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Organized by the International TRIZ Association – MATRIZ

## THE 16th INTERNATIONAL CONFERENCE

# TRIZ*fest*-2021

September 15-18, 2021

# CONFERENCE PROCEEDINGS

Editor: *Valeri Souchkov*

**Proceedings of the 16th MATRIZ TRIZ*fest*-2021 International Conference**

September 15-18, 2021

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The collection of papers «Proceedings of the 16th MATRIZ TRIZ*fest*-2021 International Conference».

The conference is intended for TRIZ specialists and users: academics, engineers, inventors, innovation professionals, and teachers.

The present book of Proceedings includes 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 friends and colleagues!

This year, because of COVIS-19 pandemic we have to switch to online format with our annual international conference TRIZ*fest*-2021, which was initially planned in Odessa, Ukraine. Last year, TRIZ*fest*-2020 was canceled completely also because of COVID. I honestly believe, we will be able to meet face to face at the next conference TRIZ*fest*-2022.

2021 is a very important year for the entire TRIZ society. It is 95th anniversary of the author of TRIZ and the first president of MATRIZ Mr. Genrikh Altshuller and it is 65th anniversary of TRIZ itself. Congratulations to everyone!

As you know, a key role of the International TRIZ Association (MATRIZ) is to guide a further development of TRIZ as a theory and its proliferation worldwide. TRIZfest-2021 is a perfect platform for performing this role. A quick glance through the list of speakers and presentations planned for three days of the conference reveals the amazing diversity of topics. They range from case studies, to developing new tools, combining TRIZ with other methodologies and teaching TRIZ. It is now a good tradition that MATRIZ conferences include a special session for TRIZ Pedagogy.

In terms of numbers, we have 114 registered participants, 42 participant of the special pedagogy session, 1 candidate for TRIZ Master Certification. The total number of papers is 27.

I am grateful to the Organizing Committee of TRIZ*fest*-2021, which has made this conference, happened.

A very warm welcome to each and every one of you. I wish us every success with the 16th MATRIZ International Conference TRIZ*fest*-2021 and I look forward to learning about the outcome.

Dr. Oleg Feygenson, TRIZ Master

MATRIZ President

Dear TRIZ*fest*-2021 Participants and Readers,

It is a pleasure to present the papers from the 16th International Conference "TRIZ*fest*-2021" which was held on September 15-18, 2021. Due to pandemic, it was decided to conduct the conference online.

This year the conference includes papers and presentations focused on the following topics:

- Theoretical, research results.
- TRIZ-related methods and tools development.
- Best practices, business experiences, integration with non-TRIZ methods/tools.
- TRIZ-Pedagogy
- Educational methods and experiences.
- Case studies.

TRIZ*fest*-2021 continued its special section "TRIZ-Pedagogy" and included discussions on several important topics regarding TRIZ and its applications.

We would like to thank all the authors and co-authors who contributed their works to include to these Proceedings and therefore provided considerable impact on further development of TRIZ and its dissemination around the world.

We would like to express our sincere gratitude to all the members of the TRIZ*fest*-2021 Organizing Committee who provided their help and support as well as to the members of the Papers Review Committee who invested their precious time to select the best papers and provide authors with comments how to improve their papers.

And at last but not least, we would like to express our thanks to all the participants of the conference from many countries who contributed to the event by their engagement and their sometime provoking questions to the speakers.

Valeri Souchkov, TRIZ Master

Co-Chair of the TRIZ*fest*-2021 Program Committee

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# CONFERENCE PAPERS

TRIZ*fest*-2021

# A CASE STUDY OF ENTERPRISE PRODUCT RESEARCH AND DEVELOPMENT BASED ON CUSTOMER DEMAND

Yan Zhao, Alp Lin, Dongshuang Xu

Beijing IWINTALL Technology Co., Ltd, China

## Abstract

This paper will elaborate the importance of demand for product R&D from the demand side, and strive to establish a demand-based R&D process of enterprise products and then verify, practice and improve it. In order to adapt to the changing society, enterprises should move from product-oriented to demand-oriented, and guide enterprise products R&D through demand. First, correctly grasp the market demand by collecting, mining, standardizing user demands and converting them to product functions. Second, conduct efficient system retrieval of function through system definition and function analysis, find a better way to map the function to structure, and optimize, evaluate and select the solution with high performance, simple structure and low cost. Finally, transform the solution into the final product through design, simulation, validation and production so that enterprises are able to obtain greater market share faced with the changing demands and achieve sustain innovation and profits.

Key words: *demand, function analysis, product R&D process*

## 1 Correctly Grasp the Market Demand

The value and mission of an enterprise is to "satisfy customer demands". Unclear needs will lead to failures in new product development of a company and the product design has to be constantly changing with low efficiency.

Product demands come from the market and from users. User demands are aimed at people, describing the problems that users encounter or the desires they want to satisfy. Every need should be necessary, and every need has a corresponding cost. Unnecessary requirements will bring unnecessary risks. In-depth and detailed analysis of customer needs is the basis for product R&D. User needs should be clustered with a standardized description and a demand glossary. We need to map the demand to function through research, clarification, standardization, classification, synthesis, verification, confirmation and ranking to lay a foundation for further development of products.

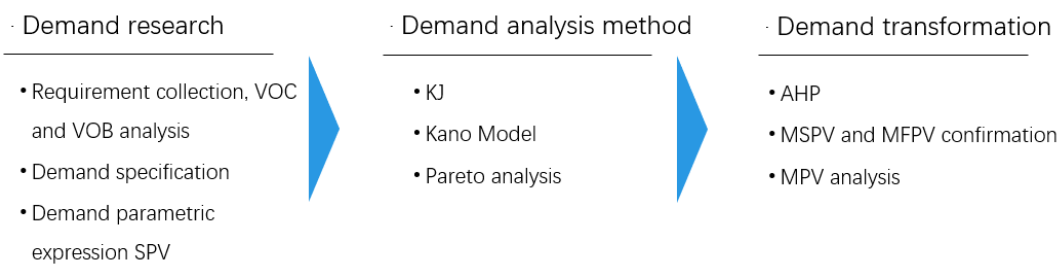


Fig.1. The steps of demand analysis

## 1.1 Demand Research

Demands come from VOC (Voice of Customer). It focuses on the needs of users and clients, upstream and downstream of the industrial chain, competitors and stakeholders. VOB (Voice of Business) focuses on a series of requirements such as corporate strategy, production operation and maintenance, profit and loss analysis, product quality inspection reports, core technology, new product development, and advanced technology pre-research. VOB provides standardized description and parameterized expression of demands.

## 1.2 Demand Analysis

Commonly used demand analysis methods such as affinity graph, Kano analysis, Pareto analysis help us sort out the demands obtained from VOC and VOB. KJ method clusters the demands, KANO model prioritizes and Pareto analysis ranks them.

## 1.3 Demand Transformation

Transform the MSPVs (Main Strategic Parameter of Value) which customers want to the MFPVs (Main Functional Parameter of Value) that engineers focus on through MPV analysis(Main Parameter of Value).

| weak△ | moderate○ | strong◎ | MPV analysis | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 9 | MFPV1 | MFPV2 | MFPV3 | MFPV4 | MFPV5 | weight | total value | rank |
| MSPV1 | | | ◎ | ○ | | ○ | △ | 9 | 144 | 2 |
| MSPV2 | | | △ | ○ | ○ | ○ | △ | 7 | 77 | 5 |
| MSPV3 | | | ○ | △ | ○ | ◎ | ○ | 5 | 95 | 3 |
| MSPV4 | | | ○ | ◎ | | ○ | ○ | 5 | 90 | 4 |
| MSPV5 | | | ○ | ○ | ○ | △ | ◎ | 9 | 171 | 1 |
| MSPV6 | | | ◎ | △ | ○ | | △ | 5 | 70 | 6 |
| total value | | | 190 | 130 | 78 | 117 | 132 | | | |
| rank | | | 1 | 3 | 5 | 4 | 2 | | | |

Fig. 2. MPV analysis

1. The rank of MSPV describes the ability of the actual product to meet customer needs;
   The total value of each MSPV represents the degree of support of all the MFPVs to the MSPV。
2. The rank of MFPV means whether a certain function provided by the actual product is necessary to meet customer needs;
   The total value of each MFPV represents the degree of support of all the MSPVs to the MFPV.

## 2 Systematically Design Product Function

Systematic thinking is important for us to analyze problems. Systematic method is used to analyze the general mode, structure and law of the system, which is our worldview and methodology for understanding a system. Systematic methods, principles, and tools will guide us when we face the needs of customers and explore the means of realization.

Product function design is a method of designing the principle, function and structure of the product from the perspective of function and the height of the system. It converts demands to functions and then functions to structure, and optimizes the product structure and design.

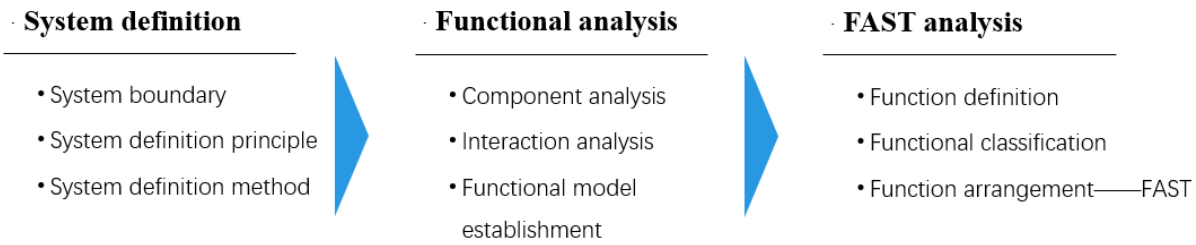


Fig. 3. The steps of product function design

### 2.1 System Definition

Defining the boundary of system is the prerequisite to analyze system functions and serves as a bridge between requirements and functions.

System definition determines the boundary of the system. It is necessary to clarify the function, working principle, and structural feature of the system to be realized internally, and understand the influence and constraints imposed by the super system and the environment externally.

The principles of system definition: demand principle; independence principle; space and time principle; controllability principle.

The methods of system definition: demand-based; function-based; problem-based; process-based; production process-based; system object-based.

### 2.2 Component Function Analysis

Function analysis is to clarify the relationship among the main functions, basic functions, auxiliary functions and additional functions of the technical system to better find out problems. Optimizing the functions and reducing the consumption of implementing functions enables the technical system to obtain greater value with small cost and improve the system.

The steps of functional analysis are as follows: 1. Component analysis; 2. Interaction analysis; 3. Functional model Establishment.

### 2.3 FAST

FAST(Function Analysis System Technique) is a powerful graphical tool for analyzing the interaction relationship between functions. It reflects what kind of the design concept used to meet users needs.

The steps of function analysis: 1. function definition; 2. function classification; 3. function arrangement.

We decompose functions until there is a specific structure to realize the function. FOS(Function Oriented Search) helps us to find more structures to achieve the function, and morphological matrix combines the solutions for further evaluation and decision-making.

## 3 Scientific Evaluation of the Product Plan

There are many factors involved when choosing a plan, including those at demand level, function level and design level. Various constraints should also be considered such as the reliability of technology, the manufacturability of production, the acceptability of market, the constraint of cost, the achievement of profit, the control of risk and so on. Therefore, the evaluation of product plan must be scientific, standardized, reasonable.

Based on the criteria of novelty, value, and feasibility, compare the generated plans, formulate evaluation criteria, select a few better ideas through analysis and comparison, and then further concretize the concepts and finally select the best one.

1. List all the concepts to be evaluated;
2. Build evaluation model, demtermine relevant user demands or standards, and set weights for each demand;
3. Organize experts to evaluate, better to have specilized experts in every process of the product life cycle;
4. Assign experts weights;
5. Apply PUGH analysis;
6. Determine product development plan.

A very important indicator in the evaluation is the fulfillment of demand. A successful product should be a product that has a market, can be produced, and yields good benefits. The organic combination of market, business, and financial effects constitutes the three-dimensional constraints of product development and the vector model of product evaluation. It comprehensively reflects the production and management effect of the product, and evaluates the optimal plan.

## 4. Demand-based Product R&D Process

Through the above three stages of analysis, summary and conclusion, try to put forward the demand-based product research and development process, and apply it to enterprise practice for substantiation and constant improvement.

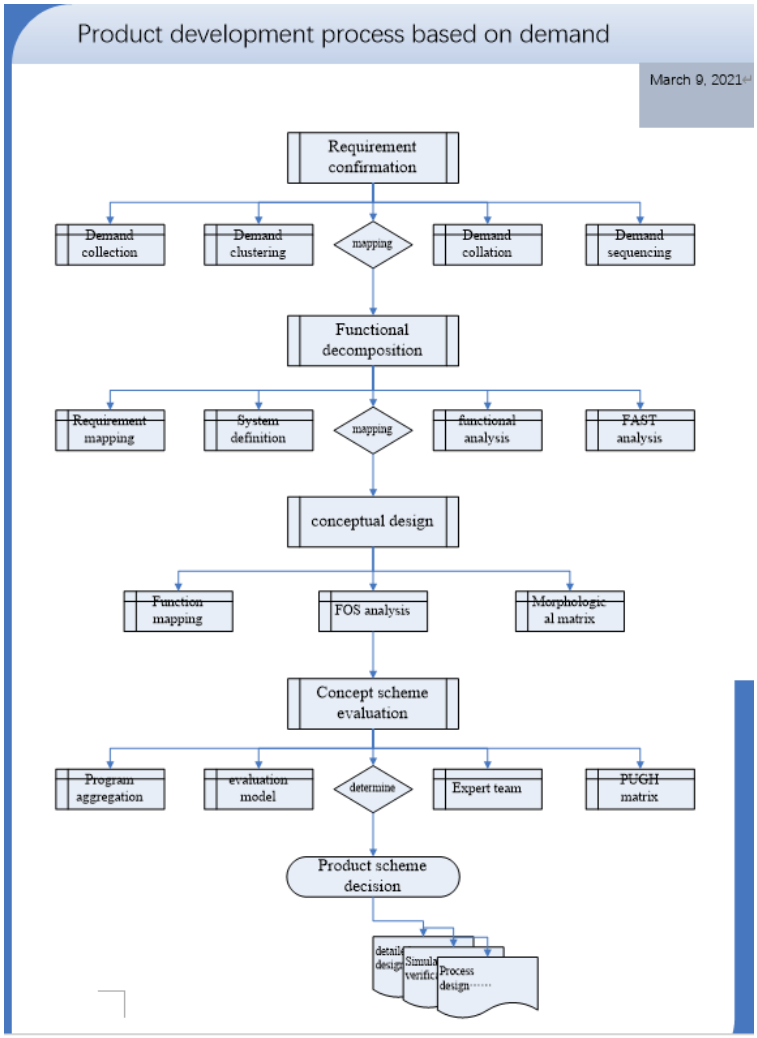


Fig. 4. Product development process based on demand

## 5. Case of Demand-based Product Development

To Improve the Reliability of alarm mechanism of the laser level

XX Company

Product introduction: laser levels are widely used in horizontal and vertical indication in home decoration with high precision and easy operation. In recent years, the company has cooperated with client A, B, C, etc. in a number of OEM (Original Equipment Manufacturer) products. The product has sold X0,000 units for three consecutive years.

Problem Description: bad alarm system directly influences user experience and takes tens of thousands of dollars every year, which has always brought trouble to production work. Engineers have used many methods to solve it, such as wiping it with ethanol, changing alarming gaskets or springs. However, the problem still remained and they had to rework all the time due to the lack of deep understanding of the cause. There was no fundamental solution to the problem.

1. Demand Confirmation

1. 1 VOC and VOB analysis

VOC:

Customer demand: to improve the reliability of the alarm function and improve its accuracy and performance;

Market feedback: the product repair rate is increased and users complain;

Competitors: high quality, low repair rate, more expensive;

Business and trade department demand: to improve performance as soon as possible, improve the quality rate, and meet customers' needs.

VOB:

Demand of the work site: to improve performance and reduce rework.;

Demand of quality inspection department: to improve performance and product quality;

Financial statement: huge economic losses and in particular reputation damaged.

1. 2 SPV Analysis

To standardize the description of demands and determine SPV.

SPV1: aesthetics (color and shape); SPV2: portability (volume and weight); SPV3: light intensity and clarity (light shape); SPV4: horizon and vertical, angle = 90 degrees; SPV5: measurement accuracy; SPV6: convenience of users' operation (simplicity, ease of use); SPV7: accurate and timely alarm (reliability of information); SPV8: power consumption (energy consumption); SPV9: laser damage to eyes (harmful factors); SPV10: case tightness; SPV11: structural strength of case; SPV12: the convenience of work site operation; SPV13: to reduce the rework rate (improve production efficiency).

1. 3 Common Demand Analysis

According to the rework data, the quality rate in the production site is **86.5%**.

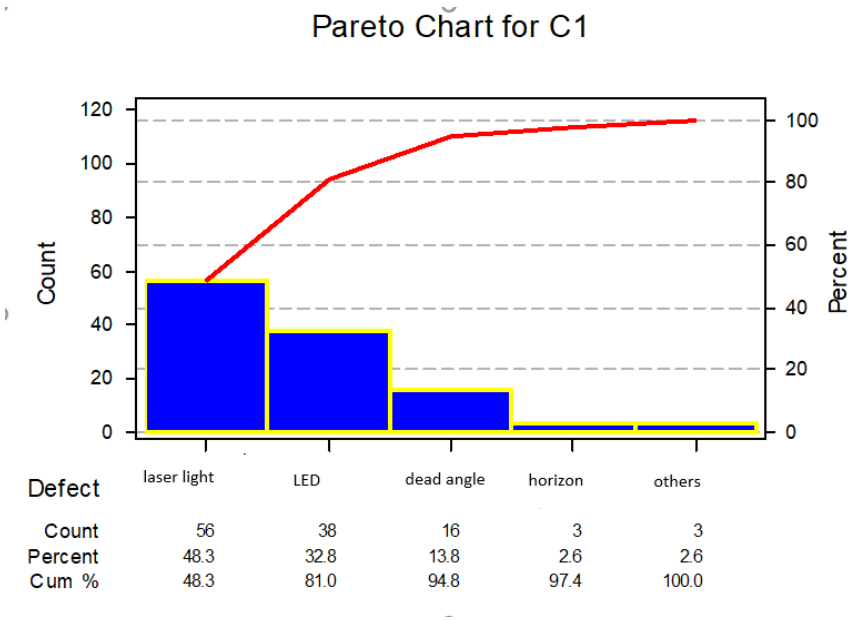


Fig. 5. Reasons for rework in production site

Fig. 6. Client inspection and Internal quality audit

1. Using KJ method to cluster demand and determine MSPV
2.

| MSPV | Potential MSPV | SPV |
|---|---|---|
| Light shape | Aesthetics | Laser color |
| | | Laser shape |
| | Laser shape | Laser intensity |
| | | Laser definition |
| Convenience | portability | Weight of line laser |
| | | Volumn of line laser |
| | structure characteristics | shell tightness |
| | | Shell structure strength |
| Alarm reliability | Alarm reachability | Alarm accuracy |
| | | Alarm timeliness |
| | Reliability of information | Information visualization |
| | | information audibility |
| | production efficiency | Rework rate |
| energy consumption | energy conservation mode | Electricity consumption |
| | | rechargeable |
| measurement accuracy | Measurement reliability | Laser level adjustment |
| | | Laser angle adjustment |
| | The operation is simple | Operation convenience |
| other | | Appearance design |
| | | Laser harmfulness |

Fig. 7. MSPV analysis

3. Weight Assignment of MSPV with AHP

| | | | | | | numerical value | % | weight |
|---|---|---|---|---|---|---|---|---|
| energy consumption | A | B | C | D | E | 0 | 0 | 1 |
| Light shape | B | B | B | D | B/E | 2.5 | 25% | 7 |
| Portability | C | | C | D | E | 1 | 10% | 5 |
| Alarm reliability | D | | | D | D | 4 | 40% | 9 |
| measurement accuracy | E | | | | E | 2.5 | 25% | 7 |
| total | | | | | | 10 | | |

Fig. 8. MSPV weight assignment

4. Describing the function from demand and determining MFPV related to the implementation of MSPV

MFPV1: controlling laser projection precision – precision control

MFPV2: flexibility and reliability of pendulum -- pendulum

MFPV3: accuracy and quality of laser – laser emission

MFPV4: adjusting the horizontal reference of the laser level to ensure that it meets the working conditions – horizontal adjustment

MFPV5: contact reliability of alarm trigger -- feedback (contact and disconnection reliability)

MFPV6: reliability of case protection – to block pollutants and dissipating heat

4 Demand Transformation

Demands and functions are closely linked. Demands should be collected and confirmed from the market and customers and be achieved at technological and manufacturing level. We should identify the demands that must be met, the functions that must be implemented and the problems that must be solved.

| weak o | moderateΘ | strong • | MPV analysis | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 9 | Control precision | Pendulum | Laser emission | Debugging level | Contact yield | Shell tightness | Weight | Total value | Rank |
| Energy consumption | | | Θ | o | • | o | o | o | 3 | 48 | 5 |
| Light shape | | | Θ | Θ | • | Θ | • | o | 7 | 175 | 3 |
| Portability | | | o | Θ | o | o | o | • | 5 | 80 | 4 |
| Alarm reliability | | | Θ | • | Θ | o | • | Θ | 9 | 252 | 1 |
| Measurement accuracy | | | Θ | • | Θ | Θ | • | o | 7 | 196 | 2 |
| Total value | | | 83 | 183 | 124 | 59 | 215 | 89 | | | |
| Rank | | | 5 | 2 | 3 | 6 | 1 | 4 | | | |

Fig. 9. MPV analysis

5 Demand Evaluation

Alarm reliability is what enterprises and customers focus on and needs to be improved. When this demand is mapped to MFPV, it is necessary to realize the improvement of contact yield. The touch and leave function should be fully reliable and the gravity pendulum should be flexible and controllable. The case tightness should be improved. All of these are the functional problems that engineers have to solve.

2 System Method of Product Function Design

2. 1 System Definition

The problem-based system definition aims at studying the bad alarm performance by putting it into the laser level system in order to obtain more resources to solve it.

The operation principle of the laser level: two lasers are used to mark the horizontal and vertical lines. The suspended pendulum is balanced by gravity. The magnetoelectric induction is used to stop damping, and the voltage changes when the spring and the induction coil contact to alarm.

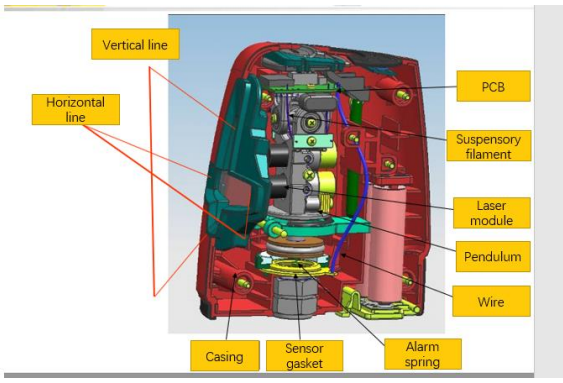


Fig. 10. Laser level's components

Problem Description: when the machine is placed on the table with an inclination of over 5 degrees, the pendulum is always vertical due to gravity and the alarm spring contacts with the sensor gasket. And the voltage added to the pendulum changes from 3V to 0V. The MCU in the PCB receives the signal and controls the laser to go out.

Problem: when the machine is over tilted, it should alarm and the light should go out but it does not, the precision of the light exceeds the standard, and the quality rate is only 87.5%.

1.2 Function Analysis

The steps of function analysis: 1. Component analysis; 2. Interaction analysis; 3. Function modeling.

