisions taken. The Academic Secretary of the TRDC writes down the minutes of the session. Minutes of all sessions are submitted to MATRIZ Presidium and published in the appropriate section of MATRIZ website.

*Prepared by Dr. Simon Litvin, TRIZ Master and Victor Fey, TRIZ Master on behalf of TRIZ Research and Development Council*

## MATRIZ NEWS AND REPORTS

### Report: TRIZfest-2019 in Heilbronn, Germany



The 15<sup>th</sup> International Conference of MATRIZ “TRIZfest-2019” was held on September 11-14, 2019 in Heilbronn, Germany. It was organized by the International TRIZ Association – MATRIZ and hosted by the Chamber of Commerce and Industry of Heilbronn-Franken.

The conference was visited by over 120 participants. Most of them represented Germany, others came from many different countries including China, India, South Korea, Thailand, USA, Vietnam; in addition to European countries, and certainly Russia and Ukraine. It was quite exciting to observe that Germany continues building rather strong TRIZ community with representatives from top German companies.

The pre-conference day featured six different tutorials: Design for patentability; Advanced analysis of information with TRIZ; Hybridization; Creative Imagination Development; Trends of Evolution of Business Systems, Finding a proper spot for innovation. Although the tutorials were run at parallel sessions, it was pleasant to see that no room was missing audience; each tutorial gained almost the same number of attendees as the others thus demonstrating equal interest in different subjects of TRIZ.





The conference started with an opening and awards ceremony. The opening speeches were provided by Dr. Mark Barkan, Executive Director of MATRIZ and Prof. Dr. Dr. h.c. Harald Unkelbach, President of the Heilbronn-Franken Chamber of Commerce and Industry. The award of TRIZ Champion by MATRIZ was presented to Pavel Jirman (Czech Republic), special awards for contribution to MATRIZ development were given to Dr. Mark Barkan (USA) and Dr. Yuri Fedosov (Russia), now ex-President of MATRIZ. A group of other participants received certificates of their advanced degrees in TRIZ and certificates of new regional TRIZ associations which became members of MATRIZ.



Special MATRIZ awards were provided by MATRIZ VP on Europe Dr. Robert Adunka to a group of German students for their distinguished works on inventions developed with TRIZ.





The conference program provided 43 paper presentations, two keynotes and two panels. Judging by statistics, papers and presentations focused on the following topics (some papers were focusing on more than one):

- Theoretical, research results: 6
- TRIZ-related methods and tools development: 14
- Best practices, business experiences, integration with non-TRIZ methods/tools: 11
- TRIZ-Pedagogy: 5
- Educational methods and experiences: 6
- Case studies: 18

The event featured two keynote talks. The first one presented an overview of TRIZ at Schaeffler Group by Rainer Eidloth and Dr. Armin Lau. Schaeffler Group is a company well known in aerospace and automotive industries with 92.000 employees. The second keynote talk was given by Thomas Bayer, Director of Innovation Lab of Wittensten SE, about developing a new S-curve by creating a radically new type of gear – Galaxie Gear® with TRIZ. Citing Mr. Bayer, this invention disrupts 500 years of gear's basic design principles. Needless to say, the invention collected numerous awards.



The conference included a special session on TRIZ-Pedagogy run by Dr. Mark Barkan. TRIZ-Pedagogy is the growing area which suggests new principles of education based on a number of key TRIZ principles and concepts in a modern highly dynamic world; and the TRIZ community does its best to contribute to this new approach.



The first conference panel focused on the issues of TRIZ applications in industry, in particular on the aspects of implementing TRIZ at both large corporations and SMEs. One of the critical questions is how to integrate TRIZ with already existing processes and business practices at organizations while implementing it. Without solving it, TRIZ is used sporadically and dispersedly and does not contribute very much to the growth of intellectual property of a company.