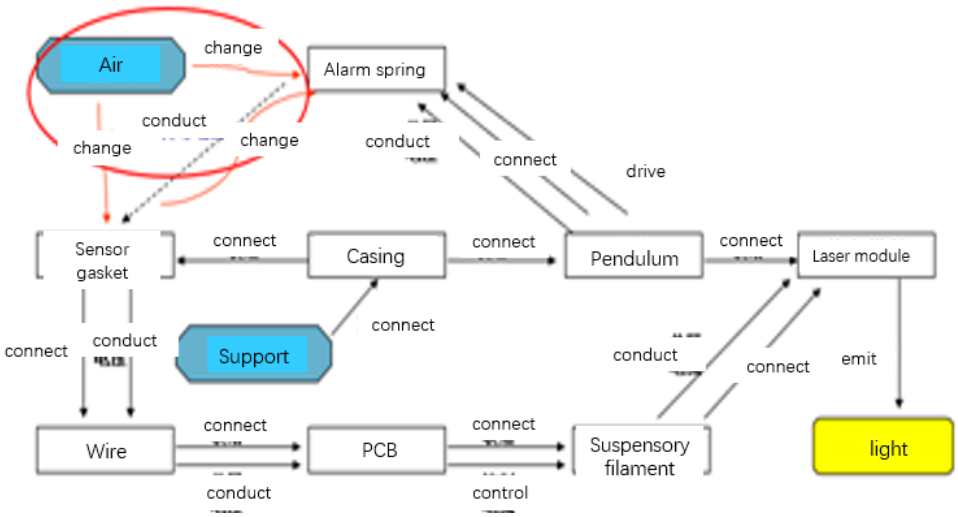


Fig. 11. Function model

To identify the functional defects:

Harmful functions in the system: the air changes (oxidizes) the sensor gasket and the alarm spring, and the sensor gasket changes (extrudes) the alarm spring;

Useful but insufficient functions: the function of conducting current of the alarm spring to sensor gasket is insufficient;

Insufficient functions in the system: lack of effective measure device for swing angle of the pendulum.

2. 3 FAST—Function Analysis System Technology

Based on the overall target function, we should think and design the product structure or system structure that can realize the function and seek the optimal solution.

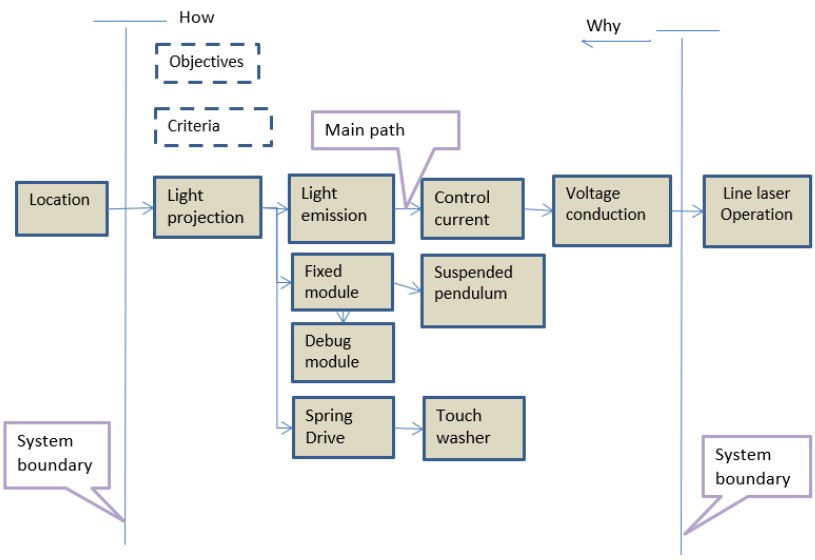


Fig. 12. FAST model

2. 4 Function-oriented Research

According to the previous process of functional analysis, we should clearly define the functional problems and search for the corresponding principles, effects, structures and methods, and put forward specific solutions.

Plan 1: To add a level base between the machine and the table.

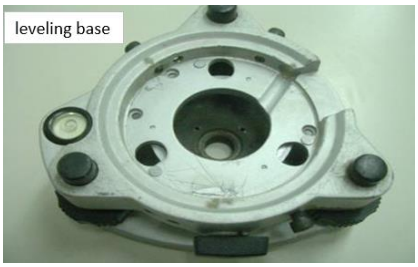


Fig. 13. Plan 1

Plan 2: To improve its electrical conductivity by plating pure gold rather than imitation gold on the sensor gasket and alarm spring.

Plan 3: The photoelectric switch emits and receives the light signal. The pendulum swings over 5 degrees. The reflective paper deviates from the photoelectric switch and the photoelectric switch cannot receive the signal reflected by the reflective paper, and then the system alarms.

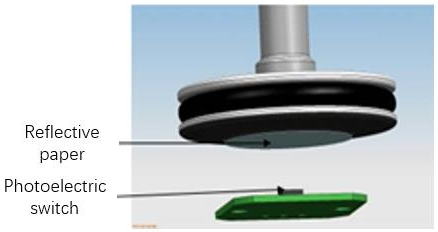


Fig. 14. Plan 3

Plan 4: To replace the aluminum alloy on the pendulum with purple copper to increase the weight of the pendulum and solve the problem of low pressure. The number of spring coils can be increased to improve the compressive resistance of the spring.

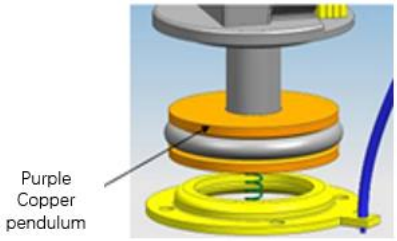


Fig. 15. Plan 4

Plan 5: To make a lot of small bumps on the inner surface where the sensor gasket and the spring contact to increase the pressure. At the same time, the diameter of the spring wire can be increased to improve its compression capacity.

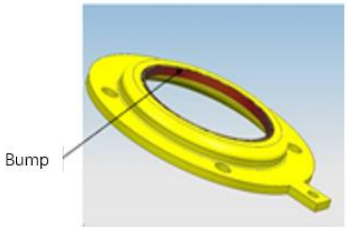


Fig. 16. Plan 5

Plan 6: To Introduce gas pendulum sensor SX into pendulum S2.

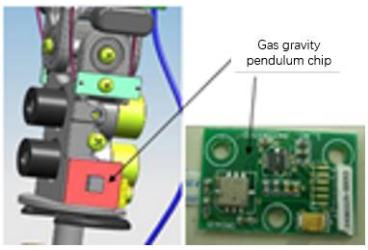


Fig. 17. Plan 6

Plan 7: To combine the induction washer and current into a capacitor.

2. 5 Morphological Matrix

Based on the function decomposition of the laser level, we should explore a better way to realize the function.

| Functional element | Standard structure | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| light source | laser | infrared | | | | |
| Control current | Touch structure | | | Non touching structure | | |
| Contact switch | Gold plating | Copper pendulum | Convex point and rib | Light sensitive switch | Capacitor chip | Gas pendulum |
| Debugging mode | Horizontal base | Module screw | | | | |
| Power Supply | Battery | rechargeable battery | | | | |

Fig. 18. Morphological Matrix of laser level's functions

The number of permutation plans is 2 × 2 × 6 × 2 × 2 = 96.

3. Scientific Evaluation of the Product Plan

3.1 Evaluation Model Establishment

| Evaluation | symbol | parameter | unit | influence | weight |
|---|---|---|---|---|---|
| | L | light accuracy | point | positive | 20 |
| | S | system reliability | point | positive | 20 |
| | M | Manufacturability | point | positive | 15 |
| | E | ease of use | point | positive | 15 |
| | C | cost | yuan | negative | -30 |

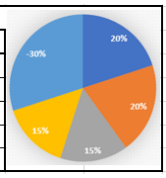


Fig. 19. Evaluation model

3.2 Plan Collection and Evaluation

| | Plan | cost, (yuan) | accuracy | reliability | Convenience | Manufacturability | Evaluation |
|---|---|---|---|---|---|---|---|
| 1 | Plan 3: to introduce a photoelectric switch | 2元 | 10 | 10 | 10 | 8 | 100 |
| 2 | Plan 7: to combine a capacitor | 2元 | 10 | 10 | 10 | 5 | 92 |
| 3 | Plan 6: to introduce gas pendulum sensor | 15元 | 10 | 10 | 10 | 3 | 57 |
| 4 | Plan 2: to plate pure gold | 4元 | 5 | 5 | 5 | 5 | 46 |
| 5 | Plan 4: to use purple copper | 6元 | 7 | 5 | 5 | 3 | 42 |
| 6 | Plan 5: to make small bumps | 4元 | 5 | 5 | 5 | 3 | 40 |
| 7 | Plan 1: to add a level base | 20元 | 5 | 5 | 3 | 3 | 0 |

Fig. 20. Plan evaluation

Finally, the best plan is the alarm system with photoelectric sensor and reflective paper.

3.3 Experimental Verification

According to plan 3, the first experiment with 30 prototypes was carried out, and there was not any alarm defect.

| | Total | Underperformance | Quality rate |
|---|---|---|---|
| Day 1 | 30 | 0 | 100% |
| Day 2 | 30 | 0 | 100% |
| Day 3 | 30 | 0 | 100% |
| Day 4 | 30 | 0 | 100% |
| **Total** | 120 | 0 | 100% |

Fig. 21. Experimental verification of quality rate

Current sigma level: short term: 3.89; long term: 2.3954

Plan 7 (inductive gasket capacitive alarm system):

The patent application was approved to submit now and has been being written.

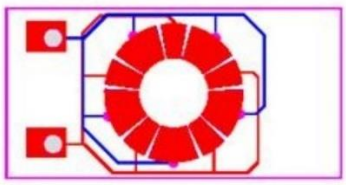

Fig. 22. Plan 7

Plan 6 (alarm system with the angle chip):

No prior patent for the application of electronic angle module in the vertical crosslaser level under gravity can be found, so the plan is patentable. At present, the patent application has been approved to submit, and the patent is in the process of application.

**Financial Income Accounting**

Total investment: 4400 yuan

Estimated total revenue: 22910 yuan

Actual net income: 18510 yuan

Project review:

1. Restoring the confidence of internal and external customers and increasing the purchasing power of external customers;
2. Bringing a good reputation to the company.

## 6. Conclusion

Through the analysis of the above case, we have clarified the development direction and process of a new product. On one hand, we should carry out positive design based on customer needs. On the other hand, we need to analyze the functions of the existing product, seek functional alternatives, and form new products.

The demand-based product R&D process is still in the exploratory stage. Different products, technologies, market environments and enterprise backgrounds have different demands for the process. Although this process has been preliminarily confirmed in the later two enterprise projects, it still needs to be continuously improved, modified and optimized. The social responsibility for future enterprise development sets a higher goal for demand. Demand is the source and the product is the fruit.

## 7. Acknowledgement

Thanks to Nanjing company for its strong support and cooperation in the implementation of the project, the engineers of the project team for their hard work and data collection in the later stage, and Dr. Lin Yue for his wonderful guidance on theory, method and application, which make the project a success.

## References

1. Zhao Min, Shi Xiaoling, Duan Haibo. TRIZ Introduction and Practice [M]. Beijing: Science and Technology Press, 2009:
2. Sun Yongwei, edited by Sergei Ikovenko. TRIZ: The Golden Key to Innovation I [M]. Beijing: Science and Technology Press, 2015:
3. Kevin n. Otto, Kristin L. Wood. Product Design [M]. Beijing: Electronic Industry Press, 2017:
4. Yuri Salamatov. How to be An Inventor: Learning to Create in 50 Hours [M]. Beijing: Beijing University of Technology Press, 2006:
5. Cao Fuquan. Overview of Innovative Thinking and Methods[M]. Harbin: Heilongjiang Education Press, 2009:
6. Lin Yue, Yang Chuanfeng, Cao Lihua. Efficient Innovation - Manual of TRIZ Innovation for Skilled Workers [M]. Beijing: China workers publishing house, 2020:
7. Sergei Ikovenko. The Art of TRIZ, Theory of Inventive Problem Solving[M]. Qinhuangdao: Yanshan University Press, 2020.7. (Russia)

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TRIZ*fest*-2021

# APPLICATION OF TRIZ IN DESIGNING A SIMPLE MONITORING DEVICE FOR CHECKING ELECTRICAL GROUNDING CONNECTIONS

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## Abstract

Grounding is an effective solution to guarantee the safety of the electrical system. Good grounding provides both safety of personnel and protection of plants and equipment. However, electrical devices sometimes lose their grounding connections for several reasons. The real problem is people especially domestic users often cannot systematically recognize whether a specific device has suitable grounding connections or not. This paper aims to exploit TRIZ theory in order to seek and produce some solutions for solving this problem.

Keywords: *TRIZ, Electrical grounding, binding and connections, ground monitoring*

## 1 Project

From the beginning, the use of electricity has presented copious challenges ranging from how to generate the energy appropriately to how to install a safe electrical system so that people can enjoy the power without difficulty. Grounding is an effective solution to guarantee the safety of the electrical system. The NEC, National Electrical Code describes a ground as: "a conducting connection, whether intentional or accidental between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth."[1]. in essence, in a grounded system, when a phase contacts to the body of an electrical device the grounding systems could transfer the current from the body to transformer via solid earth. Solid earth or general mass of earth is part of earth, beneath the upper level of the ground, that the potential of each point of it is zero. Therefore, it can transfer the current such as a cable[2].

Good grounding provides both safety of personnel and protection of plants and equipment[3]. Figure1 Demonstrates a grounded device and an earthing system. After the creation of a fault, grounding system can establish a passage for the fault to flow. Accordingly, the protective devices on the path could detect the fault easily. Besides, touching an appropriately grounded device is safe even if a fault has electrified the device's body[4]. Accordingly, ungrounded or even bad grounded electrical devices are not safe. Moreover, electrical devices sometimes lose their grounding connections. Generally speaking, Sometimes, people receive an electrical shock while they are touching bodies of electrical devices such as refrigerators or washing machines[2]. The shock is a sign of two different problems in the system. First of all, the grounding

connections do not work accurately. Second, there is a fault in the device that enables the body's device to be electrified[2].

Being ungrounded could be raised for several reasons, from loose grounding connections at the equipment to corrosion of copper ground bars in the earth due to environmental conditions or even copper ground theft[5]. If a device has lost its grounding connections, neither its electrical faults would be detectable, nor it is safe enough to be touched (figure 2). One of the acute problems in grounding concepts namely in specific devices used in homes such as refrigerator or washing machine is that people cannot timely recognize when their devices have lost its grounding connections so that they will repair the grounding rapidly[2].

This paper aims to exploit TRIZ to seek and produce some solutions for creating a system in which consumers could be aware of the grounding conditions of their devices so that if the grounding does not work correctly, they could repair it as soon as possible.

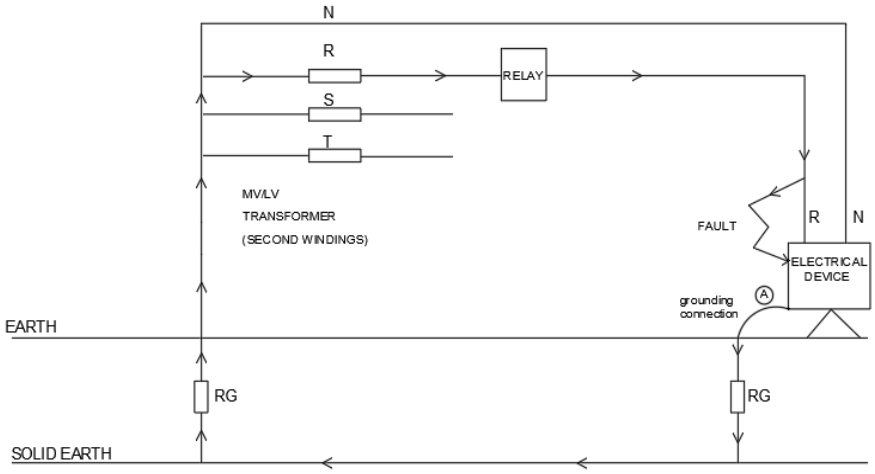


Figure 1. a grounded device and earthing system during a fault

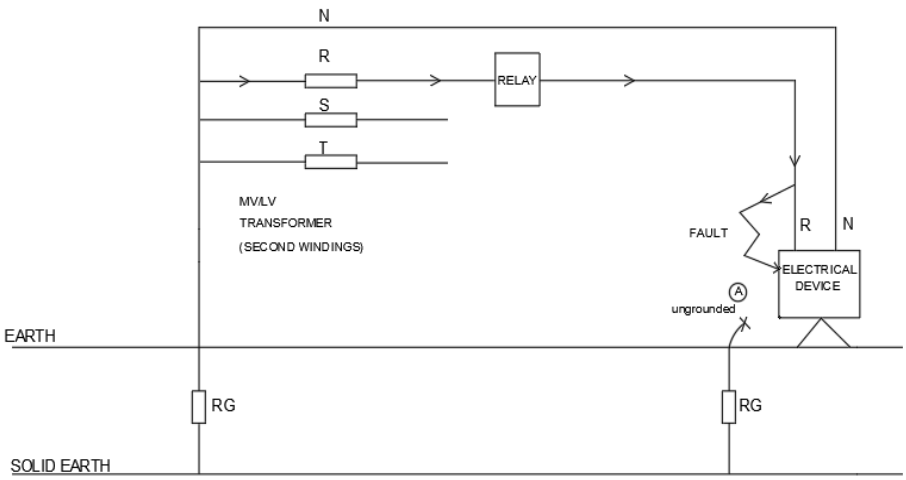


Figure 2. ungrounded device

# 2 TRIZ relation

TRIZ is a systematic way of thinking for solving problems[6]. It is a set of tools, principles, algorithms and strategies developed by years of research and studies over millions of innovations. This knowledge-based systematic methodology of inventive problem solving was introduced by Genrich Altshuller and his colleagues in 1946 in the former USSR at first. Then it became widespread in the scientific concepts in the world[7]. In this methodology, Researchers by scrutinizing the wide variety of innovations such as patents elicit their conventional principles which play a key role in their innovations. Next, they employ these principles in developing other systems via especial distinctive tools. This process is also called structured innovation.

For solving the problem by TRIZ in this paper. First of all, the problem will be defined. Then, we will create an interaction matrix. The functional analysis will be performed in the next step. Then, the contradiction will be diagnosed. The final step will be exploiting TRIZ principles to creating ideas for solving the problem.

## 2.1 The problem definition

People cannot timely recognize when their devices have lost their grounding connections to repair the grounding rapidly.

## 2.2 Idea final result

The ideal final result (IFR) of this problem is designing a system that people could timely find out when the grounding's connections has been lost.

## 2.3 Interaction matrix

An interaction matrix eases producing a functional model. In this section, the system's physical components interacting have been chosen in Table1. Then, the elements that have physical contact with each other and are in the same hierarchical level (system's level) have been marked. (see table 2)[8].

Table 1. components of the system

| *ELEMENT* | *HIERARCHICAL LEVEL* |
|---|---|
| POWER SYSTEM | SUPER SYSTEM |
| PHASE | SYSTEM |
| NEUTRAL | SYSTEM |
| GROUND | SYSTEM |
| ELECTRICAL DEVICE | SUPERSYSTEM |
| DEVICE'S BODY | SYSTEM |
| ENGINE | SYSTEM |
| HUMAN | SUPERSYSTEM |
| HUMAN'S PART | SYSTEM |

Table 2- interaction matrix

| | PHASE | NEUTRAL | GROUND | DEVICE'S BODY | ENGINE | HUMAN'S PART |
|---|---|---|---|---|---|---|
| PHASE | | | | | ✓ | |
| NEUTRAL | | | | | ✓ | |
| GROUND | | | | ✓ | | |
| DEVICE'S BODY | | | ✓ | | ✓ | ✓ |
| ENGINE | ✓ | ✓ | | ✓ | | |
| HUMAN'S PART | | | | ✓ | | |

## 2.4 Functional model

The functional analysis can vividly indicate why problems are occurring in the system. The functional analysis has been generated by exploiting interaction matrix. Four types of relationships, including useful, insufficient, excessive, and harmful interactions, have been considered for generating the model. Figure 3 demonstrates functional analysis.

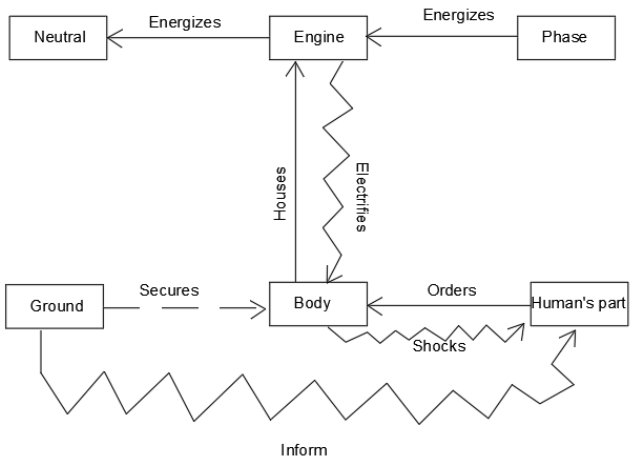


Figure 3. functional analysis

## 2.5 Contradiction

According to functional analysis, the contradiction can be defined as this way:

"We want the grounding system to be informative for users because the users should be aware when the grounding does not work, And the ground system's condition cannot be informative for users since neither are users able to constantly monitor the system's situation, nor the system has some kind of self-awareness about its situation to inform users about malfunctions."

Thus, the system should inform people about its malfunctions, while it cannot do it since the grounding system cannot monitor itself. To put it differently, if the system is forced to inform users, it would have severe difficulties in detecting and monitoring itself.

## 2.6 Features and solutions

According to 39 features of the contradiction matrix, the system will be more reliable if it can inform misconnections. However, measuring and detecting the troubles is extremely difficult. Thus, feature number 27 (reliability) will be improved, whereas feature number 37 (difficulty of detecting and measuring) will be worsened. According to the contradiction matrix following specific principles can ease the contradiction:

### 2.6.1 Principle 27: cheap disposable

Replace an expensive object with multiple inexpensive objects, compromising certain qualities.

Solutions:

No idea was considered

### 2.6.2 Principle 40: composite material

Change from uniform to composite (multiple) materials and systems.

Solutions:

No idea was detected

### 2.6.3 Principle 28: mechanical interaction substitution

Replace a mechanical method with a sensory method

Solution of principle:

Checking grounding connections, electricians usually exploit two mechanical methods. First of all, they can exploit a simple circuit and put one side on the phase outlet and the other in the ground port. If the circuit has a flow of current, it seems the grounding system is working correctly. Otherwise, there are not any appropriate grounding connections. Figure 4 displays a simple light bulb used to examine the grounding connection. Second, they can use a multimeter to check the grounding. They can regard the voltage or impedance of the system to be aware of the suitability of the ground loop (figure5)[9].

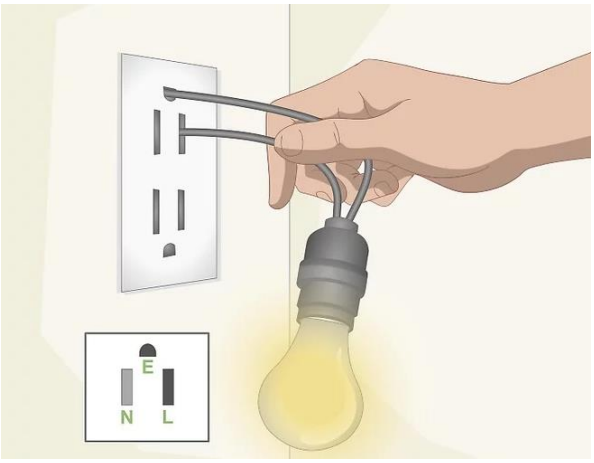


Figure 5. using lightbulb for checking the ground[9]

Figure 6. using multimeter to check the ground[9]

If it is going to replace a mechanical method with a sensory approach, we can exploit some microcontrollers to constantly scan the voltage or impedance of the ground system to be aware of malfunctioning whenever it happens. For instance, we can design a specific multimeter for checking the ground of a refrigerator. The multimeter is connected to both the phase voltage of the fridge and the ground connection. Therefore, if the voltage or impedance changes, it can warn immediately.

#### 2.6.3.1 The difficulty of the solution

Although designing a multimeter to monitor the ground conditions constantly can solve the problem, there is no need for permanent monitoring. According to principle 19 (periodic action), system scanning can be performed in particular regular times. The multimeter can send a pulse of voltage to the grounding system and look after the extent of the current. Consequently, it can calculate the impedance of the system. If there is an inconsistency in the calculated impedances (impedances shifts), it can alarm users.

#### 2.6.3.2 The solution of the problem

Accordingly, with aid of micro controllers we can design a device that sense the current and voltage and calculate the impedance of the system. In other words, the microcontroller will be

sending a pulse at a specific time from phase and receiving its feedback from the ground passage. Then, they will calculate the impedance to be sure that the grounding system is working accurately.

## 2.7 Modifying the solution

Although the proposed Solution can clear up the problem, there are some issues to be considered. Having microcontrollers and cabling procedures, the device is not too economical in order to be used in domestic devices. It is not advisable that every household exert an apparatus for every casual device such as refrigerators and washing machines. Accordingly, a new contradiction can be defined in the following form:

"We want use the apparatus to ease the measuring, and we do not want to use this device since it is way complicated and expensive."

Thus, the apparatus can ease the measuring. However, this is too complicated (expensive) to be used in non-industrial non-sensitive applications; accordingly, feature number 37 (measuring and detecting difficulty) is improving whereases it is too complicated to be used in a home. That is to say, feature number 36 (device complexity) is deteriorating. According to TRIZ matrix following principles can cure the contradiction:

### 2.7.1 Principle 12: Equipotentiality

Change operating conditions to eliminate the need to work against the potential field.

Solutions:

Nothing was detected

### 2.7.2 Principle 40: composite material

Change from uniform to composite (multiple) materials and systems.

A hint of a solutions:

In the previous solution, phase and ground were being exploiting. If the neutral is added to these two factors, we will move to more composite solution.

### 2.7.3 Principle 17: dimensionality change

Move from an object in two- or three-dimensional space. Use a multi-story arrangement of objects instead of single-story management. Tilt or oriented the object. Lay it on its side use its other side.

A hint of Solution:

The previous Solution was exploiting comparing the impedances to recognize faults in the system. Impedance is calculated from voltage and current. As a result, if the purpose is simplifying the apparatus, then, one dimension (only current or voltage) could be compared instead of considering two dimensions.

### 2.7.4 Principle 26: copying

instead of an unavailable expensive object, use similar inexpensive copies. Replace an object, system, or process with optical copies.

A hint of Solution:

The components of the first solution will be cables, wires, microcontrollers, monitors, ETC. Micro controllers' function is processing voltages and currents extends. Thus, we have to exploit something inexpensive to calculate these subjects instead of microcontrollers.

### 2.7.5 Solution

According to principles, a simple apparatus for comparing voltage or current should be considered. Actually, Op-amps are incredible, simple elements to comparing signals. Figure 7 Demonstrates a circuit with op-amps, called a feedback circuit. According to relationship 1, the output voltage can be scaled by setting the R1 and R2 resistors.

The op-amp has positive and negative inputs. The positive input has been grounded in this circuit, while, negative one has been connected to the phase. As a result, the output of the op-amp is generating based on the extents of resistors and these two input voltages (look at relationship 1). In essence, if every one of these factors (two resistors and voltages) changes, the output will be changed. Accordingly, if, for instance, the negative input of the op-amp in the circuit will be lowered or increased, the output will be altered. Exploiting this feature, we can use two of these circuits, totally identical, for monitoring the situation of the ground system.

Two op-amp circuits have been drawn in figure 8. All factors, resistors, and input voltages of these circuits are quite similar. The negative input of the first op-amp has been connected to the neutral. Likewise, the negative input of the second op-amp is connected to the ground. As long as neutral and ground are equal, considering all other factors are identical too, the outputs of both op-amps are same (look at relationship 2). Thus, if a LED is established between these two outputs, it won't be on. In essence, potential differences between these outputs will be zero.

On the other hand, if the ground potential has any difference with neutral, the output of two op-amps would not be equal anymore. Hence, the LED will be on (figure9 and relationship 3).

This simple device can detect any inconsistency or misconnections between neutral and ground. It can be attached to casual domestic electrical devices. It receives a branch of the phase voltage outlet of the device and a branch of ground and neutral. Thus, whenever the values of grounds and neutral were not equal, it can detect and alarm it.

Moreover, it is noteworthy to mention that neutral is grounded in MV to LV section of the electrical system; thus, if a ground system is working correctly, the potential of the ground should be approximately equal to the potential of the neutral. In fact, we have exploited this feature for solving this problem[2].

Furthermore, although we have been considered neutral and ground equal, these two extents are not quite same in reality. For this reason, while installing this device on the particular apparatus, we should set the resistances (resistances are variable) of the circuit so that the LED will be off (output voltages will be equal). Then, if there is any difference between these two voltages later, the device can recognize it.

In addition, in this solution, the circuit does not consume energy unless there is an inconsistency between ground and neutral. Since the potential of op-amps' out-puts are equal in normal situation the current does not flow between Vout1 and Vout2 points. This is like installing a bell behind a door. Whenever the door is opened the bell moves and rings. Otherwise, the bell is fixed and it does not consume any energy. Nevertheless, the op-amp, itself, consumes energy in normal situation way negligible in comparison with the electrical devices' energy consumption.

Besides, this circuit includes op-amps and some resistors. These elements are among the cheapest electrical elements available in market. Therefore, the cost of this protective device could be sensible for domestical applications.

$$V_{out} = V_{in} \times (1 + \frac{R_2}{R_1}) \,. \quad (1)$$

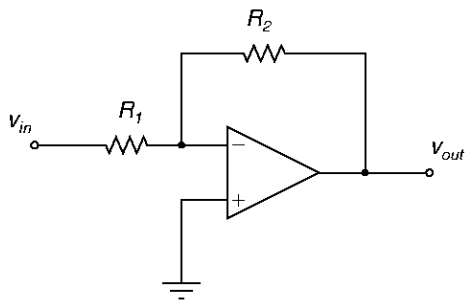


Figure 7. op-amp in feedback circuit

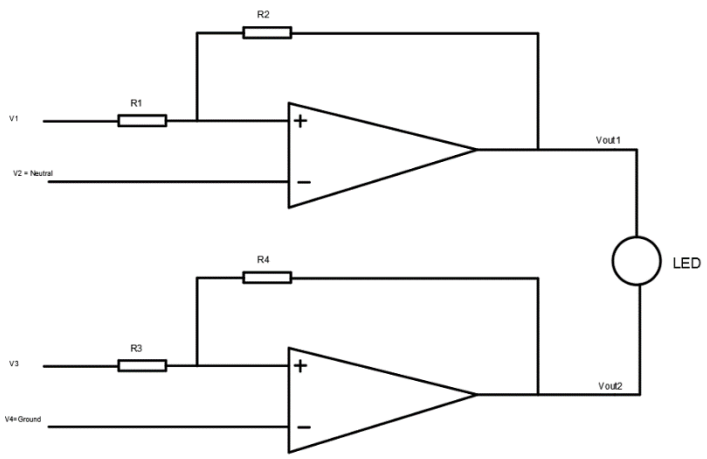


Figure 8. comparative circuit

$$\left.\begin{array}{l} V_1 = V_3 \,.\, (2) \\ V_2(Neutral) = V_4(Ground) \,.\, (3) \\ R_1 = R_3 .\, (4) \\ R_2 = R_4 .\, (5) \end{array}\right] \xrightarrow{(1)} V_{out1} = V_{out2} \,.\, (6)$$

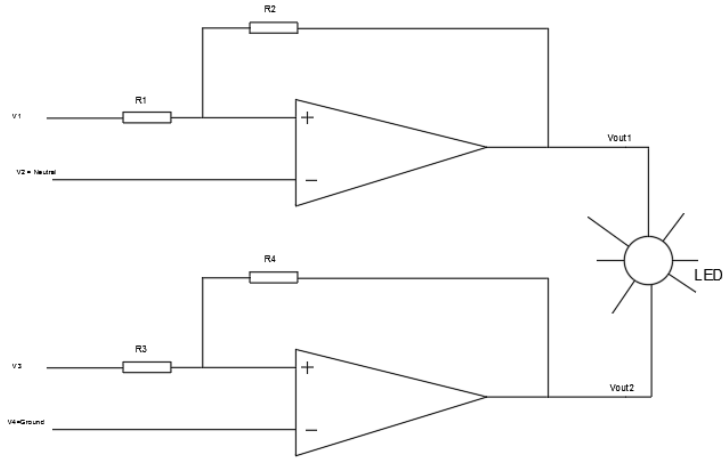


Figure 9. LED is on

$$\left.\begin{array}{l} V_1 = V_3 = V_{Phase} \,.\, (7) \\ V_2(Neutral) \neq V_4(Ground) \,.\, (8) \\ R_1 = R_3 .\, (9) \\ R_2 = R_4 .\, (10) \end{array}\right] \xrightarrow{(1)} V_{out1} \neq V_{out2} \,.\, (11)$$

## 3 Result

The proposed instrument has been simulated in Proteus 8 professional software. Figure 10 displays a condition that both op-amps receives same potential on their negative input. In other words, one of them is a ground and other is neutral. Thus, since neutral and ground are equal in normal condition, the voltage between two out puts is zero.

However, if the ground in first op – amp would be deleted (misconnection in grounding), there is difference between output voltages. Therefore, the device can warn about this problem (figure 11).

In the circuit $R_1$=$R_3$= 1K ohm, $R_2$=$R_4$=10K ohm, $V_{phase}$=12 V,50 HRTZ and op-amp model is LM741

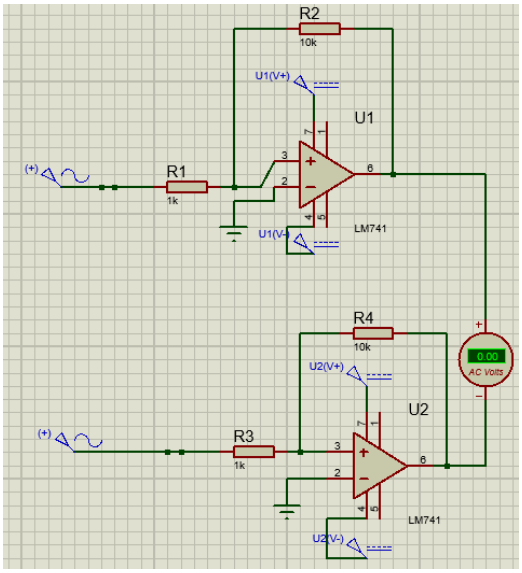


Figure 10. negative inputs are equal

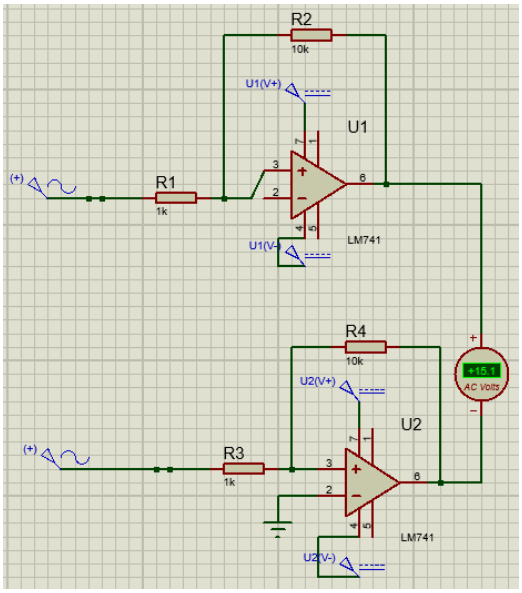


Figure 11. negative input is cut

## 4 Conclusion

Checking grounding connections is essential for guaranteeing the safety of electrical devices. Sometimes, users are not aware of misconnections in their grounding systems. Thus, the electrical devices could be unsafe while they are exploiting them. This paper intended to exert TRIZ tools and principles for designing a simple, effective tool for solving the problem. As a result, a specific instrument by exploiting op-amps was systematically designed to constantly monitor the ground situation. In case, the grounding connections would not be available, the device would create output voltage to enable an LED or a buzzer so that users could detect the fault and fix it as soon as possible.

## References


1. N. F. P. Association, "National Electrical Safety Code, 2002," *The Institute of Electrical and Electronics Engineers, Inc*, vol. 345, pp. 5-9.
2. K. P. Ingley, *Soares Book on Grounding and Bonding*. International Association of Electrical Inspectors, 2017, pp. 26,27,53,58,66.
3. I. Kasim, S. Abduh, and N. Fitryah, "Grounding system design optimization on 275 KV betung substation based on IEEE standard 80-2000," in *2017 15th International Conference on Quality in Research (QiR): International Symposium on Electrical and Computer Engineering*, 2017, pp. 400-407: IEEE.
4. P. Simmons, *Electrical Grounding and Bonding*. Cengage Learning, 2020.

   *Grounding sensor*. (2021). https://serverscheck.com/. Last Access: March 13, 2021
5. S. D. Savransky, *Engineering of creativity: Introduction to TRIZ methodology of inventive problem solving*. CRC Press, 2000, pp. 21-27, 59-69, 230,231.
6. V. Fey and E. Rivin, *Innovation on demand: new product development using TRIZ*. Cambridge University Press, 2005.
7. K. Rantanen, D. W. Conley, and E. R. Domb, *Simplified TRIZ: New Problem Solving Applications for Technical and Business Professionals*. Productivity Press, 2017.
8. *How to Check Earthing at Home* (2020, March 20).

   https://www.wikihow.com/Check-Earthing-at-Home. Last access: March 13, 20201


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TRIZ*fest*-2021

# ARCHITECTURE AND DESIGN IMPLEMENTATION OF INNOMETRIC SYSTEM

Ahmad-Ramez Kassou

## Abstract

How to use the unique data of inventive problems, tasks, ideas and solutions to perform innovation projects better and faster? What is an Innometric system? A pilot approach and application are observed in this article, to enable the move toward a new type of integration between TRIZ practices and artificial intelligence.

The lifecycle of an innovation project could be described and operated by the status control of each of its main entities: P-Problem, T-Task, I-Idea, S-Solution. The PTIS entity is initiated and updated during the innovation process, which was conducted by TRIZ roadmap and methods. The approach suggests modeling based on PTIS-pattern formation and its usage in software applications.

Keywords: *Innovation, Innometric system, Machine-learning (ML) method, Process, Project lifecycle, PTIS-pattern (entity), PTIS passport database (db), Service, Quality management system, TRIZ.*

## 1 Modelling PTIS-Pattern to Meet Project Management Requirements

TRIZ based project and services can be delivered by different ways depending on the scope of methods applicability and expectation of output quality for projects/service stakeholders. Here, the author considers the innovation projects and services that could be regulated by phases of implementation and delivery (Data gathering and preliminary analysis, problem/task analysis, problem/task solving, verification and deployment). The author's interpretation of term "innovativeness" of a project or service conditioned by the usage of innovation methods (e.g. TRIZ analytical tools) [3].

The purpose, structure of suggested PTIS-pattern (*Слепок инновационной задачи*), and its functionality were described [2], as well as the classification of innovation tasks (phases of a TRIZ-based project).

The PTIS-pattern is an entity that can be created and updated at any phase of an innovation process (project or service). It could be created when identifying a problem, forming a task, generating an idea or substantiating a solution. The PTIS entities that belong to one topical substance are distributed sequentially along through the innovation process when delivering a project or a service. That means, once the PTIS-pattern is created at the beginning of a project's life-cycle, it should be cloned and modified at the end of each next phase where the entity's story is enriched.

Thereby, this service information enables performing different business cases with means of deep automation, e.g. problem search, identifying and developing innovation tasks/solutions

and quality control. The architecture of entities and their applications were inspired by the Author's long experience with multi-modal biometric/expert systems [4] and usage of ML methods, dealing with biometric patterns and samples (such as voiceprint, face, fingerprint, iris, etc.).

The author introduces here another notion "The Innometric System" to deal with PTIS entities (*Inno-* abr. of innovation task parameters). As for the biometric system [5], sampling and comparing individual characteristics is a basic process in handling the increasing volumes of unique data of common typical parameters/classifiers, and in software products with frequent users' requests.

To understand the nature of the PTIS entity and its role in Innometric systems it would be helpful to overview fragments of datatypes of developed PTIS sampling model. The Innometric system and its usage scenarios will be discovered next.

The descriptors of PTIS entities consist of coded sets of classifiers and parameters (Fig. 1). The innovation TRIZ methods has their classifiers in this modeling for each of analysis, solving phases. Some sets are predetermined or extendable lists, the others are for arbitrary insertion by the user. The first category can be used directly in Innometric systems, the second could be available in similar automatic services as soon as the specialized tools are applied (e.g. the data-mining algorithms of arbitrary texts and files).

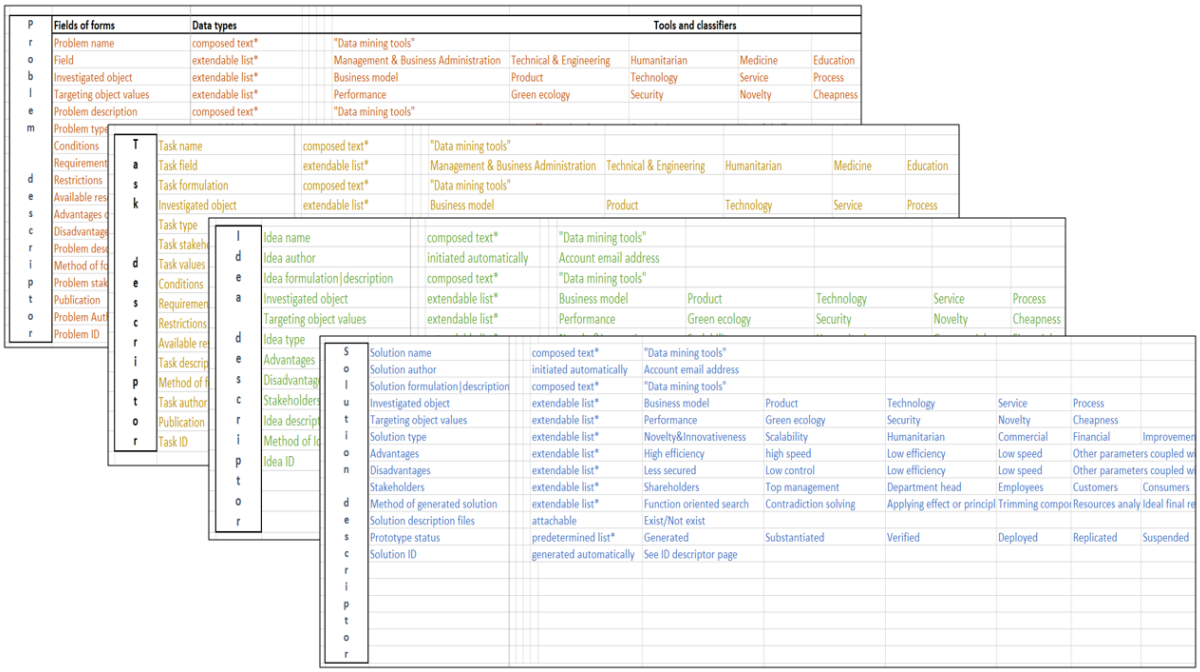


Fig. 1. Fragments of data types descriptors for patterning PTIS entities.

Patterning PTIS entities is based on structuring codes of high-level sets and values of classifiers. When the user inserts their data when describing a problem, task, idea or problem, they activate the corresponding codes and values which form a unique structure that initiates a unique identifier. The combination of codes of entities is predetermined at each considered version of PTIS software (Fig. 2.).

| High-level code | Fields of forms | PTIS v.1.0 | PTIS v.2.0 | PTIS v.2.1 | PTIS v.3.0 |
|---|---|---|---|---|---|
| PN | Problem name | | y | y | y |
| FN | Field | y | y | y | y |
| ION1 | In | | | | |
| TOV1 | Ta | | | | |
| PD | Pr | | | | |
| PTN | Pr | | | | |
| CP | Co | | | | |
| RP | Re | | | | |
| RRP | Re | | | | |
| ARP | Av | | | | |
| AES | Ac | | | | |
| DES | Di | | | | |
| PDF | Pr | | | | |
| MN1 | M | | | | |
| PS | Pr | | | | |
| PN1 | Pu | | | | |
| A1 | Pr | | | | |
| PID | Pr | | | | |

| | | | | | |
|---|---|---|---|---|---|
| TN | Task name | | y | y | y |
| TF | Task field | y | y | y | y |
| TD | Task formulation | | y | y | y |
| ION2 | Investigated object | y | y | y | y |
| TTN | Task type | y | y | y | y |

| | | | | | |
|---|---|---|---|---|---|
| IN | Idea name | | y | y | y |
| A3 | Idea author | y | y | y | y |
| ID | Idea formulation\|description | | y | y | y |
| ION3 | Investigated object | y | y | y | y |
| TOV3 | Targeting object values | y | y | y | y |

| | | | | | |
|---|---|---|---|---|---|
| SN | Solution name | | y | y | y |
| A4 | Solution author | y | y | y | y |
| SF | Solution formulation\|description | | y | y | y |
| ION4 | Investigated object | y | y | y | y |
| TOV4 | Targeting object values | y | y | y | y |
| ST | Solution type | y | y | y | y |
| AES4 | Advantages | y | y | y | y |
| DES4 | Disadvantages | y | y | y | y |
| SS | Stakeholders | y | y | y | y |
| SDF | Solution description files | | | partially y | y |
| ST | Prototype status | y | y | y | y |
| SID | Solution ID | v.1.0 | v.2.0 | v.2.1 | v.3.0 |

Fig. 2. Fragments of the structuring codes for different PTIS software versions

## 2 Background and Hypothetical Scenarios

The common scenario of handling innovation projects (TRIZ-based tasks) considers applying traditional tools of project management and human-like operations (Fig. 3). Normally, when having a limited amount of projects and implementation resources (mainly TRIZ specialists), such a scenario is adequate and efficient. But this traditional project management and quality of service are becoming complicated and costly. Considering the accumulated knowledge about tasks of innovations and dealing with the increasing number of tasks with some typical parameters require (hypothetical scenario) the usage of a specialized expert system (Fig. 4). This new approach allows reaching a deeper level of automation (the design of Innometric system), which should reduce the cost of implementing innovation projects and improve their quality by extracting, transferring and adoption of typical knowledge about tasks and projects.

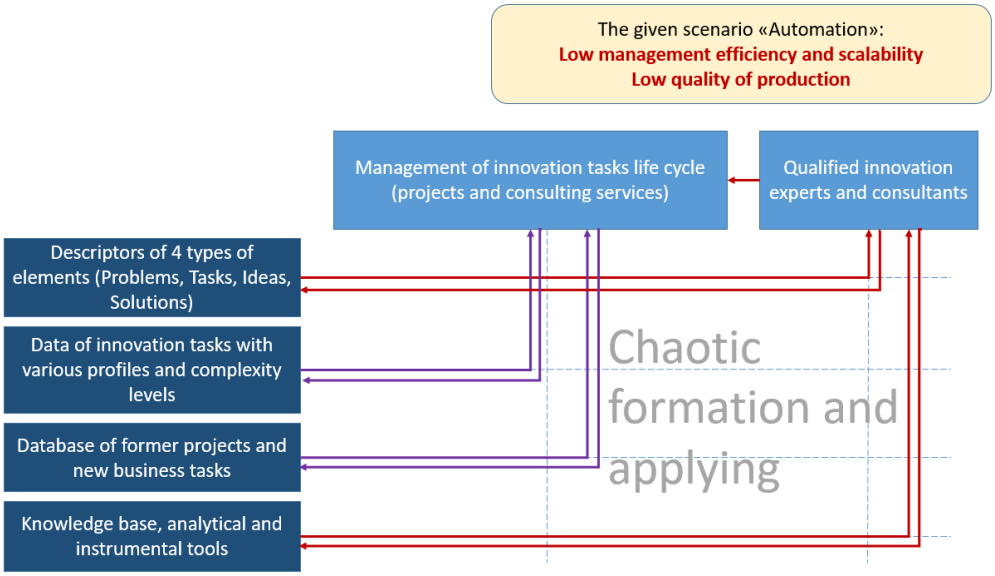


Fig. 3 The background (current) scenario of managing TRIZ-based innovation projects

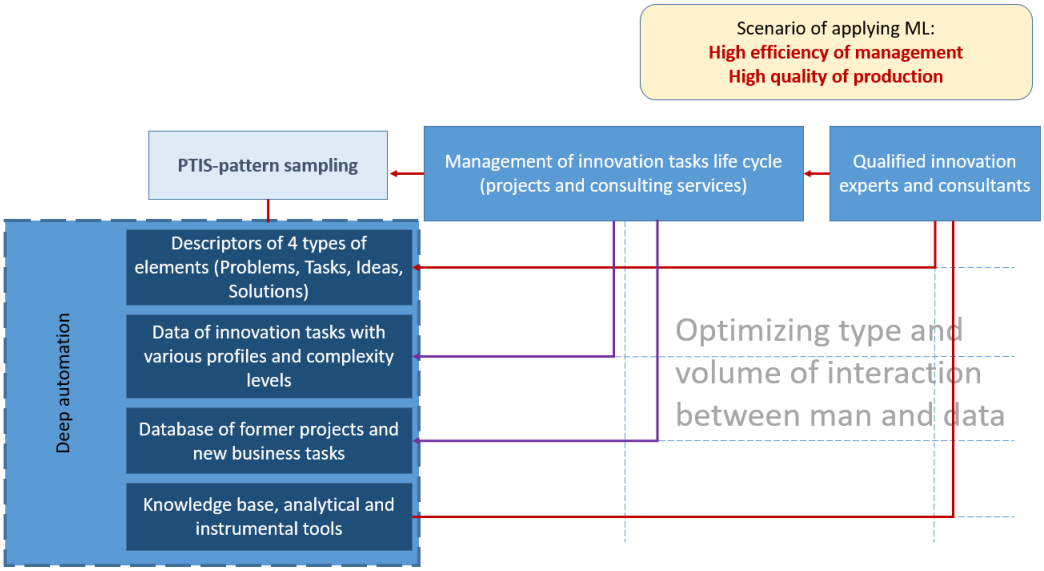


Fig. 4. The hypothetical (future) scenario – the usage of a specialized expert system

Advantages:

- Standardization of input/output data format during the implementation of instruments and project phases. This improves the performance and applicability of quality control metrics.
- Reducing the cost of innovation projects and services via reducing efforts of highly qualified TRIZ specialists (project managers, experts, consultants).
- Implementation of new smart types of projects and services appears via the usage of accumulated knowledge and PTIS entities (modelling and machine-learning tools).