The second panel was dedicated to TRIZ training/certification issues by MATRIZ which demands a better structure and more clarification. It was exciting to observe willingness of the audience to discuss existing challenges and look for ways to achieve positive changes and common agreements at both panels.



The first part of the final day was dedicated to TRIZ Master degree defense. Unfortunately, this year we have no new TRIZ Masters. Although a presentation by TRIZ Master candidate Mr. Anton Kozhemyako won 4 votes against 3, it was not enough to get the degree. Other candidates postponed their promotions till next year.



The final part of the event was MATRIZ Congress which is conducted bi-annually. Besides a usual report from MATRIZ Executive Director Dr. Mark Barkan, the reports



were provided by those who held key roles at MATRIZ. One of the decisions made was to continue a balanced development of MATRIZ along three main strategic directions: “Classical” TRIZ, TRIZ for Business and Management, and TRIZ-Pedagogy.

Then a new MATRIZ Board (Presidium) was elected. The new MATRIZ Board members are: Dr. Oleg Abramov (Russia), Mr. Hyunsoo Ahn (South Korea), Dr. Robert Adunka (Germany), Dr. Oleg Feygenson (South Korea/Russia), Dr. Alexey Fomenko (Russia), Dr. Sergei Ikovenko (USA), Dr. Oliver Mayer (Germany), Mr. Valeri Souchkov (The Netherlands), Dr. Sergei Yatsunenkov (Poland).



Before completing the event, the new Board elected a new MATRIZ President: Dr. Oleg Feygenson.

As usual, the organizers ensured several social events which included a cocktail party and the conference gala dinner. It was a coincidence that at the same time there was a local wine festival in the city of Heilbronn which provided additional social program for many participants. But MATRIZ, of course, welcomes responsible drinking only.

TRIZfest-2019 was an excellently organized, intensive and fruitful event. Some sceptics often tell me that TRIZ came to the stagnation or even decline stage. But events like this – due to the opportunity to meet and talk to many different people - show it certainly did not. TRIZ works well, but one of the key issues is that TRIZ is not yet well known; it seems to be too complex but all the attempts to simplify TRIZ did quite a damage to its reputation. TRIZ must not be simplified; instead, it must be properly structured, learned, and implemented. Only then the real results will come, and they will do it at a large scale. But we must admit that TRIZ has reached a turning point: it must be capable of supporting innovation in all the new and emerging technologies and methodologies of the 21<sup>st</sup> century: AI, big data, design thinking, sustainability, IoT, new approaches to education, and so forth.





The conference proceedings is an open access publication and available at the MATRIZ website:

<https://matriz.org/trizfest-proceedings/>

*Prepared by **Valeri Souchkov**, TRIZ Master, Vice President of MATRIZ*

## MATRIZ NEWS AND REPORTS

# Report: TRIZ-based Innovation Week in India - TRIZ for X 2019

The annual TRIZ Innovation Week and Conference TRIZ for X are being organized by TRIZ Association of Asia (TAA) since 2014.

This year, a weeklong Innovation activity was conducted, wherein Mr. Valeri Souchkov, TRIZ Master, President of the International Business TRIZ Association (IBTA) and Vice President of the International TRIZ Association (MATRIZ) conducted a public training workshop (11-13, Nov 2019) on learning how to apply TRIZ to improve and accelerate business and management innovation. The workshop participants, from major Indian conglomerates, learned basic TRIZ tools which help to recognize demands and clarify innovative problems and challenges as well as tools providing systematic access to the relevant patterns of innovative solutions to solve specific problems.



The Conference “TRIZ for X: Business and Services” was held on 15, Nov 2019 and was attended by 120+ participants from industry, academia and consulting business across India.

The conference started with Mr. P V Narayan (*Director of TRIZ Deployment of MATRIZ in India & President - TRIZ Association of Asia*) reading the greeting letter of Dr. Oleg Feygenzon (President, MATRIZ).