Disadvantages:

- At an early stage of implementing the Innometric system, a set of unwanted effects could happen and should be eliminated or minimized:
    - The inaccurate format/volume of gathering data about entities (Problem, Task, Idea, Solution) and the insufficient level of modeling classifiers/parameters will limit data applicability wherefore the system production slowdowns. **Measure:** It is necessary to dynamically develop, verify and update the user's modeling parameters and new data formats.
- Additional expenses are required at succeeding stages for involving data-mining tools specialized in the analysis of arbitrary user data (text, files, images etc.). **Measure:** Gradual (step-by-step) involvement of such tools with efficiency control (testing) before the next step.

## 3 Deploying ML-Method and A\B Testing

In real conditions, the deployment of ML method and deployment is reasonable after a successful gathering of enough volume and quality of user data. Several cycles of the following steps to be performed:

1. Data organization (preparing formats and settings parameters) for developing interfaces to receive project information from users.
2. Describing/tuning the given user data about projects and tasks.

3. Forming requirements for handling user data with data-mining tools.
4. Forming the version prototype of PTIS-pattern.
5. Deploying the automation system of PTIS prototype usage in real project management tasks.
6. Rounds of verification, data correction and elaboration of ML-method (Fig. 5) (and considering the feedback of end-users).

Those are the necessary testing steps to provide more accurate results at each cycle (version testing) until reaching the aimed level of efficiency. The super-system conditions of performing a\b testing should also be changed (the deployment of PTIS prototypes must pass high intensity of applied projects and user's requests).

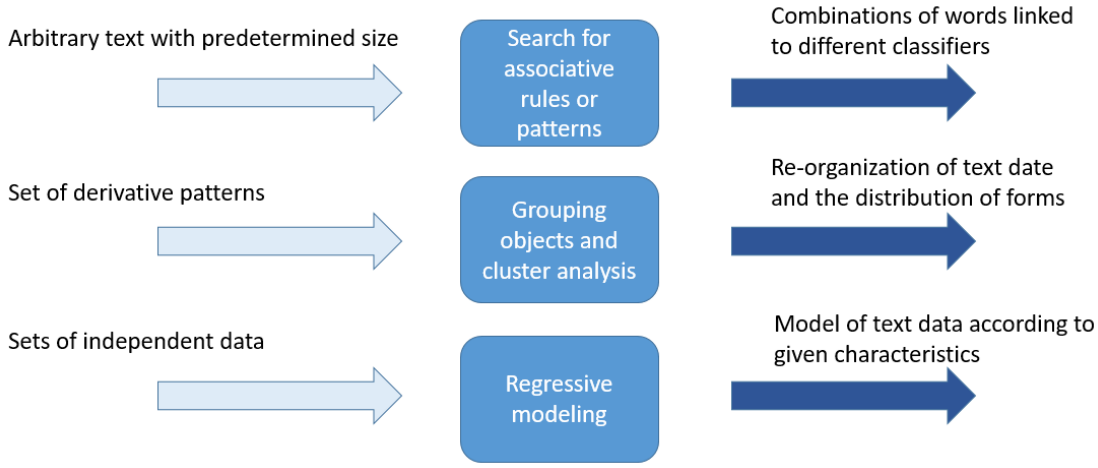


Fig. 5. The activity of the ML method. Input factors and results.

Testing modes of the applied algorithm:

- Multitasking in the short-term project lifecycle
- Multitasking in the long-term project lifecycle

To check the hypothetical scenario and tuning testing results, the Innometric system must provide the end-user (project manager, or consultant) with the feature of operative handling a big amount of parallel independent innovation tasks (selection and processing TRIZ roadmaps).

## 4 Innometric System Applications

As shown above, the Innometric system might have different business purposes and functionality. Here are some of the available varieties, described by a diagram of components and functions:

### 4.1 Gathering, Modeling and Storage

This basic system can be used by stakeholders of services or platforms to develop their various business solutions (Fig. 6).

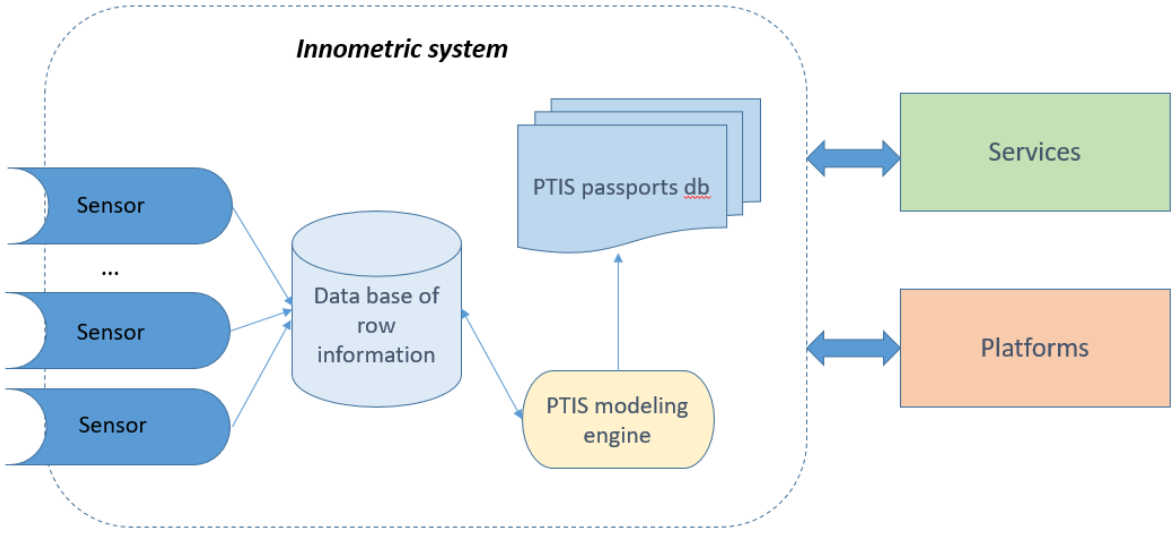


Fig. 6. Application 1 – Gathering and modelling

## 4.2 Quality Control and Project Management

The central element here is the Quality Management System which is integrated with PTIS components to enable real-time estimation and tuning of roadmaps and input data at each phase of an innovation process (Fig. 7).

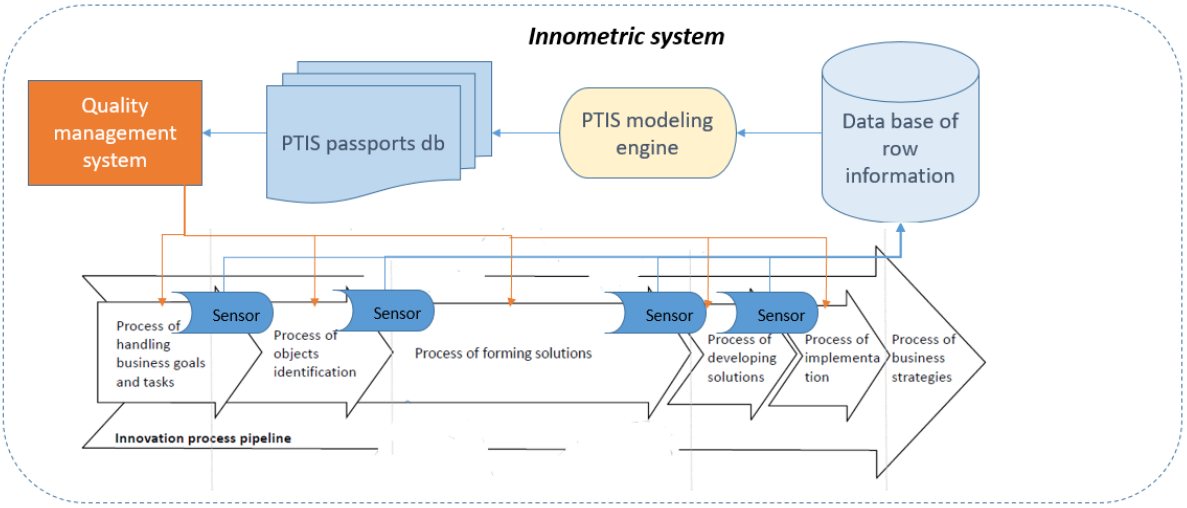


Fig. 7. Application 2 – Quality control

## 4.3 Search and Identification

The end-user (Project manager or Consultant) looks for a specified data with typical parameters of their unique entity (Problem, Task, Idea, Solution) to match their needs during phases of the innovation process (Fig.8). E.g. the user starts to study the given specific engineering problem. They insert problem data into the Innometric system, where the problem-pattern will be generated and a search request will be initiated to find in the database of PTIS-patterns (PTIS passport DB) the corresponding references of matching patterns, then the original data will be invoked with suggesting solving directions and other useful information to the end-user.

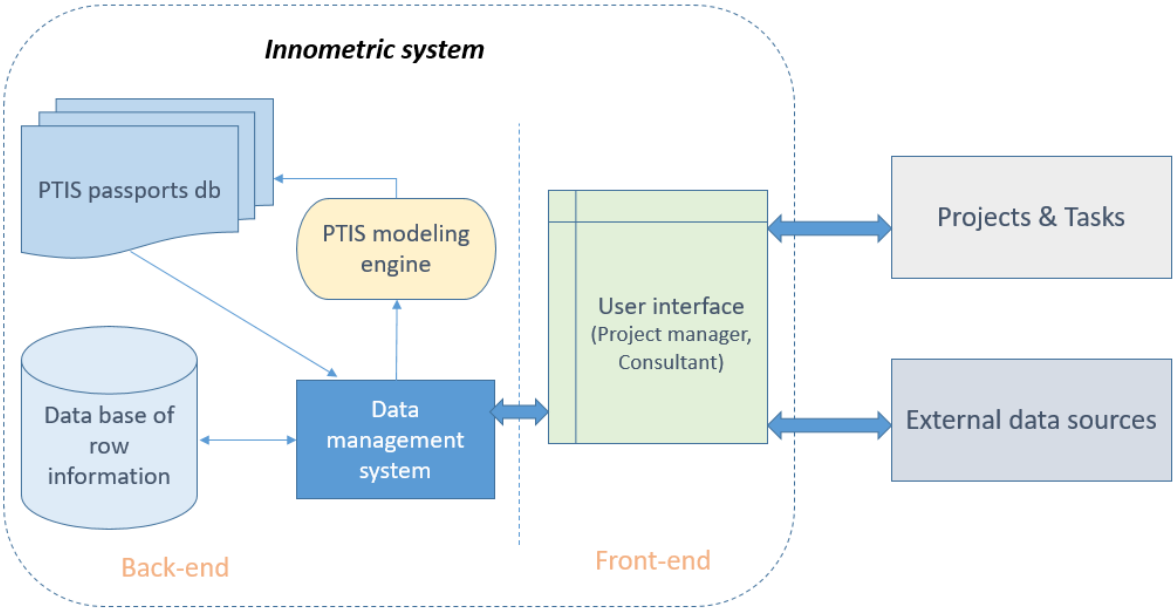


Fig. 8. Application 3 – Search & Identification

## 4.4 Recognition and Synthesizing

The opportunity of such application (Fig.9) type depends on spreading the trend of freeing up computing resources of AI business. In this case, the Innometric system is enforced by new automatic modules (Synthesizer and Recognizer) and perception means to integrate with its informational environment (super-system components).

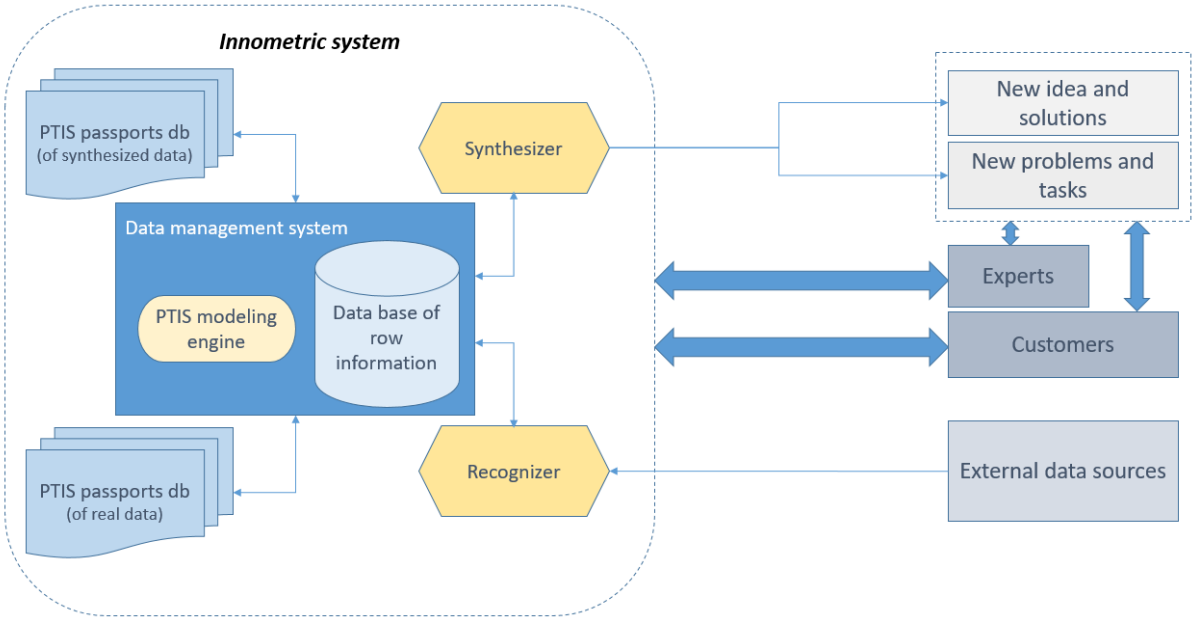


Fig. 9. Application 4 – Recognition & Synthesizing

The listed types of application are briefly described here to give business architects and developers of Innometric systems the opportunity to precise and suggest new forms of PTIS-pattern usage.

## 5 Conclusions

The overviewed approach is under continuous improvement due to the process of design and usage with real objects and entities. As mentioned in the partition of deployment, testing the current architecture considers multiple cycles of data gathering and estimation.

The initial forms of data types were inspired by templates and studies of a) the questionnaire list of problem\task analysis at the first phase of TRIZ-based innovation projects b) feedback forms for the clients of innovation services b) the author's experience in project management and research [3].

The standardizing process of innovation management [1] gives space for submitting additional tools which could consider TRIZ roadmaps and methods. The announced PTIS-pattern, Innometric system and applications can be considered as an additional resource and tool and bridges for studying innovations and dramatic increase of creating new. Accumulating data and their interrelationships as an open-source framework could be a great chance to speed up the process for achieving common goals.

## Acknowledgements

The author expresses his gratitude to i-NESIS.net organization and members for provided platform and efforts in deploying the PTIS prototype in process of gathering and handling data about innovation tasks of different types. It is significantly important to keep improving this prototype and enrich it with new deployment practices to match the increasing amount/needs of tasks and users.

## References

1. Innovation management ISO 56002:2019 https://www.iso.org/standard/68221.html
2. Kassou A-R.M. "A pattern of an innovative TRIZ task as a tool for identification, assessment and performance management (in Russian) https://triz-summit.ru/triz/metod/inno/kassou-inn/
3. Kassou A-R.M. "Providing efficient quality management of innovation projects based on methods of their standardization and parametrical modelling". Ph.D. dissertation material, Saint-Petersburg Polytechnical University, 2010. (in Russian)
4. Publications on the LinkedIn network https://www.linkedin.com/pulse/clouds-biometric-samples-realistic-fantasy-fantastic-kassou-ph-d-/ https://www.linkedin.com/pulse/evolution-biometric-identification-products-moving-kassou-ph-d-/
5. Shyam Sunder Yadav, Jitendra Kumar Gothwal, Prof. (Dr.) Ram Singh "Multimodal Biometric Authentication System: Challenges and Solutions", Global Journal of Computer Science and Technology Volume 11 Issue 16 Version 1.0 September 2011.

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# BENEFITS OF TRIZ APPROACH TO ENABLE PROPER HOLISTIC EDUCATION

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## Abstract

The mission of the paper is to show that in order to overcome the contradiction in education: achieve considerately a lot of benefit with little effort, is suitable apply the TRIZ approach (The secret of deciphering innovative perfecting of conditions, creators and creations) in the form of the Framework of the cycle of mutual perfecting of conditions, creators and creations (7 = 1 + 2 x 3 in the Appendix 2) developed according to the laws of education from the message of the teacher of the nations (Comenius, 1670), according to the Law of perfecting maturity of meaning of input to output transfer (Maupertuis, 1746) and according to the laws of invention (Altshuller 1946).

The mission of the Framework of the cycle of mutual perfecting of conditions, creators and creations (Framework of perfecting) is interestingly encourage creators what to use - input of transfer, clearly convince why to use it - meaning of transfer and memorizable show how to use it - output of transfer.

Keywords: TRIZ, holistic education, upbringing, teaching, inventing

## 1 Mission of holistic education

The aim of lifelong holistic education is to multiply individual benefits of different types of education:

- school - formal (upbringing, teaching and inventing)
- work - informal (science, research and exploitation)
- leisure - nonformal (entertainment, interest and competition)

for the preparation of an exceptional personality - creator who is constantly perfecting his holistic qualities - competencies for:

- spiritual maturity, the right habits, principles and needs, what to use
- mental maturity, the right knowledge, professionality and perseverance, why to use it
- physical maturity, the right skills, experience and reliability, how to use it

In this paper, we focus on the mission of school education (hereinafter referred to as holistic education), which, thanks to computer support, becomes ubiquitous, versatile and all-perfecting. A step forward is new ways of targeted overcoming challenges with the growing scope, uncertainty and complexity within artificial advanced thinking (AI, Artificial Intelligence) such

as hereditary procedures (GA, Genetic Algorithms), meaningfulness of uncertainty (FL, Fuzzy Logic), neural networks (NN), which have found use in the approach to deep learning (DL) and in creations of demanding education (IL, Immersive Learning), replacing and supplementing reality, extended reality (XR), which includes creations replacing reality (VR, Virtual Reality) and Augmented Reality (AR).

The councils for improving the maturity - humility of holistic competencies left to us by the teacher of nations and the discoverer of laws in education (Comenius, 1670) are still valid even after 350 years:

| | | | | |
|---|---|---|---|---|
| PQ | Pannuthesia | all-perfecting | leader | predetermines |
| EQ | Panegersia | all-awakening | challenger | motivates |
| IQ | Pansofia | all-cognition | scientist | explores |
| TQ | Panaugia | all-enlightenment | inventor | overcomes |
| AQ | Panglottia | all-understanding | manufacturer | adapts |
| MQ | Panpaedia | all-education | educator | instructs |
| RQ | Panorthosia | all-correction | negotiator | convinces |

The aim - challenge for perfecting the current way of education is to prepare future pioneers for meeting the requirements on competencies of tomorrow according to the conclusions of the World Economic Forum (WEF, 2020, 2021) through holistic education. The challenge for advanced holistic education for the professions of the future is to lead to the ability to harmonize simultaneously belonging, specificity and cohesion:

- input harmonization: consequences of attitudes, foresight, prudence - responsibility
  humanity (upbringing - art): principles, searching up the correct incentives,
  what to use
- meaning harmonization: depth of knowledge, penetration, professionality - interest
  expertise (teaching - science): knowledge, choosing the correct rules, why to use it
- output harmonization: breadth of context, overview, versatility - synergy
  ingenuity (inventing - craft): skills, using the correct practices, how to use it

The perfecting creations, which is, thanks to adaptation, independence and predetermination, twice as fast as the perfecting of creators, thus becomes a suitable model and a demanding challenge for holistic education (upbringing, teaching and inventing):

- change of preset properties by taking over and combining benefits from different approaches: adaptive hybridization
- targeted self-adaptation: autonomous adaptronics
- intentional holistic multiplicative predetermination: active synergy

If we want to build a reliable building, then we must first build a reliable foundation. If we want to move in the right direction, we must humbly return to the groundbreaking legacy (Altshuller, Shapiro, 1956), which is the basis for the incentives, rules and procedures of the TRIZ approach for mutual perfecting of creators, creations and conditions, which is the mission of holistic education.

Successful best ranking world universities are rapidly moving to a holistic way of education (upbringing, teaching and inventing) in order to prepare students to acquire the transferable holistic competencies (principles, knowledge and skills) needed to meet increasingly demanding challenges (quantity, diversity and complexity), so they included in the content of preparation the incentives, rules and procedures from the TRIZ approach:

(https://matriz.org/resources/triz-in-academia/).

## 2 TRIZ approach for perfecting conditions, creators and creations

Altshuller was the first in the history of mankind who revealed the laws of inventing which can be applied on perfecting of every human activity. By analysis successful breakthroughs in human history, he revealed principles of perfecting conditions – input for transfer to output:

- proportionality, proper use of opportunities,
- economy, proper availability of facilities,
- sustainability, proper protection of resources,

By analysis of success life stories, he revealed principles of perfecting the creators for harmony of physical, mental and spiritual maturity - meaning of transfer:

- empathy, helpfulness, correct attitudes - habits,
- efficiency, correct knowledge - expertise,
- effectiveness, correct skills - overcoming,

By analysis of successful inventions, he revealed the principles of perfecting creations (subjects, procedures, and attitudes) - output of transfer:

- usefulness, correct mission - function of subjects - technics,
- purposefulness, essence of procedures - technology,
- usability, rules of attitudes - art,

The TRIZ approach is a generalization of the laws of perfecting the maturity of fulfillment of the mission of creators, creations, and conditions which are based on the idea of advanced needs, advaned use of resources, and advanced overcoming of contradictions.

### 2.1 TRIZ approach and meaning - values of transfer input to output

People have survived by revealing the secrets of nature, now they are revealing the secrets of thinking for nature to survive. If we want to understand the laws of thr development of the world events, it is necessary to equally replace its infinite complexity with a finite number of suitable representatives - patterns (conditions, creators and creations), so that our brain equipped with a finite number of sensors and states of evaluators can them distinguish (Turing, 1937).

The attractor is the final state (perfection) for a variable - dynamic system of world events (Gräbe, 2020). The ubiquitous manifestations of perfecting world events (mutual perfecting of the maturity of creators, creations and conditions) are the consequences of the effect of perfection (attractor) on world events through the attraction of perfection (Palčák, 2017). This driving force of creativity - ingenuity - discovery manifests itself according to the principle, the rule, the lawfulness of the least possible action - drawing resources to best fulfill the mission (Maupertuis, 1746) as a generally valid permanent, reliable and fair Law of perfecting the maturity of meaning of input to output transfer (1):

(V) meaning of transfer: why - values = (F) output of transfer: how - mission / (C) input of transfer: what - resources

$$V = \frac{F}{C} \quad . (1)$$

The creator - pioneer uses the conditions - resources (input, C) for valuable transfer (meaning, V) of input to output to achieve the mission of creations - means (output, F).

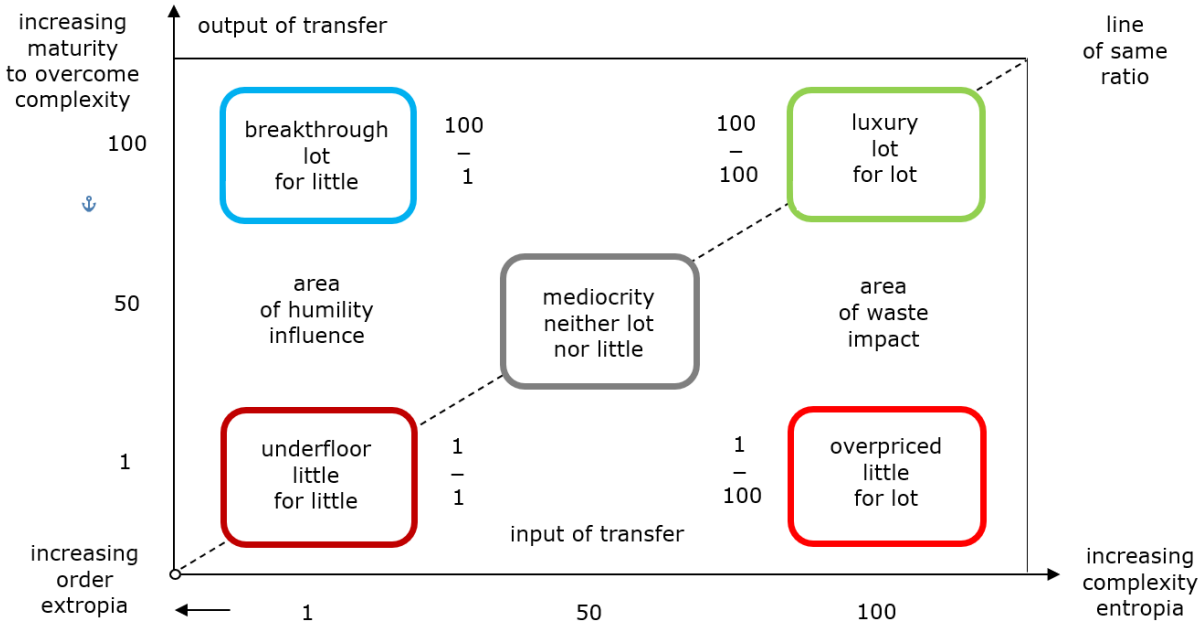


Fig. 1. Meaning - values of transfer input to output

## 1.1 TRIZ approach: incentives, rules and procedures

**Incentives - tools, art: intention what to use, timing, input of transfer.**

Support - multiplying benefits
leader predetermines, PQ (Perfecting Quotient)
multiplication, perfecting of holistic maturity, Ideality,

Incentives - input of transfer
challenger encourages, EQ (Emotional Quotient)
assignment, conditions, natural, personal and group resources,
scientist examines IQ (Intelligence Quotient),
generalization, essence of mission, Functionality - Value,

Overcoming - meaning of transfer
inventor overcomes, TQ (Technium Quotient)
defeat of contradictions,
manufacturer adapts, AQ (Adversity Quotient),
consideration, relationship of phenomena, space, time and areas, Space - Time - Domain - Interface,

Application - output of transfer
educator teaches, MQ (Mission Quotient),
utilization, transfer of essence, System Transfer,
negotiator convinced, RQ (Relationships Quotient),
harmonization, directions of transformation, System Transition,

**Rules - laws, science: reason why to use, outcomes, meaning of transfer.**

TRIZ approach covers all known approaches, as its rules are based on three laws:
The law of perfection essence, input of transfer: what to use
the ubiquitous attraction of perfection is the driving force behind perfecting the creativity, ingenuity and discoveries in order to best meet the physical, mental and spiritual needs.

The law of perfection importance, meaning of transfer: why to use it
creator, creations and conditions are perfecting in the way: "considerably lot for little" with an effort to be emphatic, effective and efficient of the transfer of the proportionality, sustainability and economy of input response to the usability, efficacy and usefulness of the output.

The law of perfection procedure, output of transfer: how to use it
The mission essence of creators, creations and conditions is perfected according to the Laws of mutual improvement - dialectics (Hegel, 1837) for overcoming contradictions, for skipping (S - curve) and for progress (self - similar fractal helix).

Table 1. Transition from current to advanced state

| Current state | Advanced state |
|---|---|
| What is used:<br>spontaneity<br>random trials - errors<br>habits | What needs to be used:<br>purposefulness<br>generalized incentives - tools<br>adaptability, guidelines, principles |
| Why it is used:<br>Inertia of thinking<br>fragile optimization<br>presumptions | Why it should be used:<br>rules - laws<br>resilient breakthrough innovation<br>evidence, knowledge |
| How it is used:<br>closedness, dependences<br>benefit, prediction<br>sum of benefits | How to use it:<br>openness, procedures - instructions<br>humility, predetermination<br>multiplication of benefits |

**Procedures - instructions, craft: way how to use, realization, output of transfer.**

Sequence of the ARIZ steps (Petrov, 2019) from the point of view of the TRIZ Access Framework:
Analysis - input of transfer

- assessment of baseline, needs, challenges,
- setting a generalized target,
- recognition of contradictions: administrative - challenge, technical - external, physical - internal,

Proposal - meaning of transfer,

- generalized way of resolving the contradiction,
- use of resources: time, space, field, matter, knowledge - data,
- feasible way of meeting given requirements and possible change of the assignment,

Evaluation - output of transfer,

- benefits of the proposal,
- the possibility of making the most efficient use of resources,

- using the way to meet the challenge of perfecting pioneers training.

## 3 TRIZ approach for holistic education (upbringing, teaching and inventing)

Everyone is naturally curious, playful and creative - inventive, but to become a successful leader - creator who can handle current and future challenges: sustainability of survival conditions, a growing number of incentives and rapidly changing demands for holistic competences: a high degree of consideration (principles, input, what) a deep look of expertise (knowledge, meaning, why), and broad overview of openness (skills, output, how). The creator - pioneer should focus on his innate talents and collaborate with experts who will help him his talents:

- detect (doctor - psychologist)
- develop (teacher - lecturer)
- exploite (counselor - trainer)

A friendly, successful and effective way of using the incentives (what), rules (why) and procedures (how) of the TRIZ approach in education to acquire holistic competencies is based on proven results of research into the laws of holistic coexistence - humanity, cognition - expertise and creation - invention.

### 3.1 Framework of holistic coexistence - humanity

The aim for upbringing: the uplift for coexistence (principles), the artist encourages

What

- goodness - behavior, dedication, resilience
- goodness - thought, enthusiasm, attitudes,
- goodness - pleasantness, consideration, relationships,

Why

- health, physical maturity, beauty,
- responsibility, mental maturity, good,
- harmonization, spiritual maturity, love

How

- adequacy, diligence, regularity,
- importance, consistency, consequences,
- reliability, compassion, belonging,

### 3.2 Framework of holistic cognition - expertise

The TRIZ approach unifies research on the way of thinking:

Holistic thinking (Flavell, 1976):

- there is holistic supervising, harmonizing and multiplying thinking throughout the brain (generalizing beyond cognition - metacognition in the superconscious),

  goal: upliftment, humanity - helpfulness, ingenuity

Contemplative and imaginary thinking (Sperry, 1961):

- conscious contemplative thinking takes place in the left part of the brain,
- subconscious imaginary thinking takes place in the right part of the brain,

Slow and fast thinking (Kahnemann, 2012):

- deliberate conscious slow and strenuous evaluative thinking takes place in the upper part of the brain,

  goal: truth - essence, pleasure, effectiveness,
- spontaneous subconscious fast and easy thinking takes place in the lower part of the brain,

  goal: correctness - mission, survival, success,

It has been confirmed that the knowledge we often deal with will remain in our memory for a longer period of time, because:

- spontaneous thinking is constantly imaginatively looking for context necessary for the meaningfulness of uplift, therefore it has an important influence on the correctness of the consequences in the formation of judgment - ideas for decision - making
- deliberate thinking focuses on truthfulness and essence, especially in terms of benefits,
- harmonizing - supervising thinking switches the involvement of fast thinking (for common challenges) or slow thinking (for demanding challenges) according to the difficulty and thus multiplies the individual benefits of subconscious experience, conscious expertise - knowledge and superconscious generalization of ideas - inspiration, intuition.

Instruction for cognition (knowledge - expertise), the scientist convinces

What

- subconsciousness: imagination, action,
- consciousness: reasoning, evaluation,
- superconsciousness: harmonization, multiplication, synergy

Why

- liveliness, lightness,
- purposefulness, effort,
- supervision, metacognition,

How

- search, choosing the right stimuli, needs
- evaluate, research of correct laws,
- use, apply good habits,

## 3.3 Framework of holistic creation – invention, the pioneer overcomes

The TRIZ approach unifies:

Eastern - empirical approach in the subconscious is focused on evaluation - analysis,

- favors experience, induction, foresight,
- from individual to general,
- what is needed, artist, principles, input of transfer

Western - rational approach in the consciousness is focused on assembly - synthesis,

- favors knowledge, deduction, prediction,
- from general to individual,
- why it is necessary, scientist, knowledge, meaning of transfer

Holistic - discovery approach in the superconscious is focused on multiplication - synergy,

- favors imaginativeness, abduction, predestination,
- from improvement to breakthrough,
- how is needed, inventor, skills, output of transfer

Inventing for embodiment (skills - ingenuity), a pioneer overcomes

What

- experience, knowledge, ideation,
- imagination, entrepreneurship, alertness,
- opposites, jump, progress,

Why

- attractiveness,
- transfer
- conversion,

How

- discrepancy recognition, contradiction, entry,
- similarity search, analysis, transfer,
- invention of substance, decipherment, output,

## 4 Application of the Framework of perfecting

The features of the Framework of perfecting are based on the principles for e-learning of today's Z generation of zoomers that resize images on touch screens:

- one view-image, what is necessary to use: one incentive of the Framework of perfecting, (the 7-steps cycle of mutual perfecting conditions, creators and creations),
- one reason-essence, why is necessary to use: one rule of the Framework of perfecting, maturity equation (meaning = output / input),
- one instruction-sequence, how is necessary to use: one procedure of Framework of perfecting, (contradiction, analysis, decipherment),

The methodology of Framework of perfecting for education was successfully applied in numerous lectures, theses (BSc., MSc., PhD., habil.) and projects for industry (automotive, railway, aircraft, white goods, earthmoving machinery, nuclear) for more than 20 years at Faculty of Mechanical Engineering, Slovak University of Technology (FME STU) Bratislava, SK. Details can be found in the selected links (References 13 - 17).

http://atc.sjf.stuba.sk/english/e_projekty.html

http://atc.sjf.stuba.sk/english/e_theo_mech.html

https://triz.sk/en/papers.html

My suggestion as member of Scientific Council at FME TUL to apply Framework of perfecting into education was accepted by Assoc. Prof. P. Lepšík, PhD, Vice-Dean for Doctoral Studies and Development, who was on scientific stay at MIT, Cambridge, Massachusetts, USA (supervisor Prof. S. Ikovenko, TRIZ Master). In his habilitation thesis (2018) the TRIZ approach was applied to increase efficiency of nanofibers production.

Strategy RDI + 2030, Faculty of Mechanical Engineering, Technical University of Liberec, CZ.

http://www.fs.tul.cz/en/faculty/strategy-r-d-i-/

## 5 Conclusions

A great example of the impact of the Law of perfecting is the development of the brain which constantly strives to accomplish its mission as best as possible: taking the right decisions to best meet the right physical, mental, and spiritual needs (survival, pleasure and upliftment), while

exerting the least effort and consumption on the basis of right choice, comprehension and compliance of the right incentives - challenges.

The TRIZ community should strive to make a significant contribution to perfecting Altshuller's gift to the world through holistic education so that it would touch the heart of everyone, and make the TRIZ approach available (cheap), intelligible (favorite), and uplifting (useful).

According to the Law of perfecting based on the action of the attraction of perfection, the time has come when, after periods of survival (dealing with matter) and pleasure (dealing with information), comes a period in which humanity will engage in uplift (dealing with relationships). This means challenging the use of appropriate tools, rules and procedures (TRIZ approach) and trying to humanize creations (objects, procedures and attitudes) that can already emulate and often surpass the physical strength and achievements of human thinking and strive for advanced use of resources aiming to align the maturity of the creator, creations and conditions.

The Framework of the cycle of mutual perfecting of creators, creations and conditions allows to use the holistic complexity of tools, rules and procedures of TRIZ approach and simultaneously is concise, understandable and applicable to meeting educational challenges: recognizing, understanding and applying the right principles, knowledge and skills.

The sign - logo (Fig. 2) of a Framework of perfecting is a flower that represents manifestations of humility:

- transcendent - spiritual upliftment - love (belonging)
- inner - mental values - good (satisfaction)
- external - body beauty (harmony)

The unifying competence of holistic education is ingenuity, which combines imagination, knowledge, adaptability, anticipation, prediction and predestination, overcoming obstacles, and which is a promise for a full life, for survival, pleasure and humility.

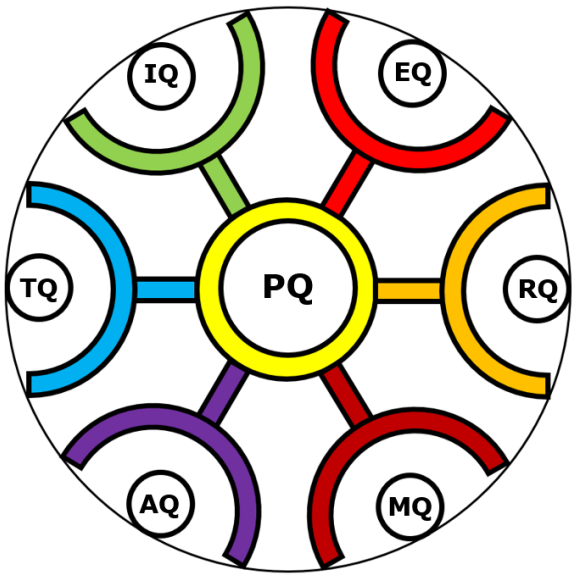


Fig. 2. Framework for the cycle of mutual perfecting creators, creations and conditions

## Acknowledgements

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## References


1. Komensky - Comenius, J. A. “General consultation on the correction of human affairs“, Publishing House Svoboda, Praha, ISBN 80-205-0220, 2, 4, 9, 1992. (origin 1670).
2. Maupertuis, P. L. “Derivation of the laws of motion and equilibrium from a metaphysical principle“, 1746.
3. Altshuller, G. S., Shapiro, R. B. “About Psychology of Inventive Creativity, The Questions of Psychology“, No. 6, p.37-49, 1956.
4. World Economic Forum, http://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf, 2020, http://www.weforum.org/agenda/2021/06/workplace-skills-learning-linkedin-report/, 2021.
5. Turing, A. M. “On Computable Numbers, with an Application to the Entscheidungsproblem“, https://doi.org/10.1112/plms/s2-42.1.230,1937.
6. Palčák, F. “Become user of TRIZ tools instead to play hide and seek“, Conference TRIZ Fest Krakow, Poland, 2017.
7. Hegel, G. W. F. “Phenomenology of the spirit“, Cambridge University Press, 2018, ISBN 0-52185579-9, (origin 1837).
8. Petrov, V.: “Logic of ARIZ: TRIZ“, Independently published, ISBN-13: 978-1698989273, 2019.
9. Flavell, J. H. “Metacognitive aspects of problem solving“. In L. B. Resnick (Ed.), The nature of intelligence (pp. 231-235). Hillsdale, NJ: Lawrence Erlbaum. 1976.
10. Sperry, R. W. “Cerebral Organization and Behavior: The split brain behaves in many respects like two separate brains, providing new research possibilities“. Science, 133 (3466): 1749–1757. PMID 17829720. doi:10.1126/science.133.3466.1749, 1961.
11. Kahneman, D. "Two Selves. Thinking, Fast and Slow". New York: Farrar, Straus & Giroux. 2011.
12. Gräbe, H. G.: "TRIZ and Systemic Transitions, Leipzig", Version of 21 June 2020, https://hg-graebe.de/EigeneTexte/sys-20-en.pdf.
13. Palčák, F.: „Trends in Development of positioning mechanisms“, XI. Int. Conf. on the Theory of Machines and Mechanisms, 2012, 4.-6. sept. 2012, Liberec, pages 43-48. Mechanisms and Machine Science, Volume 8, Advances in Mechanisms Design, Proceedings of TMM 2012, Springer, ISSN 2211-0984, ISBN 978-94-007-5124-8, 2012,
14. Palčák, F.: „Application of TRIZ Approach in the Research of Seismic Resistance“, Humanities and Science University Journal, Sankt Peterburg, USJ-T/2014#10(10), pp. 60-70., 2014,
15. Palčák, F.: „TRIZ approach for innovation in engineering“, TRANSFER 2015, 16th International Scientific Conference, November 5.-6., Faculty of Special Technology TnUAD, Trenčín, SK, p. 6, 2015.
16. Palčák, F. Improvement of Dynamic Characteristics of the Car in the Light of Technological Evolution (pp. 391-397). Springer International Publishing. http://doi.org/10.1007/978-3-319-44087-3_53, 2017.
17. Palčák, F.: Why is it so important for everyone to get acquainted with the TRIZ approach, http://fablabnet.net/wp-content/uploads/2018/10/18_Fablab_Palcak_TRIZ.pdf , 2018,

## Appendix 1

Table 2. Perfecting the maturity of meaning of input-to-output transfer for conditions, creators, and creations through the principles of art, knowledge of science, and craft of skills to handle the quantity, diversity, and complexity of inputs.

| | **Perfecting the maturity of meaning of input-to-output transfer** | | |
|---|---|---|---|
| | **Input of transfer** | **Meaning of transfer** | **Output of transfer** |
| | conditions, investment<br>what to use, principles<br>economy | creators, pioneers<br>why to use it, knowledge<br>efficiency | creations, products<br>how to use it, skills<br>purposefulness |
| | art, upbringing<br>incentives, love, spiritual<br>advice, superconsciousness | science, teaching,<br>rules, goodness, mental<br>reason, consciousness | craft, inventing<br>procedures, beauty, body<br>way, subconsciousness |
| | quantity<br>diversity<br>complexity | search<br>selection<br>use | timing<br>correctness<br>reliability |

The seven principles (7 = 1 + 2 x 3) of the Framework of the cycle of mutual perfecting conditions, creators and creations (Framework of perfecting) under the law of perfecting the meaning of input-to-output transfer from TRIZ approach for holistic education (upbringing, teaching and inventing) to acquire holistic competences (principles, knowledge and skills) is in the Appendix 2, Tab. 2.

- Framework for perfecting the three aspects of conditions (sources, opportunities and means) in the seven steps of the integral cycle of input to output transfer: (alignment, human resources, knowledge resources, natural resources, preparedness, equipment, and sustainability).

- Framework for perfecting the three aspects of creators (spiritual, mental and physical) in the seven steps of the integral cycle of input to output transfer: (leader, challenger, scientist, inventor, producer, educator, and negotiator).

- Framework for perfecting the three aspects of creations (rules, procedures and mission) in the seven steps of the integral cycle of input to output transfer: (predetermination, needs, motor, transmission, tool, sensor, and guidance).

## Appendix 2

Table 3. Seven principles (7 = 1 + 2 x 3) of the Framework of the cycle of mutual perfecting conditions, creators and creations (Framework of perfecting) under the law of perfecting the meaning of input-to-output transfer from TRIZ approach for holistic education (upbringing, teaching and inventing) to acquire holistic competences ( principles, knowledge and skills)

| **The Framework of the cycle of mutual perfecting of conditions, creators and creations** | | | | |
|---|---|---|---|---|
| | **Input of transfer** | **Meaning of transfer** | **Output of transfer** | |
| | conditions, investment<br>what to use, principles<br>economy | creators, pioneers<br>why to use it,<br>knowledge<br>efficiency | creations, products<br>how to use it, skills<br>purposefulness | |
| PQ | harmonization<br>maturity of input, meaning and output of transfer | exceptionality<br>passionate multiplication of benefits | maturity<br>predetermination<br>significance | **maturity of transfer** |
| EQ | human resources<br>pioneer,<br>assessor, advisor | soulfulness<br>active incitement<br>of innovating | adaptability<br>needs<br>curiosity | **input of transfer** |
| IQ | knowledge resource<br>lesson, information<br>discovery | expertise<br>patient evaluation<br>of analyses | dexterity<br>engine<br>intelligibility | |
| TQ | natural resources<br>phenomena, fields,<br>substances, time, space | openness<br>imaginative overcoming of challenges | usefulness<br>transmission<br>memorability | **meaning of transfer** |
| AQ | energy<br>readiness<br>do the work | resilience<br>persistent adaptation<br>of innovations | economy<br>tool<br>manageability | |
| MQ | amenities<br>opportunities<br>usability | dedication<br>strenuous education<br>to accountability | instructiveness<br>sensor<br>fun | **output of transfer** |
| RQ | sustainability<br>renewable<br>resources | consideration<br>convincing justification<br>for unification | friendliness<br>guidance<br>inflammation | |

The seven principles (7 = 1 + 2 x 3) of perfecting maturity of meaning- value of input to output transfer according to abilities of creator - pioneer:

7: PQ = EQ x IQ x TQ x AQ x MQ x RQ

1: unique law for perfecting maturity of input to output transfer,

PQ for maturity of transfer

2: two types of access (deliberateness, spontaneity) to overcome challenge,

3: three pairs of competencies

| | |
|---|---|
| EQ, IQ | for input of transfer |
| TQ, AQ | for meaning of transfer |
| MQ, RQ | for output of transfer. |

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TRIZ*fest*-2021

# Big Data Analysis: A Component / Resource to be considered in TRIZ

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## Abstract

Functional Analysis is a key tool in TRIZ. As elements components that have a rest mass and technical fields are accepted elements. Software per se and parameters are not allowed. Nowadays Big Data, Artificial Intelligence (AI) and software are getting more and more importance in technical system as elements that change parameters of other components and fields. We have suggested at TRIZfest 2019 to introduce Big Data as a resource. In the intense discussion this idea was rejected and suggested to think about introducing Big Data (AI & Software) as a field to function analysis. Simon Litvin suggested to allow software as a field. This paper will emphasis on this idea and present examples how this could look like.

*Keywords:* Fields, Big Data, Data Analysis, Function Analysis

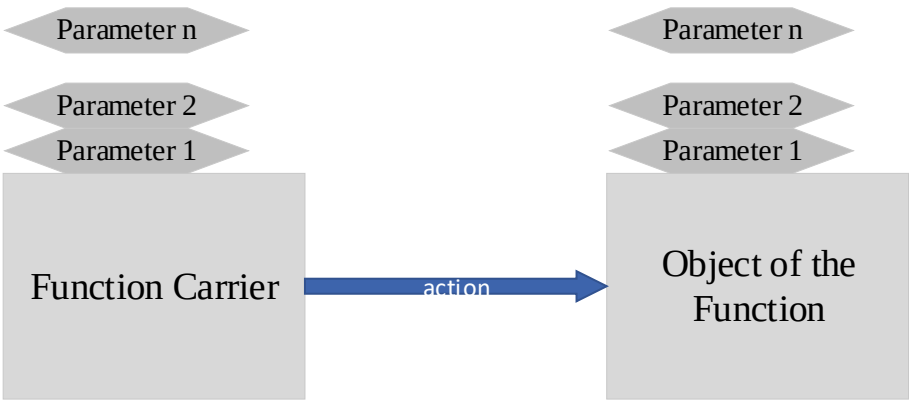
## 1 Functional Analysis in TRIZ

### 1.1 TRIZ Theory State-of-the-Art

In TRIZ provides several procedures to solve problems. Originally the focus laid on technical systems and products, handling of contradictions and Trends of Engineering System Evolution (TESE). Functional Analysis is a key element in TRIZ for the modelling of technical system and understanding the harmful and useful functions in a system. Today's technologies tend to include more and more software algorithms to generate the desired functionalities. A function is performed when a parameter of the object of the function is changed (or maintained).

### 1.2 Software in Functional Analysis

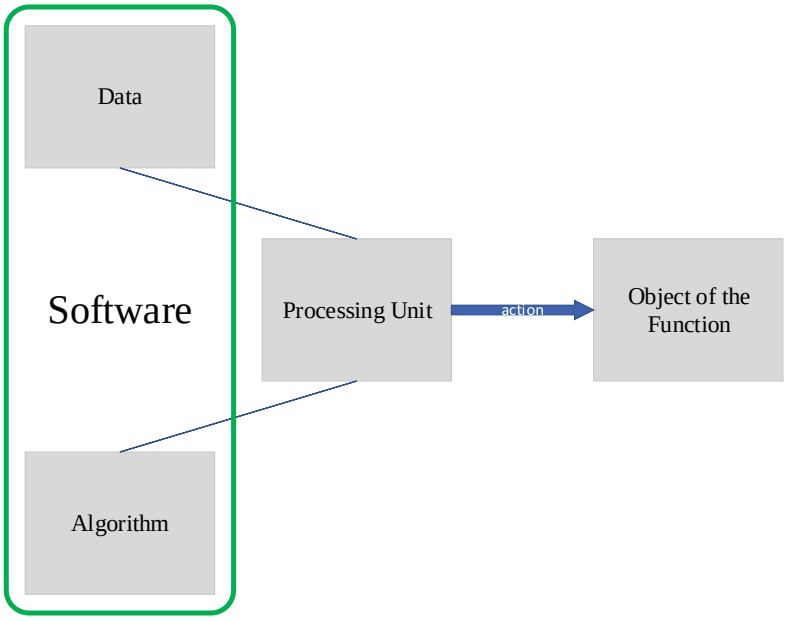
Functional Analysis starts with the detection of the function carrier. This is the unit that is executing an action on the object of the function in order to change (or preserve) at least one parameter of the object of the function.