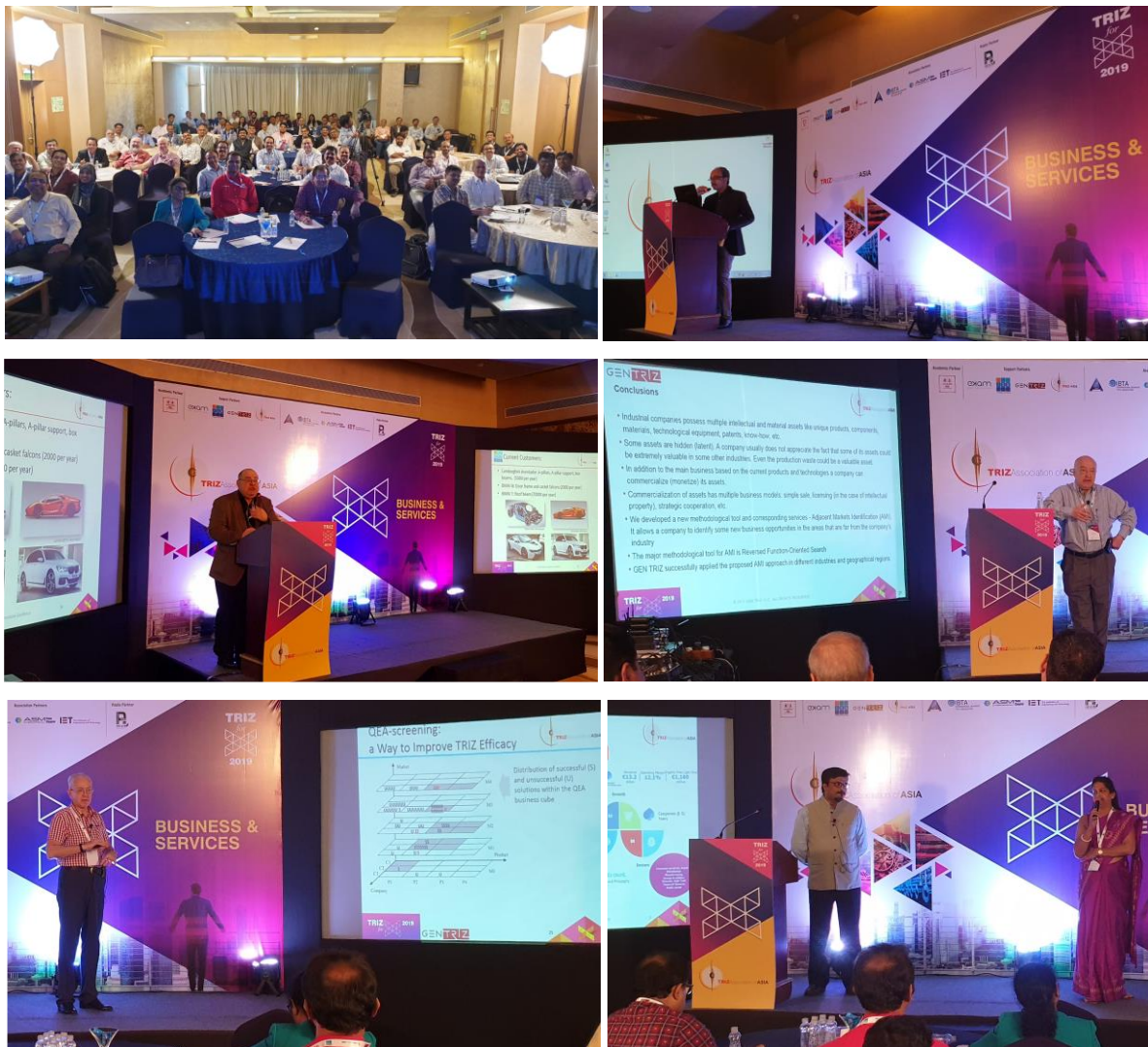
TRIZ Master Mr. Valeri Souchkov deliberated on ‘Best practices of application of TRIZ in the areas of business and management’.