Software (SW) per se is, according to the Naumann definition, an acronym for a program (algorithm) and associated data. It can contain additional components such as software documentation in the digital or printed form of a manual as an accessory.

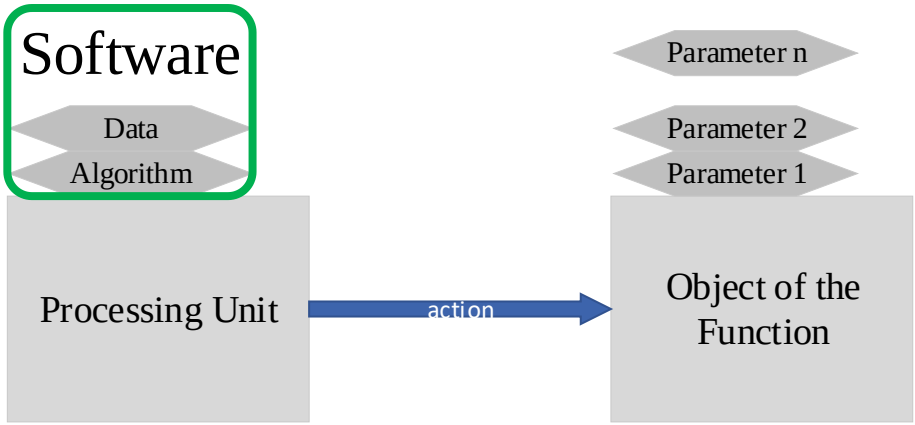
Software determines what a software-controlled device does and how it does it (roughly comparable to a manuscript). The hardware (the device itself) executes software (processes it) and thus puts it into action. Software is the totality of information that must be added to the hardware for a software-controlled device to be usable for a defined range of tasks. Due to the software-controlled working principle, a rigid hardware can work individually. Today, it is not only used in classical computers, but also in many embedded systems, such as washing machines, mobile phones, navigation systems and modern TV sets.

The structure of a software



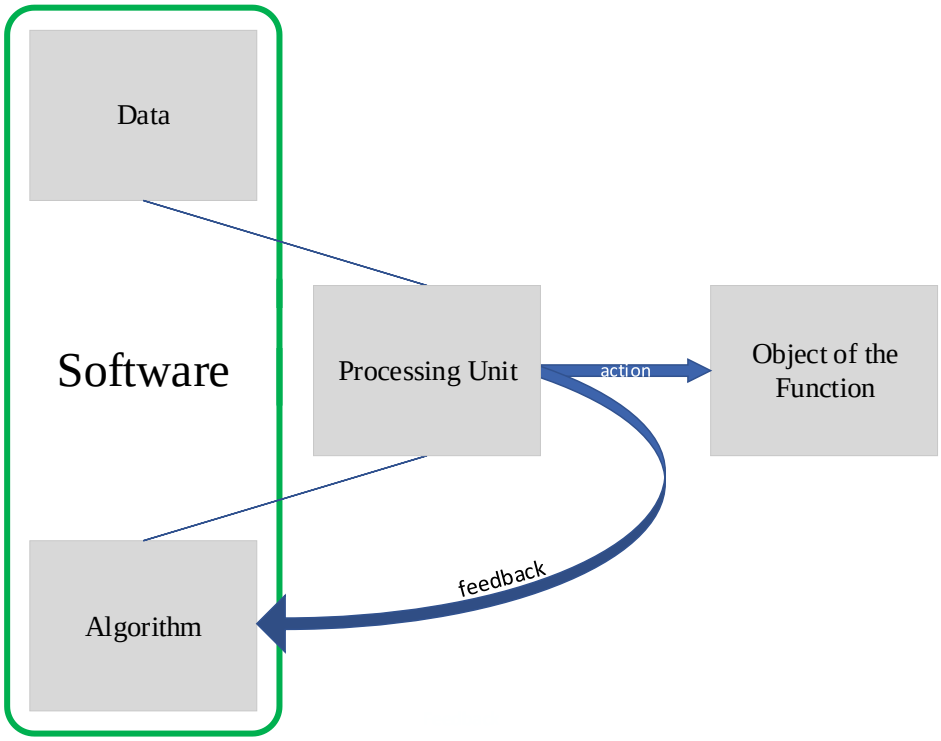

The processing unit usually starts the algorithm. The algorithm is set up in a Neumann machine as alternating command (what to do) and the information which data to use (on what to do). The result is a change of a parameter of the processing unit (an output signal is changed).

With this model one can define Software (Algorithm & Data) as parameters of the processing unit. This would be consistent with FA on components having a rest mass.



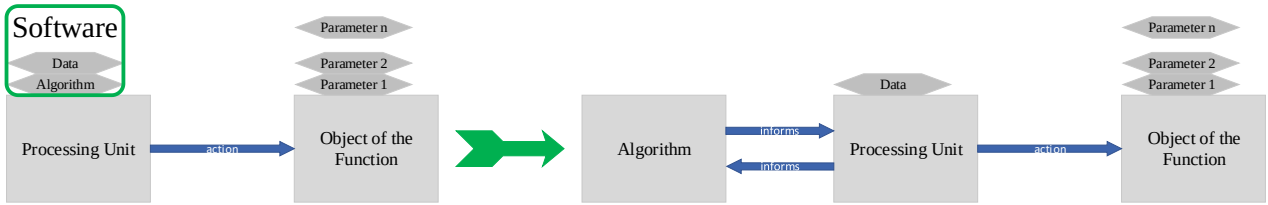

## 1.3 Artificial Intelligence (AI) in Functional Analysis

Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL) are technologies that are currently on hype. The basic research on these technologies has started in the 1950s to 1970s. The reason for its accelerated use today is now available resources like computers and storage. The core of AI, ML, DL is still a software with an operating algorithm. The difference to a "conventional" software is that the software is parametrized and changes its parameters on its own. The algorithm runs a feedback loop on itself on basis of the data input.




In the above definition of Algorithm being a parameter that would mean that a parameter changes itself – this will not work.

The suggestion in this case is to define an AI, ML or DL algorithm instead of being a parameter as a Field. A Field represents in TRIZ a component that has no rest mass but influences the parameter of the object of the function. As data is not affected on change it will stay a parameter.




## 2 Conclusions

Software (SW) is getting more and more important in technologies. Especially with the upcoming of Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL), software is changing its properties: from being a static algorithm towards changing its own parameters by itself. Up to now taking SW as a parameter of a processing unit worked. With AI systems we need to find other way to deal with SW in TRIZ. As a first rudimentary approach it is suggested to allow SW to be a field. This is set to discussion and we know that it needs more research to foster hypothesis.

## References

1. *Duden, Informatik : ein Sachlexikon für Studium und Praxis.* Dudenverlag, Mannheim u. a. 1993, ISBN 3-411-05232-5.
2. Wolfgang Lassmann: *Wirtschaftsinformatik : Nachschlagewerk für Studium und Praxis.* Gabler, Wiesbaden 2006, ISBN 3-409-12725-9, Kap. 4.1 Grundlagen. Zitat *„Software ist ein Sammelbegriff für die Gesamtheit der Programme, die zugehörigen Daten und die notwendige Dokumentation, die es erlauben, mit Hilfe eines Computers Aufgaben zu erledigen.“* (books.google.de)
3. *Lehr- und Übungsbuch Informatik: Grundlagen und Überblick.* Band 1, Hanser Verlag, 2003, ISBN 3-446-22543-9, S. 311. (books.google.de)
4. Tessen Freund: *Software Engineering durch Modellierung wissensintensiver Entwicklungsprozesse.* Berlin 2007, ISBN 978-3-940019-11-0, Kap. 2.1.1 „Software“, S. 25, Zitat Edmunds *„Software includes computer programs and data that is used by theses programs […] Software determines what a computer does and how it does it.“*; (books.google.de)
5. Tessen Freund: *Software Engineering durch Modellierung wissensintensiver Entwicklungsprozesse.* Berlin 2007, ISBN 978-3-940019-11-0, Kap. 2.1.1 „Software“, S. 25, Zitat Rothhardt; (books.google.de)
6. Litvin, S., Prokofiev, A., ”TRIZ Approach of Internet of Things”, TRIZfest 2018

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TRIZ*fest*-2021

# Horological TRIZ ruminations

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## Abstract

The author undertook to create a catalogue of examples for the application of the 40 inventive principles as used in the field of mechanical watchmaking. During the research for said catalogue a number of observations were made which are presented in this paper.

Keywords: *TRIZ, 40 Inventive Principles, Trends, Horology, Patents*

## 1 Introduction

The 40 Inventive Principles are generalized models for solutions, and they constitute one of the most popular tools of TRIZ [1]. When the founder of TRIZ Altshuller was studying inventive solutions and tried to extract the core of how inventors achieved their inventive step he abstracted these 40 "generalized models of solutions" [2]. And the documents he most studied were in fact patents [3].

Patents as a source of study of innovation have several advantages. Firstly, they are highly structured. After a summary of relevant names, dates and classifications, an abstract is given, followed by an explanation of the background, the problem the invention is attempting to solve and an in-depth description of the invention mostly using a number of drawings. The document finishes with the claims, a concise description of what the inventor wishes to be granted – the core of the invention so to speak.

In the years since Altshuller many authors have shown in various publications how the inventive principles are applied in various fields of industry. Papers that have been published on this topic include the application of these principles in the food industry [4], in shoe design [5], in the service industry [6] or in Semiconductor and High Tech [7], for example. Most, if not all of those recent studies show a basic catalogue of ideas however, rather than an in-depth study of the field based on patents. Looking through most recent TRIZ books the same picture emerges, patent documents are hardly ever mentioned [8, 9, 10] and this holds true even of some of Altshullers works [10]. Occasionally patent documents are quoted in relation to the 76 standard solutions [11], but in the same book those patent quotes are missing when the 40 inventive principles are discussed. A regular mentioning of patent documents, or more precisely Author's Certificates, in relation to the 40 inventive principles is in Altshullers standard work: "The Innovation Algorithm" [12], where he describes the inventive principles in the chapter "the inventor's instruments", and illustrates each one of them with one or more patent examples. The

advantage of this approach is obvious. Not only is the link to the engineering practice demonstrated, but furthermore a solution can be linked directly to the problem description as the inventor saw it.

In extension of this work, it was thus the objective of an investigation to explore one specific field of industry and using examples from the fundus of the patents as they are presented by the publicly available database of ESPACENET [13]. As a field of industry horology was chosen, and there particularly wristwatches. The International Patent Classification (IPC) code for Horology is G04, and it is classified under "Physics". A classification search reveals that 197 911 documents are filed under that code (April 13, 2021), the oldest document dating from August 4th, 1845 [14] the newest from March 16th, 2021 [15]. Looking further, the classification G04B denotes:

> *"MECHANICALLY-DRIVEN CLOCKS OR WATCHES; MECHANICAL PARTS OF CLOCKS OR WATCHES IN GENERAL; TIME PIECES USING THE POSITION OF THE SUN, MOON OR STARS".*

A classification search here had 99 111 hits (April 11, 2021) and this was indeed the classification used for most searches in the context of the paper, due partly to honour the mechanical heritage of TRIZ, but also to satisfy the curiosity of the Author with respect to mechanical timepieces. Some items required the search envelope to be widened, more on that later.

During this investigation several observations were made, and those are explained in the following paragraphs.

## 2 On the classification of patents

Some inventions are easy to classify. Take for example "GB189919583A Improvements in the Construction of Watches" [16]. The title is rather general and could apply to almost any of the inventions catalogued in the overview under consideration. The Problem description is more revealing [Page 1, Line 4 to 6]:

> *The object of my invention is to construct or convert watches to go from one day to seven or eight days or for a longer period if required with one winding up.*

Continuing to the solution proposed and claimed by this invention we read [Page 1, Line 30 to Page 2, Line 4]:

> *I employ two main-springs and barrels (or spring wheels) of suitable power, in lieu of the single main-spring and barrel. The said barrels … are connected by and drive the pinion of an extra or intermediate wheel C, the said intermediate wheel being placed behind the centre wheel so as to gear with and drive the centre pinion; the rest of the watch consisting of trains of wheels with the ordinary English, Swiss, American, or other mechanism.*

Classification is easy here, employing two main springs instead of a single one points towards Inventive Principle #1, Segmentation, and specifically to "divide an object into independent parts" [17].

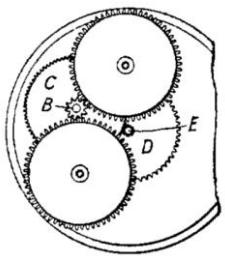


Fig. 1. Illustrating from the invention of GB189919583A, filed September 29th, 1899

Other documents however were more difficult to classify. Take for example "US7896542B2 Timepiece movement fitted with a vibrating alarm" [18]. The title suggests clearly that vibration is used, which points to Inventive principle #18, "Mechanical vibration". However, a careful study of the problem description reveals the following [Column 1, Paragraph 4]:

> *… This watch has drawbacks, however. Indeed, the alarm mechanism includes specific elements enabling the mechanism to operate in silent alarm mode, which increases the complexity and size of the structure …*

This sets the scene in that the problem to be solved is related to the complexity and size of the structure. The authors proposed solution to the problem is succinctly described in claim 1 [Column 9, Paragraph 1]:

> *A timepiece movement including: (a) a first energy source, wherein said first energy source is coupled to an oscillating weight by a first kinematic chain for automatically winding said movement; and (b) a second energy source, wherein said second energy source is coupled both to an activating device, and to a vibrating element, by a second kinematic chain, to form a vibrating alarm mechanism that can be activated or triggered at a predetermined time; wherein the vibrating element of said vibrating alarm mechanism is said oscillating weight*

Thus more close investigation reveals that, the proposed solution is based on the inventive principle #5, Merging / Combination, and specifically to "… bring closer together (or merge) identical or similar objects, assemble identical or similar parts to perform parallel operations." [19]

So while the overall topic of using vibration to alert a user is an application of one Inventive Principle, this is not the problem solved by this specific patent document.

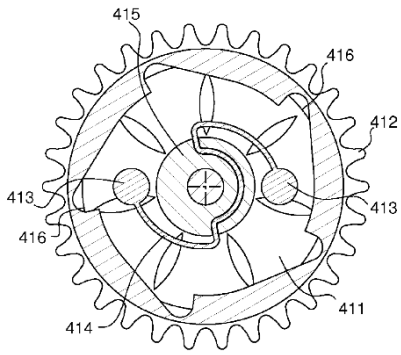


Fig. 2. A drawing from the patent document US7896542B2, filed December 1st, 2008

There is an analogy from the above to the general application of TRIZ tools. It pays to carefully investigate the problem before applying the tools. Specificity and exactness are important and pay off, both, to obtain good classification examples as well as to achieve proper TRIZ problem solving results.

## 3 On the MPV of patents

Another observation relates to the direction in that horology patents develop. One would expect that this development by and large follows the S-curve. If one assumes the Trend of the S-curve to be true [20], one should see a steady and obvious increase of the MPV in this field also reflected in the patents filed through time. This is however not patently obvious when investigating which features are used in recent new watch releases of mechanical watches and specifically in "haute horology" and the directions initially seem rather random.

Take, for example the development of the face of a mechanical watch. One sees a classic evolution from a single hand depicting only the hours in 12 or 24 intervals, to a two-handed construction whereby the hours are depicted in 12 intervals and the minutes are superimposed in 60 intervals. Modern wristwatches add a third hand for the seconds, and this arrangement has established itself as the standard version for the face of an easy reading timepiece, see figure 3.

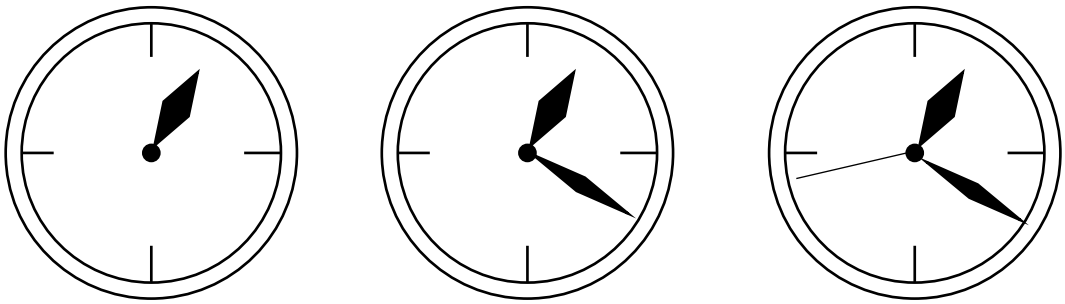

Fig. 3. Illustrating from left to right a single hour hand, a hour and minute hand and a hour minute and central second hand

It is safe to assume that the single hour hand was born as the initial and simplest technical version of showing time, and the invention was too early to be recorded in any modern patent database. A watch face showing a short hour hand in combination with a longer minute hand is today widely used on church towers or alarm clocks. Without the seconds, or in combination with a small satellite second hand it is also the epitome of elegant dress-wristwatches. All these applications do not require the reading of time with the precision of a second. If at all, the small satellite second will indicate predominantly that the watch is still running rather than an exact indication of time. However, with a central second hand added a watch becomes suitable for all-round usage whereby for example races may be timed to the second, and this type of dial has become the default watch face for most watches.

In this way the development trend seems to be clear. Why then has the format of the single-handed watch been recently resurrected in a wristwatch format and is marketed as representing the pursuit of quality time, rather than the race to capture the very last second [21]? And why are new patents filed in this field even today [22]?

Fig. 4. Illustration from document WO2016012126A2 SINGLE HAND WATCH, filed July 23rd, 2014

Take another example: Clocks with a so-called regulateur dial were used in specific applications where utmost precision was of particular importance, in watch factories as master clocks, and also at train stations for example. Apart from being provided with a very exact movement, they

distinguished themselves by separating the axis of the hour indicator from the axis of the minute indicator as shown in Figure 5.

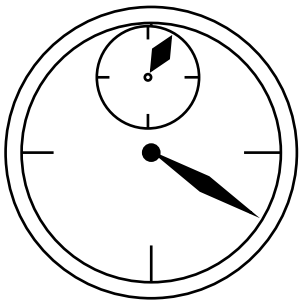

Fig. 5. Illustration of a typical watch face of a regulateur type watch

As a consequence of the arrangements the hands of the watch only overlap each other once every 12 hours. Also, the prominent minute hand makes it easy to read the time exactly. Again, after having been virtually forgotten, this type of watch face design surfaced in 1987 for the first time in wristwatches [23]. And many companies not only produce such type of watches, but are also patenting new ideas as to their workings [24, 25]

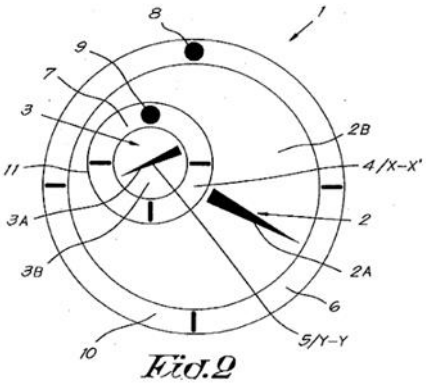


Fig. 6. Watch face and mechanism from document EP2510406B1, filed December 11th, 2009

Thus, the question arises: how does the renaissance of long-forgotten techniques increase the MPV? What is it that makes these techniques relevant today? Likely the answer lies in part in the nature of mechanical timekeeping. Mechanical watches for the purpose of timekeeping has long been surpassed in exactness and convenience, first by electronic and quartz watches, and later by mobile devices and smart watches. The precision provided for time keeping has moved from the mechanical domain to a supersystem of linked networks. The place that mechanical watches occupy in the market, has thus moved from one of exactness of timekeeping to one of status. Thus, the normal rules of utility do not apply. Complexity, individualism and character [26] may play a much more pronounced role than exactness of timekeeping. This again fits perfectly in the trend of the s-curve, the special case of systems in stage 4: reincarnation [27]. In fact, a large part of the swiss watch industry seems to be thriving by following this trend, after their near extinction during the “quartz crisis” of the 1980ies.

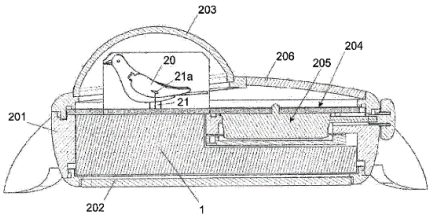


Fig. 7. Watch with integrated automaton from document EP2880498A1, filed July 31st, 2012

There is however another explanation that, at least in part accounts for some of the aforementioned developments. The filing of patents and success in the market are two different things. Whereas success in the market is in line with a growth of MPV, a granting of a patent is not. Furthermore, the quality of the filed patent documents varies widely. Some of the documents are merely patent applications, which were filed but never granted, due to lack of novelty or inventiveness or several other reasons. Other documents are granted patents, but the examination procedure and the quality of examination may vary with country and individual examiner, so also here the quality is not guaranteed, and some inventions may even not work as proposed in the patent. Furthermore, a patent application may be aimed at fulfilling rather esoteric needs [28].

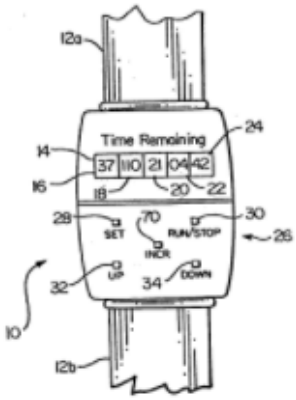


Fig. 8. An image from US5031161A, a watch that, based on a set of data, calculates and displays the wearer's remaining life expectancy; filed February 15th, 1991

## 4 The mists of time

During the attempt to find examples for all inventive principle, it became apparent that many obvious examples of the application of inventive principles in horology were missing in the patent database. Especially the inventors of some of the oldest and fundamental inventions of mechanical watchmaking are unknown.

Early mechanical clocks, for example, often had a single hand only to indicate the hours [29]. As clocks and watches became more accurate a single hand was not sufficient any more to indicate the exact time. Inventive Principle #1 was applied, and clocks and watches moved from displaying the time with a single hand to two or more hands. However, this change happened in the middle ages, patent law did not exist, and neither the inventor nor the history of the invention has been recorded.

In the centuries following the middle ages, patent law was slowly established, and it did exist to some extend during the time of Abraham-Louis Breguet who lived at the time of Napoleon and was one of the foremost innovators in watchmaking who patented many of his inventions. These include some milestones in the development of watches [30], both in terms of practicality as well as accuracy, such as the self-winding watch (1780), the ratchet key for winding clocks and watches (1789), the constant force escapement (1798) and the tourbillon (1801). However, while these inventions were patented, the patent documents are too early to be included in the modern patent database and will thus not be found when searching.

Furthermore there is also a cultural bias in that many early inventions made, for example in China, India, or the Arabic countries are not recognized, documented or known in the Western world.

Thus, there is a gap in knowledge either due to the fact that over time the inventors have been forgotten, that they belong to a cultural horizon not well documented in our western society, and/or due to the incompleteness of the available databases, and unfortunately, this gap includes some of the most fundamental inventions ever made with respect to horology.

## 5 The specificities of mechanical timepieces

Another difficulty appeared when trying to identify examples for some of the inventive principles. Most inventive principles are very general and can be widely applied in all fields of science. However a few seem specifically aimed at a much narrower technical field. While examples of utilizing them in horology may exist, their main application lie elsewhere.

Take, for example, Inventive Principle #38: Strong oxidants. The first recommendation is to move “from ambient air to oxygenated” air [31]. Only after extensive search a patent by Rolex was identified [32]. It discusses that self-compensating spiral springs for a mechanical balance-spiral spring oscillator for a watch or clock movement or other precision instrument can be made of an Nb-Hf paramagnetic alloy possessing a positive thermal coefficient of Young's modulus (TCE), capable of compensating for the thermal expansion of both the spiral spring and the balance. In the manufacturing of these springs, during heating and cooling, it has been found that the initiation of recrystallization and its development depend on the oxygen concentration, which in turn is a key parameter to influence the TCE.

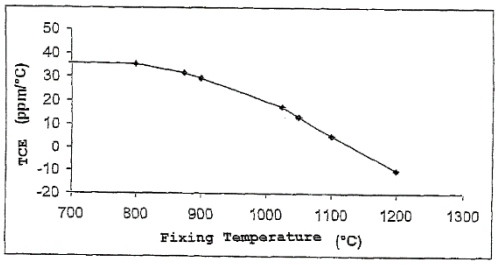


Fig. 9. shows a graph of TCE (ppm/[deg.] C.) charted with respect to the fixing temperature ([deg.] C.). Filed May 18th, 2001

It is apparent that the invention, while being important to improve a specific component that is utilized in a watch, may just as well be applicable to the manufacturing of components in other industries. Still, it may be the best example available for the use of this inventive principle in horology. Therefore, in many ways luck is needed to identify suitable examples for some of the inventive principles.

Another related issue appears with Inventive Principles that relate to techniques used in non-mechanical watchmaking. Take for example Inventive Principle #28, Mechanics substitution [33]. Replacing mechanics in mechanical watchmaking mostly leads to identifying inventions in electronics or smart watches [34], which on one hand leaves the original scope of the investigation but on the other hand points clearly towards the direction that the industry has taken as a whole.

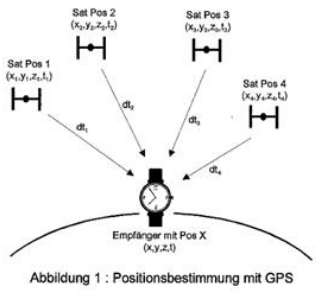


Fig. 10. Drawing from document DE19821320A1, filed May 13th, 1998

## 6 Conclusions

At the conclusion of this paper, the work on identifying a suitable set of 40 inventive principles for horology has not yet been concluded. Several interesting observations can nevertheless already be made:

1. To illustrate the inventive principles well, it is paramount to be precise and to carefully identify both, the problem to be solved as well as the solution found in the respective patent documents.
2. As mechanical timepieces and "haute horology" specifically are by and large in the "reincarnation" phase of the s-curve, the MPV is not based on utility, but on other, mostly status-related factors.
3. Many fundamental inventions in mechanical watchmaking have been made a long time ago, and the inventors have been forgotten, and/or their documents are not available in today's publicly available databases.
4. While many inventive principles are easy to illustrate, some are much less so, as their proposed direction leads away from the core of the field to be investigated: mechanical timepieces.
5. Finally, and not to be forgotten, the research has offered the author an extremely interesting insight into a fascinating world where mechanical excellence has not been replaced with electrons and bits.

## References


1. Altshuller, Genrich; "40 Principles, Extended Edition". Technical Innovation Center, Worcester, MA, 2005, ISBN 0-9640740-5-2. p. 7.
2. Gordon Cameron; "TRIZICS". CreateSpace 2010, ISBN 97881456319892. p. 298.
3. Altshuller, Genrich; "40 Principles, Extended Edition". Technical Innovation Center, Worcester, MA, 2005, ISBN 0-9640740-5-2. p. 12.
4. Barry Winkless et al; "Food Product Development and the 40 Inventive Principles". The TRIZ Journal, May 13th, 2001. https://triz-journal.com/food-product-development-40-inventive-principles/. Last accessed: April 13th, 2021.
5. Darrell Mann; "40 Inventive (Shoe) Principles". The TRIZ Journal, September 4th, 2019. https://triz-journal.com/40-inventive-shoe-principles/. Last accessed: April 13th, 2021.
6. Nadhmi Gazem et al. "Game Cards for TRIZ 40 Inventive Principles in service". The TRIZ Journal, April 24th, 2018. https://triz-journal.com/game-cards-for-triz-40-inventive-principles-in-service/ . Last accessed: April 13th, 2021.
7. Richard Platt. "40 Inventive Principles with examples from Semiconductor and High Tech". https://www.slideshare.net/rplatt/40-inventive-principles-with-examples-for-high-tech-and-semiconductor . Last accessed: April 13th, 2021.
8. S. D. Savransky. "Engineering of Creativity". CRC press Florida, USA, 2000. ISBN 0-8493-2255-3, pp 204-219 and 365-367.
9. V. Fey et al. "Innovation on Demand". Cambridge University Press, 2007. ISBN 978-0-521-82620-4. pp 106-222.
10. D. Mann. "Hands on Systematic innovation". CREAX press, Belgium, 2002. ISBN 90-77071-02-4. pp. 203-218 and pp. 245-271.
11. G. Altshuller et al. "Tools of Classical TRIZ", ISBN 978-1928747024. pp. 119-189.
12. G. Altshuller. "The Innovation Algorithm". Technical Innovation Center, Worcester, MA, 2007, ISBN 0-9640740-4-4. pp. 131 - 162

13. https://worldwide.espacenet.com/patent/my-espacenet last accessed: April 13th, 2021.
14. John Bliss et al; "US4135A Improvement in the compensation-balance of time-keepers". Filed May 26th, 1845.
15. 南京邮电大学; "CN112506030A A time-to-digital converter based on the PVT detection circuit"; Filed February 4th, 2021.
16. GANTER JOHN; "GB189919583A Improvements in the Construction of Watches". Filed September 29th, 1899.
17. Altshuller, Genrich; "40 Principles, Extended Edition". Technical Innovation Center, Worcester, MA, 2005, ISBN 0-9640740-5-2. pp.24, 25.
18. BORN JEAN-JACQUES et al.; SWATCH GROUP RES & DEV LTD; "US7896542B2 Timepiece movement fitted with a vibrating alarm". Filed December 1st, 2008.
19. Dr. Sergei Ikovenko et al. "Theory of Inventive Problem Solving – State of the Art". Warsaw, 2019, ISBN 978-83-65899-??-?. p. 166.
20. Alex Lyubomirskiy et al; "Trends of Engineering System Evolution (TESE)"; TRIZ Consulting Group, MATRIZ, Nurnberg, Germany, 2018. pp. 10-36.
21. Meistersinger watches. https://www.meistersinger.com/int/portrait/. Last accessed: April 12th, 2021.
22. ZEOLI STEFAN; "WO2016012126A2 SINGLE HAND WATCH". Filed July 23rd, 2014.
23. www.chrono24.com: https://eur01.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.chrono24.com%2Fmagazine%2Fregulator-watches-p_11413%2F&data=04%7C01%7C%7Cab6aa79732bc431d751608d8fe72b359%7C1a407a2d76754d178692b3ac285306e4%7C0%7C1%7C637539115878178659%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000&sdata=nku54SKgU65R%2B9ODAaehyqT%2Fg4pgZ2WyoG%2BtSazA2dM%3D&reserved=0 . Last accessed: April 12th.
24. LANG GERD-RUEDIGER; Chronoswiss. "WO02075460A1 WATCH MOVEMENT". Filed March 21st, 2009.
25. Benoit Mintiens; Ressence. "EP2510406B1 DIAL MODULE FOR A WATCH, AND WATCH INCLUDING SUCH A DIAL". Filed December 11th, 2009.
26. JUNOD FRANÇOIS; MONTRES JAQUET DROZ SA. "EP2880498A1 WRISTWATCH PROVIDED WITH AN ANIMATION ABOVE THE DIAL". Filed July 31st, 2012
27. Alex Lyubomirskiy et al; "Trends of Engineering System Evolution (TESE)"; TRIZ Consulting Group, MATRIZ, Nurnberg, Germany, 2018. p. 34.
28. KENDRICK DAVID; "US5031161A Life expectancy timepiece". Filed February 15th, 1991
29. Eric Bruton; "The History of Clocks and Watches"; Macdonald & Co (Publishers) Ltd, London, 1989. p.54
30. https://www.breguet.com/en/timeline/1747-1800/milestones#. Last accessed: April 14th.
31. Altshuller, Genrich; "40 Principles, Extended Edition". Technical Innovation Center, Worcester, MA, 2005, ISBN 0-9640740-5-2. p. 98.
32. BAUR JACQUES et al; ROLEX SA. "US6705601B2 Self-compensating spiral spring for a mechanical balance-spiral spring oscillator"; filed May 18th 2001.
33. Karl Koltze et al; "Systematische Innovation". Hanser Verlag München Wien, 2011. pp. 80 – 81

34. GASSNER CHRISTIAN; "DE19821320A1 Wristwatch with satellite receiver for navigation and time transmission". Filed May 13th, 1998.

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# HOW TO HOLD STRATEGIC SESSIONS VIA TRIZ TOOLS

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Paper category: Systematic creativity, methods for automated inventing, and innovation management in the dialog with TRIZ or any other topic related to TRIZ.

## Abstract

The TRIZ Business Association [16] has accumulated sufficient experience in conducting strategic sessions [1] for commercial organizations using TRIZ. The objectives of strategic sessions may vary, but most often come down to finding strategic decisions that need to be made for the survival and development of an organization in a changing market environment. It is the rapid changes in the market environment that impose significant restrictions that render ineffective the organization's previous business models, products and / or key business processes that provide a sustainable value proposition for the company (Figure 1). The main assumption that was postulated when developing a strategic session program is that the value proposition of a commercial organization should maximally meet the requirements of the main stakeholders of the business system and key supersystems. The methodology for conducting a strategic session, proposed in this work, is based on this assumption. The purpose of the strategic session is to develop a set of measures to solve the initial problem posed by the customer.

Keynotes: TRIZ, strategic sessions, MPV-analysis, system of technical contradictions.

## 1 Introduction.

The objectives of strategic sessions may vary, but most often come down to finding strategic decisions that need to be made for the survival and development of an organization in a changing market environment.

It is the rapid changes in the market environment that impose significant constraints that render ineffective the organization's previous business models, products and / or key business processes that provide a sustainable value proposition for the company (Figure 1).

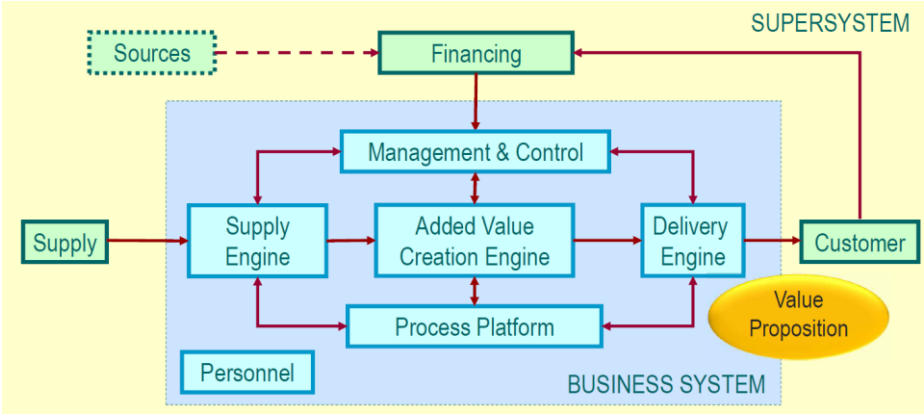


Fig. 1. The concept of a business system, taken as a basis in business TRIZ [2].

The main assumption that was postulated when developing a strategic session program is that the value proposition of a commercial organization should maximally meet the requirements of the main stakeholders of the business system and key supersystems (Figure 1). The methodology for conducting a strategic session, proposed in this work, is based on this assumption.

The purpose of the strategic session is to develop a set of measures to solve the initial strategic purpose posed by the customer.

Examples of strategic sessions purposes:

3. How, while maintaining the quality of bread production significantly reducing the capital intensity of production and the required area of the enterprise to scale up the business?
4. How to increase revenues at least 10 times for a startup «Fightingnet»?
5. How to provide Russia's strategic projects with unique equipment in the face of increasing sanctions pressure of USA?
6. Development of measures to support the construction industry in the Ural Federal District in the face of restrictions associated with COVID-19 in 2020 in Russia etc.

## 2 The sequence of actions during the strategic session and the applied TRIZ tools.

The strategic session is holding in the following sequence:

1. Statement of the strategic goal as if a problem.
2. Schematization of the inventive situation [3].
3. Selecting key stakeholders.
4. Determining the requirements of key stakeholders.
5. *Choice of the target hypothesis*.
6. Determination of the degree of compliance with the requirements of stakeholders in the framework of the selected target hypothesis.
7. Definition of gaps.
8. Selection of preliminary solutions for bridging the gaps.
9. Determination of secondary undesirable effects.
10. Modeling contradictions.
11. Resolution of contradictions.

Below is a table of the correspondence of TRIZ tools to the performed action from the above sequence (Table 1).

Table 1. Correspondence of TRIZ tools to the performed action from the sequence during the strategic session.

| N | **Activity** | **TRIZ tools and other tools** |
|---|---|---|
| 1 | Statement of the strategic goal as if a problem. | • Administrative contradiction [13].<br>• Description of innovative situation. |
| 2 | Schematization of the inventive situation [4]. | Schematization [4]. |
| 3 | Selecting key stakeholders. | Schematization [4]. |
| 4 | Determining the requirements of key stakeholders. | MPV-analysis [5]. |
| 5 | Choice of the target hypothesis. | *See bellow* |
| 6 | Determination of the degree of compliance with the requirements of stakeholders in the framework of the selected target hypothesis. | MPV-analysis [5]. |
| 7 | Definition of gaps. | MPV-analysis [5]. |
| 8 | Selection of preliminary solutions for bridging the gaps. | • Brain storming [7].<br>• List of Contradictions in ITB form. |
| 9 | Determination of secondary undesirable effects. | • Brain storming [7].<br>• List of Contradictions in ITB form. |
| 10 | Modeling contradictions. | Technical contradictions. |
| 11 | Resolution of contradictions. | • Contradiction analysis [3].<br>• Inventive Principles [10].<br>• IFR + Resources for business TRIZ [4]. |
| 12 | System assembly and analysis of the obtained transformations. | • Mind Map [8].<br>• Multicriterial matrix of solutions [2].<br>• Ideas Landscape [2]. |

## 3 Choice of the target hypothesis.

Table 1 shows that you should use existing TRIZ-tools. There are materials described TRIZ tools mentioned in paragraph 4 of this paper.

There is only a step in the proposed algorithm to describe in detail. It is the point 5 in the table 1.

This tool is not specific to TRIZ. Nevertheless, we have added this tool to the toolkit of strategic sessions for a reason. The fact is that strategic sessions are always associated with forecasting tasks, with an attempt to look into the future. And the future, as you know, is always vague. The word "vague" should be understood as a problem with many unknowns. So, the target hypothesis is designed to convert some of the variables into constants through the formulation of hard constraints. In this case, we are not trying to predict any events, but artificially translate

some of the variables into constants. In such cases, consideration of the degree of compliance of the system under study with the requirements of stakeholders may turn out to be much easier, and even the search for intermediate solutions - and even more so, becomes obvious.

Here are some examples of such strategic assumptions.

Example 1:

In solving the problem of stabilizing the construction industry during the COVID-19 pandemic in 2020, we introduced the assumption that strict restrictions will last for at least 3 years (fortunately for everyone, in reality, everything turned out to be not so bad).

Example 2.

In the problem of the multiple growth of the bakery's business, the most important hypothesis was introduced:

The quality of the product remains unchanged. Hence, the task immediately arose in a new formulation: how to preserve the quality of the product, by several times reducing the capital intensity of production and the required area with the aim of further scaling up the business?

Why is that? The fact is that this enterprise has reached great heights in terms of product quality, its products have won all kinds of competitions. In this case, it was the correct focus during the strategic session.

Example 3.

Introduction of alternative hypotheses in the problem of developing a strategy for a distribution company under sanctions restrictions from the United States.

- we conditionally believe that the sanctions completely cut off access to European and American equipment. Further, we assume that this resource is 100% closed for us.
- we conditionally believe that without European and / or American equipment, in the next 5 years, large customers will not be able to solve their strategic tasks. Further, we work with the assumption that this equipment will need to be imported into Russia in any case, and the country will solve this problem at the state level.

Since the work was carried out specifically with commercial organizations, the first hypothesis was chosen about the complete prohibition of the import of this equipment into the territory of the Russian Federation, as the most unfavorable option. All the solutions found subsequently corresponded precisely to this hypothesis.

## 4 Case.

Case "How to continue deliveries of unique equipment in the face of increasing USA sanctions pressure"?

The case was supplied by a distribution company. Published with restrictions. The material has been partially changed. The course of the solution is shown before contradictions are revealed. Recommendations resulting from the session are not listed in this paper.

### 4.1 Administrative contradiction.

Problem: in the context of the sanction’s restrictions, difficulties arise with the supply of equipment for company X.

Required: to develop measures to preserve the distribution business.

System composition: company, suppliers, competitors, legal framework, consumers in the target area.

Limitations: solutions must be in the legal framework.

## 4.2 Schematization of the initial situation.

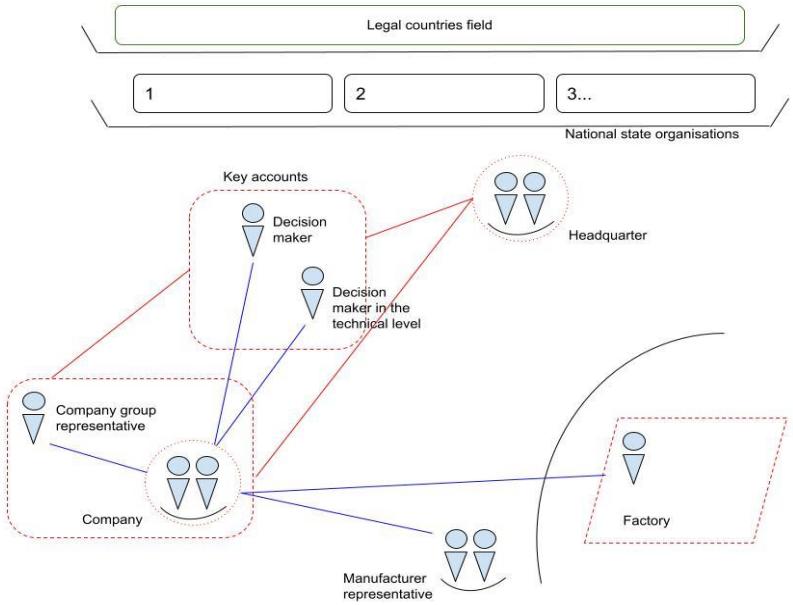


Figure 2. Schematization of the initial situation.

## 4.3 Highlighting key stakeholders on the diagram.

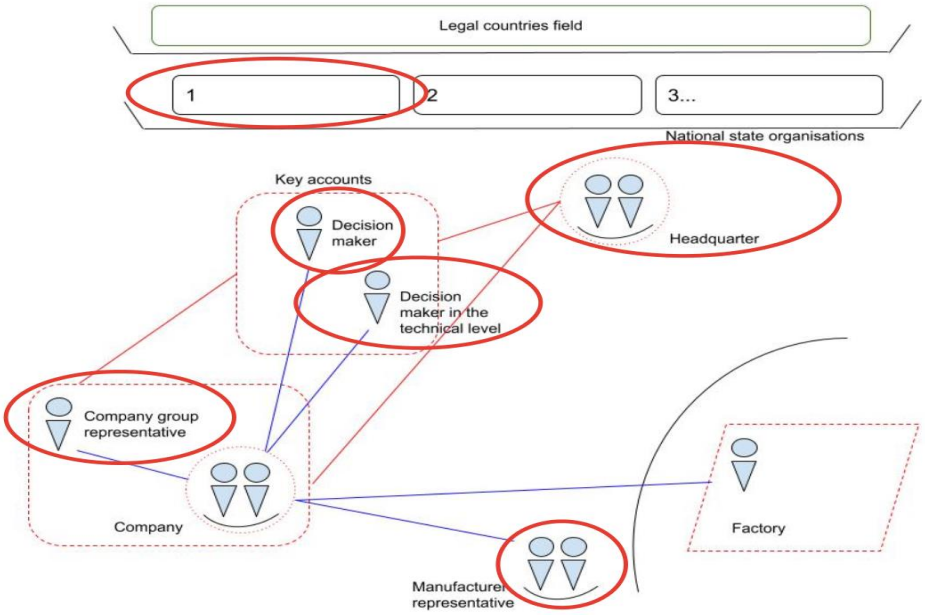


Figure 3. Highlighting key stakeholders on the diagram.

## 4.4 Determination of the Stages of the process life cycle.

Process: purchase of unique equipment.

Main steps:

- Determination of the need according to the requirements of the State Program.
- Working out the task with the customer.
- Working with the criteria for making a decision of the customer.
- Coordination and entry into the purchasing plan.
- Tender.
- Contract and placing an order with the manufacturer.
- Delivery according to the contract.

## 4.5 Definition of stakeholder's MPVs.

There are stakeholders (figure 3) in lines and stages of the process life cycle in columns.

Table 2. Definition of stakeholder's MPVs [4].

| | **Determination of the need according to the requirements of the State Program** | **Working out the task with the customer** | **Working with the criteria for making a decision of the customer** | **Coordination and entry into the purchasing plan** | **Tender** | **Contract and placing an order with the manufacturer** | **Delivery according to the contract** |
|---|---|---|---|---|---|---|---|
| **Decision maker on the top level** | Compliance of the state program with the capabili-ties of the customer | Compliance with the terms of reference | Best supplier | Deadline<br><br>Compliance of the formal requi-rements | Best supplier | - | Deadline<br><br>Compliance of the formal requirements |
| **Decision maker on the technical level** | Equipment renewal | Compliance with the terms of reference<br><br>Proposal optimi-zation | Best supplier | Minimum involvement<br><br>Compliance with the terms of reference | Compliance with the terms of reference | - | Trainings of technical staff<br><br>Technical support |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Company group rep-resen-tative** | Quantity of attract-ing invest-ment | - | Several convenient suppliers-rivals | Purcha-sing deadline<br><br>Compli-ance of the for-mal requi-re-ments | Law com-pli-ance | - | Deadline |
| **Head-quar-ter repre-sent-tative** | - | - | Several convenient suppliers-rivals | Purcha-sing deadline<br><br>Compli-ance of the for-mal requi-re-ments | - | - | - |
| **Ministry of Education and Science represent-tative** | Quantity of attract-ing invest-ment<br><br>Minimum appropri-ate scien-tific-cal base | Local manufac-turer prior-ity | - | Compli-ance of the for-mal requi-re-ments | Compli-ance with ministry restric-tion to allow for suppli-ers to par-tici-pate in the con-tracts<br><br>Local manufa-cturer pri-ority | Special ac-counts compli-ance<br><br>Cash flow control compli-ance | Deadline<br><br>PR to tar-get audi-ence |
| **Manufa-cturer rep-resent-ta-tive** | - | Participa-tion in the contest | Winning in the tender | To be al-lowed | Creating the terms of refer-ence ac-cording to their ad-vanta-ges<br><br>Compli-ance with the anti-corrup-tion agree-ment for all compe-titors | Quantity of getting revenues | Compli-ance with the anti-corrup-tion agree-ment for all com-pete-tors<br><br>Deadline<br><br>Compli-ance of the formal re-quire-ments |

## 4.6 Choice of the target hypothesis.

- *Hypothesis 1*. We conditionally believe that the sanctions completely cut off access to necessary equipment. Further, we assume that this resource is 100% closed for the target area.
- *Hypothesis 2*. We tentatively believe that without necessary equipment in the next 5 years, large customers will not be able to solve their strategic tasks. Further, we work with the assumption that this equipment will need to be imported in the target area in any case, and the government will solve this problem at the state level.
- Solution: choose the *first hypothesis* as the most unfavorable option.

## 4.7 Determination of the degree of compliance of the process with the requirements of the stakeholders, considering the chosen hypothesis. Identifying gaps.