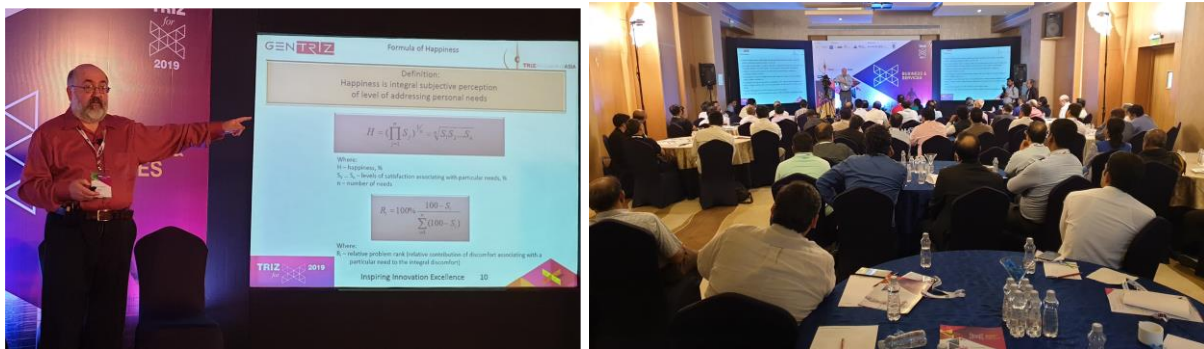
Dr. Simon Litvin (*TRIZ Master, CEO/President – GEN TRIZ, USA and Chairman of the TRIZ Master Certification Council of MATRIZ*) presented the methodology of TRIZ for Adjacent Markets Identification.

Dr. Oleg Abramov (*TRIZ Master, Board Member of MATRIZ, Chief Technology Officer - Algorithm, Ltd. a strategic partner of GENTRIZ LLC*) enlightened the audience on ‘Evaluation of the Effectiveness of Modern TRIZ Based on Practical Results in New Product Development’.

Mr. Sanjib Ghosal (*TRIZ Level 1, Lead Six Sigma - Capgemini, India*) shared his experienced-on Grassroots innovation @ Capgemini.

Mr. Alex Lyubomirskiy (*TRIZ Master, Chief Scientific Officer - GEN TRIZ*) demonstrated the ‘TRIZ based Happiness Equation for Business Growth’. Shree Phadnis, (Chairman, TRIZ Association of Asia) cleared the doubts of curious participants.





Last session was on the open discussion, where the TRIZ Masters who presented at the event and Mr. Sanjib Ghosal answered the queries of inquisitive participants. The incessant questions were aptly answered with suitable examples, and the conference concluded.

TRIZ for X 2019 offered a ring side view of how TRIZ techniques could help solve problems faced by any business function in various domains.

*The great support of partners AISSMS College of Engineering, ASM International (Pune Chapter), Institution of Engineering and Technology, MATRIZ, IBTA, EkamEco, ICG, GENTRIZ and TRIZ Asia, Radio Puneri Awaaz 107.8 FM are appreciated.*

*Prepared by **Valeri Souchkov**, TRIZ Master and **Dr. Sandeep Wankhade**, MATRIZ Level 3*



## MATRIZ NEWS AND REPORTS

### Report: The 4<sup>th</sup> MATRIZ China Conference in Beijing, China

On December 7-8, 2019, the 4th MATRIZ (International TRIZ Association) China Annual Conference was successfully held at Beijing Civil Aircraft Technology Research Center of COMAC located in Beijing Future Science City. This annual conference was hosted by MATRIZ (the International TRIZ Association), organized by NICE (National Institute of Low Carbon and Clean Energy) of China Energy Group, Shenhua (Beijing) New Materials Company, and jointly organized by China Intellectual Property Research Society and Hong Kong Innovation Society.

More than 100 TRIZ experts and other TRIZ enthusiasts from different industries participated in the conference: from NICE of China Energy Group, Samsung, CRRC, Intel, Huizhou Desay, Danaher, Joyoung, ABB, Mercedes-Benz, Changan Automobile, Sinosteel, Baotou Steel, Gree, Huawei, ZTE, Ningde New Energy, Zhongke Sanhuan, Nexteer, Supor, Tianjin Membrane, Shanghai LNG and other companies as well as from Shandong University, Beijing University of Technology, Xiamen University, South China University of Technology, Guangdong University of Technology, Hebei University of Engineering, Inner Mongolia University of Science and Technology, Henan University of Science and Technology, Qingdao University of Science and Technology, Chengdu University of Information Technology and other universities. Representatives from Shanghai Intellectual Property Training Center, Heilongjiang Innovation Methodology Application Society, Shanghai Science and Technology Innovation Center, Tianjin Institute of Science, Ningbo Material Institute also participated in the event.

The conference was chaired by Dr. Sun Yongwei, the first Chinese TRIZ Master (Level 5) in the world, director of the Advanced Methodology Department of NICE, and Vice President of the International TRIZ Association (MATRIZ).



Mr. Chen Xuelian, General Manager of Shenhua (Beijing) New Materials Co., Ltd. welcomed participants and shared his experience of using TRIZ to solve technical problems in research and development projects.



At this annual conference, the MATRIZ certificates were presented to Mr. Luo Jia, an expert who obtained Level 4 certificate in this year, Dr. Yang Jie and Mr. Zhang Binbin who obtained MATRIZ Level 1 certification this year, and several other participants who received MATRIZ certificates of Level 1, 2, 3.



The annual conference organizers also awarded plaques to companies and individuals who have achieved outstanding results in the promotion of TRIZ during the last year. Among the Excellent companies (organizations) that have been promoting TRIZ are Shanghai Panda Machinery Group, Joyoung Appliance, Gree Appliance, and Beijing University of Technology. Among the outstanding promoters of TRIZ are Li Miao (Arthur Lok from South China University of Technology), Liu Yongmou (Chengdu GET Group), Long Yinhua (NICE), Li Juan (Huawei Terminal), Peng Jianping (Shanghai Science and Technology Innovation Center).

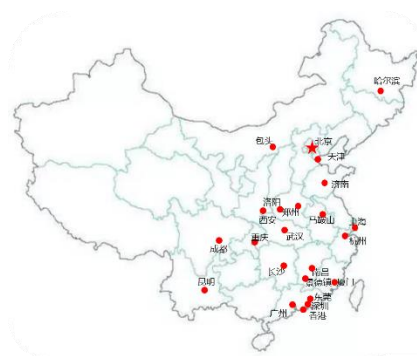


Dr. Yongwei Sun introduced the domestic and international progress of TRIZ:

- 1) The number of MATRIZ certifications has increased rapidly in China, and China has become a country where TRIZ development is growing most rapidly on global scale.
- 2) The registration and establishment of the China TRIZ Association will enhance the promotion of TRIZ in China, and will gain more degrees of freedom according to China's actual situation, thereby will become more helpful to the TRIZ promotion in China.
- 3) The TRIZ applet has been launched, including TRIZ tools such as contradiction matrix, standard inventive solutions, separation principles, library of effects, etc. There are also some learning materials for TRIZ enthusiasts to learn online on mobile phones.



- 4) After publication of TRIZ Level 1 Certification Textbooks in 2015, Level 2 Certification Textbooks will be published soon.
- 5) Conducting the International TRIZ Day celebration events. On the October 15th, the International TRIZ Day, MATRIZ China hosted TRIZ salon events in 22 cities across the country, and more than 1000 people participated in these events.





6) TRIZ introduction videos. With support of Beijing University of Technology, Dr. Sun Yongwei recorded a video of about 2 hours in the online MOOC system of the Ministry of Education for beginners without TRIZ foundation.



7) Dr. Han Kuihua, the editor-in-chief of TRIZ Review Magazine and a professor at Shandong University, introduced the status of TRIZ Review Magazine and invited to publish more contributions.



8) The International MATRIZ Conference *TRIZfest* 2019 was held in September in Germany, and the next *TRIZfest* 2020 will be held in Bangalore, India on September 9-12, 2020.

Dr. Sun Yongwei summarized that the introduction of TRIZ in China is currently at rapid development rate. After years of efforts, China has become the country with the most active use of TRIZ theory in the world. More and more companies have begun to introduce TRIZ theory to enhance their innovation capabilities and R&D levels. At present, China is in a special period. Many uncertainties concerning the international situation have brought more challenges to the development of China's technology, and the TRIZ theory can provide a strong support for dealing with these challenges at the right time. I believe that with the help of this theory, we can get rid of many restrictions, overcome difficulties, and help China's transition from a large manufacturing country to a large creative country.

The annual conference invited Dr. Jung-Hyeon Kim, TRIZ Promotion Leader, Master TRIZ (Level 5) of Samsung, who has worked for Samsung Korea for nearly 20 years. He explained the important role of TRIZ in Samsung's innovation process, in terms of growth of revenue brand value and number of patents. He introduced that Samsung Electronics promoted TRIZ step by step with the strong support of senior management,

and eventually became the most successful company in the world regarding TRIZ promotion. In more than 20 years since Samsung has introduced TRIZ, TRIZ has been playing an important role in Samsung's rapid development through many challenges. He also analyzed the application of TRIZ in Samsung with several real cases in the semiconductor chip manufacturing process. Detailed overviews of the aspects of project execution, promotion strategy, TRIZ tools, promotion activities, team building, software support, etc. were made.



Dr. Wei Chang, who had been working for General Electric in the United States for more than 20 years and currently is the CEO NICE and a DFSS (six sigma design) Master Black Belt said that at the beginning of the establishment of the institute, the advanced methodologies represented by Six Sigma and TRIZ were introduced into NICE, and were positioned as the corporate culture. After many years of hard work, they became basic skills for the majority of R&D engineers to solve technical problems. It has played an important role in promoting R&D and innovation of the institute, and it has become "the DNA of NICE." These achievements also made the NICE recognized by China domestic and foreign industry organizations. The NICE successively won the National Industrial Quality Benchmark issued by the Ministry of Industry and Information Technology, the Special Recognition Award issued by the International TRIZ Association, the 40th Anniversary Outstanding Total Quality Management Promotion Organization issued by the China Quality Association.

Dr. Sun Yongwei, the leader of the TRIZ methodology promotion of the Low Carbon Institute, also won the National Quality Technology Award, the highest award in the field of quality technology. In 2018, he was ranked as the highest level in the TRIZ field and became the first and only TRIZ master among Chinese in the world.



Ms. Chen Yan, General Secretary of China Intellectual Property Society, gave a report entitled “Application of Patent Intelligence in TRIZ Innovation”. She first expounded the relationship between patent intelligence, TRIZ, and innovation and development; and provided a detailed introduction to the decision-making counselors, innovation process navigators, innovation achievement escorts, and market competition combatants of patent intelligence in technological innovation. Finally, based on the practical case of deep integration of TRIZ and patent intelligence, the basic methods and effective approaches of the fusion of TRIZ and patent intelligence were shared.



More than 20 presentations were delivered at the conference. TRIZ experts have been researching TRIZ theory, TRIZ's promotion strategy in enterprises and universities, TRIZ and intellectual property, TRIZ's application in non-technical fields, TRIZ training for teenagers. Many TRIZ cases were reported. These reports resonated widely. Delegates expressed their opinions one after another, launched a collision of ideas, exchanged views with each other, and broadened their horizons.

Speakers	Title
Kim Jung-Hyeon	TRIZ theory application and case sharing in Samsung
Wei Chang	Advancement of Advanced Methodology in the National Energy Group's Beijing Low Carbon Clean Energy Research Institute



Chen Yan	Application of Patent Intelligence in TRIZ Innovation (Keynote Report)
Gao Guohua	Construction of innovative and innovative method curriculum system in universities
Zhang Binbin	Function-oriented search based on patent big data
Chen Yunhao	Actively exploring the TRIZ science popularization road for youth innovation
Guan Zhigang	40 invention principles 2.0 reinterpretation for non-technical personnel
Dong Zhenyu	Reform of Letters and Calls Institutions and Mechanism Innovation Based on TRIZ Theory
Han Bing	Status and Thinking of Commercial TRIZ Development
Liu Yongmou	CAI Environment-based Spring Process Innovation—Case Sharing
Long Yinhua	Using TRIZ theory to solve the problem of reduced activity of Fischer-Tropsch lubricant base oil catalysts after molding
Yan Junrong	Practice of Patent Product Evasion Based on Tailoring
Song Jian	Application of TRIZ Nine Screens in Enterprise Information System
Sun Yongwei	Patent circumvention and layout based on causal chain
Liu Demao	Design of Shortening Servo Motor Brake Length
Zhang Zonglai	Application of innovative methods in Panda Group
Ming Jinwu	Jiuyang TRIZ Road
Ji Fenglin	TRIZ takes root in Danaher
Shi Dongyan	Promotion and Application of TRIZ in Daqing Oilfield Company
Yu Na	Gree TRIZ's Promotion Strategy and Practice
Li Miao	TRIZ speeds up a process
Luo Jia	Solving tailoring problems
Yang Jie	Unmanned cleaning robot for operation and maintenance of lake ecosystem







The participating experts paid a visit NICE to study the progress of the Advanced Methodology of the NICE with TRIZ and DFSS as its core and the results achieved. They visited the science and technology corridor, learned about the application of advanced methodologies of NICE in specific R&D projects, and in the area of talent construction, learned about the NICE Advisory Board with three Nobel prize winners, as well as a dozen academicians from China and abroad guiding the direction of the low-carbon institute. It is led by 14 thousand-person plan experts (specially appointed national experts), and a team of 48% of outstanding doctoral personnel is using advanced methodologies. Before the Advanced Methodology column, they learned the TRIZ course, leadership support, strategies, results, external recognition. They really

felt the outstanding contribution of advanced methodologies to the research and development projects of NICE.



The experts also visited COMAC's Beijing Civil Aircraft Technology Research Center to learn about the state's major large aircraft projects. ARJ21, C919, C929, etc. They all were deeply impressed.



Enriched content, pragmatic cases and experience filled the two-day tight schedule. Participants reported that the content of this annual conference was very substantial and pragmatic. It greatly improved their confidence of using TRIZ to solve problems and invited to meet again in the coming year!





*Prepared by: **Dr. Sun Yongwei**, TRIZ Master (Level 5), Vice President of the International TRIZ Association (MATRIZ).*

## CALL FOR PAPERS

We invite authors to submit your manuscripts to be published in our journal.

*TRIZ Review* publishes papers on the following topics:

- Research and development of TRIZ theories and methods;
- Development of TRIZ tools for practical applications;
- Applications of TRIZ in science, engineering, business, and social environments;
- Innovation process with TRIZ;
- TRIZ-based pedagogy, education, and training;
- Case studies with TRIZ;
- Integration of TRIZ with other process, design, and innovation management methodologies.

Papers on systematic creativity, methods for automated inventing and innovation management in the dialog with TRIZ or any other topic related to TRIZ are also invited.

Deadline for submitting papers for our next issue is **July 1, 2020**.

Details and guidelines for submitting papers: <https://matriz.org/triz-review/>

### ***TRIZ Review:***

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