Table 3. Determination of the degree of compliance of the process with the requirements of the stakeholders.

| **Stakeholder's MPVs** | **Low** | **Medium** | **High** |
|---|---|---|---|
| **1) Decision maker** | | | |
| *Compliance of the state program with the capabilities of the customer* | + | | |
| *Compliance with the terms of reference* | + | | |
| Best supplier | | | + |
| Deadline | | + | |
| Compliance of the formal requirements | | | + |
| **2) Decision maker in the technical level** | | | |
| *Equipment renewal* | + | | |
| *Compliance with the terms of reference* | + | | |
| Proposal optimization | | + | |
| Best supplier | | + | |
| Minimum involvement | | | + |
| Compliance with the terms of reference | | | + |

| | | | |
|---|---|---|---|
| Trainings of technical staff | | | + |
| Technical support | | + | |
| **3) Company group representative** | | | |
| Quantity of attracting investment | | | + |
| Several convenient suppliers-rivals | | + | |
| Purchasing deadline | | | + |
| Compliance of the formal requirements | | | + |
| Law compliance | | | + |
| Deadline | | | + |
| **4) Headquarter representative** | | | |
| Several convenient suppliers-rivals | | + | |
| Purchasing deadline | | | + |
| Compliance of the formal requirements | | | + |
| **5) Ministry of Education and Science representative** | | | |
| Quantity of attracting investment | | + | |
| *Minimum appropriate scientifical base* | + | | |
| Local manufacturer priority | | | + |
| Compliance of the formal requirements | | | + |
| Compliance with ministry restriction to allow for suppliers to participate in the contracts | | | + |
| Special accounts compliance | | | + |
| Cash flow control compliance | | | + |
| Deadline | | | + |

| | | | |
|---|---|---|---|
| PR to target audience | | | + |
| **6) Manufacturer representative** | | | |
| *Participation in the contest* | + | | |
| *Winning in the tender* | + | | |
| *To be allowed* | + | | |
| *Creating the terms of reference according to their advantages* | + | | |
| Compliance with the anti-corruption agreement for all competitors | | | + |
| *Quantity of getting revenues* | + | | |
| Compliance with the anti-corruption agreement for all competitors | | + | |
| *Deadline* | + | | |
| *Compliance of the formal requirements* | + | | |

**Notice:**

- Gaps are in italics.
- MPVs of manufacturer representative are not considered further since it depends on the current situation and cannot influence it.

## 4.8 Determination of harmful effects and identification of contradictions. Modeling contradictions in the ITB format.

Further, we consider only gaps, and we try to find a previous solution by brainstorming with an expert team. After that, we are determining the second harmful effects to get contradictions.

Unfortunately, not all previous solutions in this work can be published. In some cells of the matrix, intermediate solutions have been removed and replaced with the entry "SOLUTION N ...".

Table 4. List of contradictions.

| N | IF | THEN | BUT |
|---|---|---|---|
| 1 | Compliance of the state program with the customer's capabilities is low (compiled by capabilities). | SOLUTION 1 | The negotiation process and signing of agreements can take more than 1 year. |
| 2 | Compliance of the state program with the customer's capabilities is low (compiled by capabilities). | Conduct a detailed analysis of suppliers from all non-restricted countries.<br>Conduct a product analysis of approved vendors to select strong solutions (decision revision). | Identified suppliers might not provide the required service support. |
| 3 | Compliance of the state program with the customer's capabilities is low (compiled by capabilities). | Conduct a detailed analysis of suppliers from all non-restricted countries.<br>Conduct a product analysis of approved vendors to select strong solutions (decision revision). | Customer confidence in the brand may be insufficient. |
| 4 | Compliance of the state program with the customer's capabilities is low (compiled by capabilities). | Conduct a detailed analysis of suppliers from all non-restricted countries.<br>Conduct a product analysis of approved vendors to select strong solutions (decision revision). | Insufficient supplier solvency. |
| 5 | Compliance of the state program with the customer's capabilities is low (compiled by capabilities) | SOLUTION 5 | The target channel might be closed down. |
| 6 | Compliance of the state program with the customer's capabilities is low (compiled by capabilities) | SOLUTION 6 | It is prohibited by a law. |

| | | | |
|---|---|---|---|
| 7 | Compliance of the state program with the customer's capabilities is low (compiled by capabilities) | SOLUTION 7 | The negotiation process and signing of agreements can take more than 1 year. |
| 8 | Compliance of the state program with the customer's capabilities is low (compiled by capabilities) | SOLUTION 8 | Customer's equipment has access restrictions. |
| 9 | Compliance of the state program with the customer's capabilities is low (compiled by capabilities) | SOLUTION 9 | The risk to lose business. |
| 10 | Compliance of the state program with the customer's capabilities is low (compiled by capabilities) | Development of devices that meet the requirements of a state customer. | The risk not to get the goal. |
| 11 | Compliance of the state program with the customer's capabilities is low (compiled by capabilities) | Development of devices that meet the requirements of a state customer. | Unacceptably long process. |
| 12 | Compliance of the state program with the customer's capabilities is low (compiled by capabilities) | Development of devices that meet the requirements of a state customer. | The available budget would be not sufficient. |
| 13 | Compliance with the terms of reference is insufficient | See above | |
| 14 | … | | |

You get the goals of the strategic session after resolving of all contradictions. After doing that you must sum up all solutions with the one mind map [8] to analyze them before getting the road map.

## 5 Discussion

The strategic session is not always held using the technologies described in this article. It happened that we had to use the system operator [13], flow analysis [4], functional analysis for

business systems [15], as well as the concept of ideality and the IFR in order to find innovative solutions at the upper level of the problem statement (this option was present in our practice, and it worked very successfully).

Even though the author conducted most of the strategic sessions according to the technology presented in these guidelines, as follows from the above paragraph, deviations from it are quite common.

A separate subject should be considered the use of lines of systems development in strategic sessions, specially developed for business systems. This tool belongs to TRIZ predictive tools and its use for such tasks is self-evident.

In addition, a promising direction is a synthesis of TRIZ tools with traditional methods of business analysis, including methods that are actively used in the IT environment in the conceptual design of software products.

We invite interested specialists to the discussion.

## References


1. Turn. Proven Market Capture Technique / Luke Williams. - M .: Mann, Ivanov and Ferber, 2012.
2. V. Soushkov. TRIZ and Systematic Business Model Innovation, Bergamo University Press. 2010.
3. TRIZ: solving business problems / A.P. Kozhemyako, 3rd ed. - M .: University "Synergy", 2021.
4. TRIZ: a practical guide for business / A.P. Kozhemyako. - M .: University "Synergy", 2021.
5. A. Efimov. MPV analysis technique, 2008
6. V. Soushkov. Value-Conflict Mapping ™ (VCM). To Define and Structure Innovation Strategy, 2008.
7. Breaking the template: how to find and implement breakthrough ideas / Tina Seelig. - M .: Mann, Ivanov and Ferber, 2015.
8. T.K. Tee, Azman M. N. A., M. Suriani. Buzan Mind Mapping: An Efficient Technique for Note-Taking, 2014.
9. A. Kozhemyako, V. Svobodov. TRIZ course of lectures, level 1 MATRIZ, 2021.
10. V. Sushkov. 40 innovative techniques. Application in management and business systems, 2015.
11. A. Kozhemyako. Course of lectures on Business TRIZ, level 2 IBTA, 2020.
12. V. Sushkov. Standard inventive solutions in business and management, 2019.
13. G.S. Altshuller. Creativity as an exact science. - M .: Sov. radio, 1979.
14. V. Soushkov. Breakthrough thinking with TRIZ for business and management, 2014.
15. V. Sushkov. Lines of evolution of business systems and business products, 2019.
16. TRIZ business association, about: https://bmtriz.ru/biznes-associaciya_triz/


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# IMPERCEPTIBLE DETECTION OF FLUORESCENCE – USING TRIZ TO SEE THE INVISIBLE

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## Abstract

Fluorescent markers are widely used to protect banknotes, passports, and other important documents. To make these markers visible, they must be illuminated by ultraviolet (UV) radiation, which causes special dyes to emit fluorescent light. The patterns and colors of the revealed markers are used to assess the authenticity of an object. Because the fluorescence is relatively weak, as compared to daylight and office light conditions, the examined object is usually observed in a darkened place.

Such an explicit approach is inappropriate when the detection must be performed imperceptibly. This may be the case for discretely screening people to look for marks on the skin or clothes of an assailant left by a pepper gel thrower or discretely screening banknotes to identify those passed as a ransom, etc. Because of the hidden nature of such a process, it must be performed unnoticeably, without changing the location and appearance of the examined objects. This implies that activation UV beam and emitted fluorescent light must not be visible to people witnessing the examination, yet reliable detection of the markers must still be performed.

This conflict has been successfully resolved with TRIZ, resulting in a filed patent application. The main idea of the solution is to use a low-intensity time-variable UV light source for illuminating the objects and process the objects' images acquired by a camera to detect color changes too small to be noticed with a naked eye. Simulation experiments indicated that the markers might be reasonably recognized even for the intensity share of the fluorescent light as low as 1% of the ambient light level.

Keywords: *TRIZ, contradiction resolving, ultraviolet, fluorescence, detection, human perception*

## 1 Introduction

### 1.1 Visible light and ultraviolet radiation

It is stated in the literature, that the range of electromagnetic radiation perceived by humans as visible light spans from 400 nm (violet) to 700 nm (red), while some sources specify this range as 380÷780 nm. Ultraviolet (UV) is the name of the radiation between the violet end of the visible light and the X-rays, which corresponds to the wavelength range from 10 nm to 400 nm. Official classification [1] indicates several UV bands, e.g. VUV (Vacuum UV, 10÷200 nm),

UVC (100÷280 nm), UVB (280÷315 nm), and UVA (315÷400 nm). Only the longest wavelengths of the UV range (approximately 360÷400 nm) are visible to humans as purple, while radiation shorter than 280 nm is considered harmful to living organisms [2].

When a light beam reaches the surface of an object, it is partly reflected in a specular way (as in a mirror) or in a diffuse way (when scattered on a rough surface). If the object is transparent, the light is partly refracted and transmitted, with dispersion (as in a prism) if the beam contains components of different wavelengths. In a translucent object, the light is scattered on its way through the material, resulting in diffuse transmission besides the specular one. The light is also partly absorbed by the object, especially if it is opaque [3]. Additional effects may include light polarization or diffraction, but we are only interested in reflection, making the object visible, and absorption providing energy for fluorescent light emission.

## 1.2 The physics of fluorescence

Fluorescence is a phenomenon of a very short emission of visible light after providing an object with additional energy, and this property differentiates fluorescence from phosphorescence, which is characterized by much longer light emission (glowing). The fluorescent light appears when the electrons return to their ground energy levels from the levels temporarily elevated by activating the object with radiative energy.

A convenient and widely used method of inducing fluorescence is to illuminate an object with ultraviolet radiation (which will be further called *UV light* for simplicity). It is known that the energy of radiation is inversely proportional to its wavelength. The wavelength of UV light is short enough for pumping up the electrons to higher energy states, which are unstable in a given object temperature. Some amount of the acquired energy is immediately returned as fluorescent light, and the rest dissipates within the object as heat.

Due to the energy conservation rule, the wavelength of fluorescent light is longer than the wavelength of the activating radiation, while the color (spectrum) of the emitted light depends on the chemical composition of the activated part of the object. Hence, to use fluorescent light for application purposes, the object must be illuminated with radiation of wavelength sufficiently short to energize the electrons and intensity sufficiently high to make the emitted light visible in given ambient conditions [4].

## 1.3 Detection of fluorescence

Many minerals and other natural substances manifest specific fluorescence upon energizing with UV light, which may be used to support finding and recognizing such substances. Banknotes, passports, identification cards, and other documents are protected against forgery with markers imprinted with fluorescent dyes, which remain invisible in usual ambient light and may only be seen when illuminated with UV light (as it is schematically shown in Fig. 1).

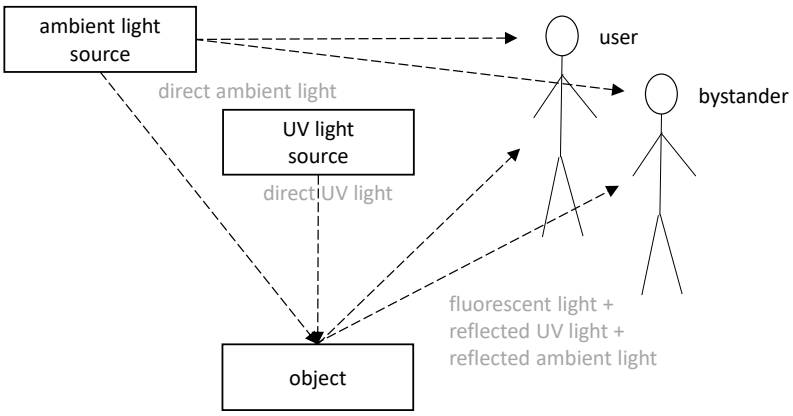



Fig. 1. A typical approach to detection of fluorescent markers – fluorescent light induced by UV light is masked by ambient light, and the results may be visible to other people

Because the fluorescence is relatively weak, as compared to daylight and office light conditions, the examined object is usually observed in a darkened place (see Fig. 2). Therefore a typical device used for verification of the banknotes comprises a UV light source installed in a case forming a shaded niche where a banknote is placed to let the user see and evaluate the markers.

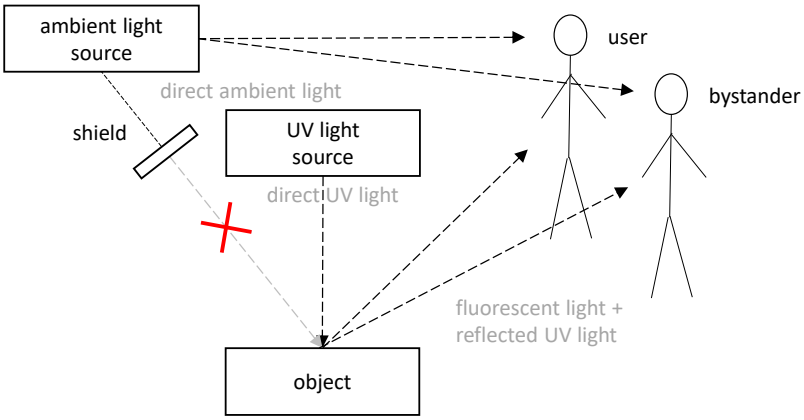



Fig. 2. An improved approach to detection of fluorescent markers – a shield is used to block the ambient light partially, but the results may still be visible to other people

The common objective of the mentioned applications is to induce fluorescence to visually detect and assess certain properties of the expected markers (such as presence, locations, shapes, and colors), which in turn indicate authenticity or other specific properties of the marked object. Such a scenario is suitable for an explicit examination of objects, and it is used in similar forms in airports and other locations where identity documents are checked. Since the markers are observed with a naked eye, any person seeing the object illuminated by the UV light has an equal chance to see the results of examination (if individual differences in perception between people are neglected).

The explicit approach is inappropriate when the detection must be performed imperceptibly to other people, especially the person being examined. This may be the case of a hidden screening of people to look for marks on the skin or clothes of an assailant left by a pepper gel thrower or hidden screening of banknotes to identify those passed as a ransom or bribe, etc. Because of the covert nature of such a process, it must be performed unnoticeably, without changing the location and appearance of the examined objects. This implies, in particular, that activation UV light and emitted fluorescent light must not be visible to people witnessing the examination.

## 2 Imperceptible detection of fluorescence in ambient light

This chapter describes how the problem was analyzed and solved using TRIZ tools. The structure and operation of the devised system are also presented, while simulation experiments and their selected results are described in the next chapter.

### 2.1 Function analysis

The multitude of possible applications of the system is generalized for further considerations as the *imperceptible detection of fluorescence in ambient light*. In some cases, the properties of the expected fluorescent markers are known in advance with details (such as for banknotes and identity documents), and in other cases, only some general characteristics of the expected markers are known (as for stains made by a pepper gel thrower). The main function of the system, verbalized as *to detect fluorescence*, is heavily constrained by two requirements: *the detection must be performed in ambient light*, and *the detection must be imperceptible to bystanders*.

The systematic approach to function modeling starts with a component model. However, following Fig. 1, we would only have UV light source, object, user, bystander, and ambient light source, with the UV light source being the whole system and the remaining items being the supersystem components. Therefore the model has been given finer granularity, resulting in the decomposition indicated below.

System components:
- UV light source
- direct UV light
- optical element
- power source
- switch (power control)
- case

Supersystem components:
- user
- bystander
- ambient light source
- direct ambient light
- object (with fluorescent markers)
- fluorescent light
- reflected UV light
- reflected ambient light

The interactions between the components have been identified for such a decomposition, and the developed function model is depicted in Fig. 3.

Table 1. Descriptions of the functions

| carrier | function | object | type | level | comment |
|---|---|---|---|---|---|
| user | controls | switch | useful | normal | |
| power source | powers | switch | useful | normal | |
| switch | powers | UV light source | useful | normal | |
| case | holds | UV light source | useful | normal | |
| case | holds | optical element | useful | normal | |
| case | holds | power source | useful | normal | |
| case | holds | switch | useful | normal | |
| case | blocks | direct UV light | useful | normal | |
| UV light source | generates | direct UV light | useful | normal | |
| optical element | shapes | direct UV light | useful | normal | |
| direct UV light | informs | user | harmful | | decreases contrast |
| direct UV light | informs | bystander | harmful | | reveals detection |
| direct UV light | illuminates | object | useful | normal | |

| | | | | | |
|---|---|---|---|---|---|
| object | reflects | reflected UV light | harmful | | decreases contrast |
| reflected UV light | informs | user | harmful | | decreases contrast |
| reflected UV light | informs | bystander | harmful | | reveals detection |
| object | generates | fluorescent light | useful | normal | |
| fluorescent light | informs | user | useful | insufficient | |
| fluorescent light | informs | bystander | harmful | | reveals detection |
| ambient light source | generates | direct ambient light | useful | normal | |
| direct ambient light | informs | user | useful | normal | regular seeing |
| direct ambient light | informs | bystander | useful | normal | regular seeing |
| direct ambient light | illuminates | object | useful | normal | regular seeing |
| object | reflects | reflected ambient light | useful | normal | regular seeing |
| reflected ambient light | informs | user | useful | normal | regular seeing |
| reflected ambient light | informs | bystander | useful | normal | regular seeing |

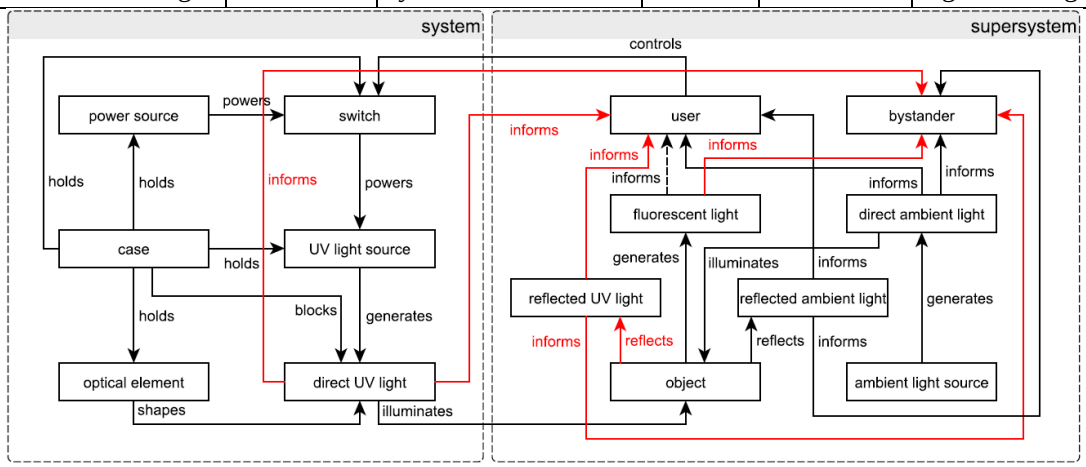



Fig. 3. Function model of a marker detector intended for an imperceptible operation in ambient light

The actual detection of the markers is performed by the *user*, being a supersystem component. Also, the *fluorescent light* performing the function *to inform the user* and the *object* performing the function *to generate the fluorescent light* are supersystem components. The main function is *to illuminate object with direct UV light* so that the *object* is the target of the system.

## 2.2 Formulating the problem

The stronger the activation light is, the brighter the fluorescent light becomes, which makes marker detection easier, but at the same time, it makes it harder to keep the examination unnoticeable to the bystanders. Hence, the problem situation may be described with the following technical contradiction:

*IF the UV light is strong*
*THEN the markers are detected properly*
*BUT the detection is perceptible to others*

On the other hand, making the activation light weaker increases the chances for the examination to be unnoticeable, but at the same time, it will make detection of markers harder because of the lower intensity of the emitted fluorescent light. So the problem situation may also be described with another technical contradiction:

*IF the UV light is weak*
*THEN the detection is imperceptible to others*

*BUT the markers are not detected properly*

Therefore a system capable of detecting fluorescent markers in ambient lighting imperceptibly to other people should provide a solution to the following physical contradiction:

- *the UV light must be strong to enable detection of the markers, AND*
- *the UV light must be weak to keep the detection imperceptible.*

The detection employs the fluorescent light emitted by the markers, not the UV light itself, and neither the UV light nor the fluorescent light may be visible to keep the detection unnoticeable, so that the original contradiction may be reformulated to a more generic one:

- *the optical changes must be visible to enable detection of the markers, AND*
- *the optical changes must not be visible to keep the detection imperceptible.*

Because these requirements refer to different roles, we may apply separation in relation:

- *the optical changes must be visible to the user to enable detection of the markers, AND*
- *the optical changes must not be visible to the bystander to keep the detection imperceptible.*

## 2.3 Cause-effect analysis

To analyze the nature and roots of the problem, the Cause-Effect Chains Analysis (CECA) has been performed for two target disadvantages derived from the contradiction mentioned above:

- *visibility of the optical changes to the user is insufficient,*
- *visibility of the optical changes to the bystander is excessive.*

Due to the paper size limitation, a detailed description of the analysis cannot be presented here, so we will only briefly summarize its course and results.

For the user, we want to increase the visibility of fluorescent light, while the UV light reflected by non-fluorescing areas of the object may decrease contrast. For the bystander, we want neither fluorescent light nor UV light to be visible, as this would violate the requirement of imperceptibility. This characterizes the main parts of the developed CECA diagram depicted in Fig. 4. The folders indicate hidden diagram fragments documenting deeper causes, and the expanded view of folder 6 is shown in Fig. 5.

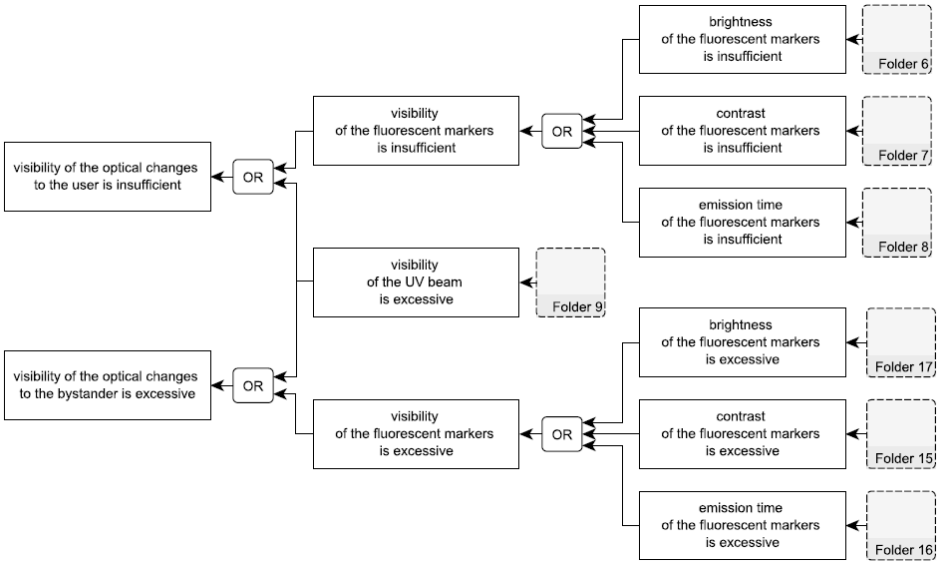



Fig. 4. An overview of the CECA diagram

The visibility depends on changes of a visual stimulus in relation to the reference level of the stimulus. Furthermore, visual sensations depend on the brightness, contrast, color (determined by the contributing wavelengths), and modulation of a light beam as well as the duration of the stimulus, and therefore changes in these parameters may increase or decrease the visibility.

Because the detection must be provided in the existing ambient light conditions, the reference level of the stimulus cannot be changed. Amplitude changes (modulation) of fluorescent light follow those of the excitation UV beam. The color of the object observed in the ambient light, color of emitted fluorescent light, and other optical properties (e.g. reflection characteristics) remain beyond control, as they are predetermined or unknown in advance.

Since the user- and bystander-related parts of the diagram describe the same optical phenomena and are significantly similar in structure, they have several common root causes. They are replicated in particular subgraphs for clarity and annotated with suffixes (see Fig. 5). 26 such shared causes were identified, triggering 60 effects in total, and the top of this list is as follows:

- *UV beam modulation is unsuitable - 5B* (5 effects),
- *fluorophore composition is unknown in advance - 4G* (4 effects),
- *fluorophore composition cannot be changed - 4F* (4 effects),
- *UV beam wavelength is unsuitable - 4D* (3 effects).

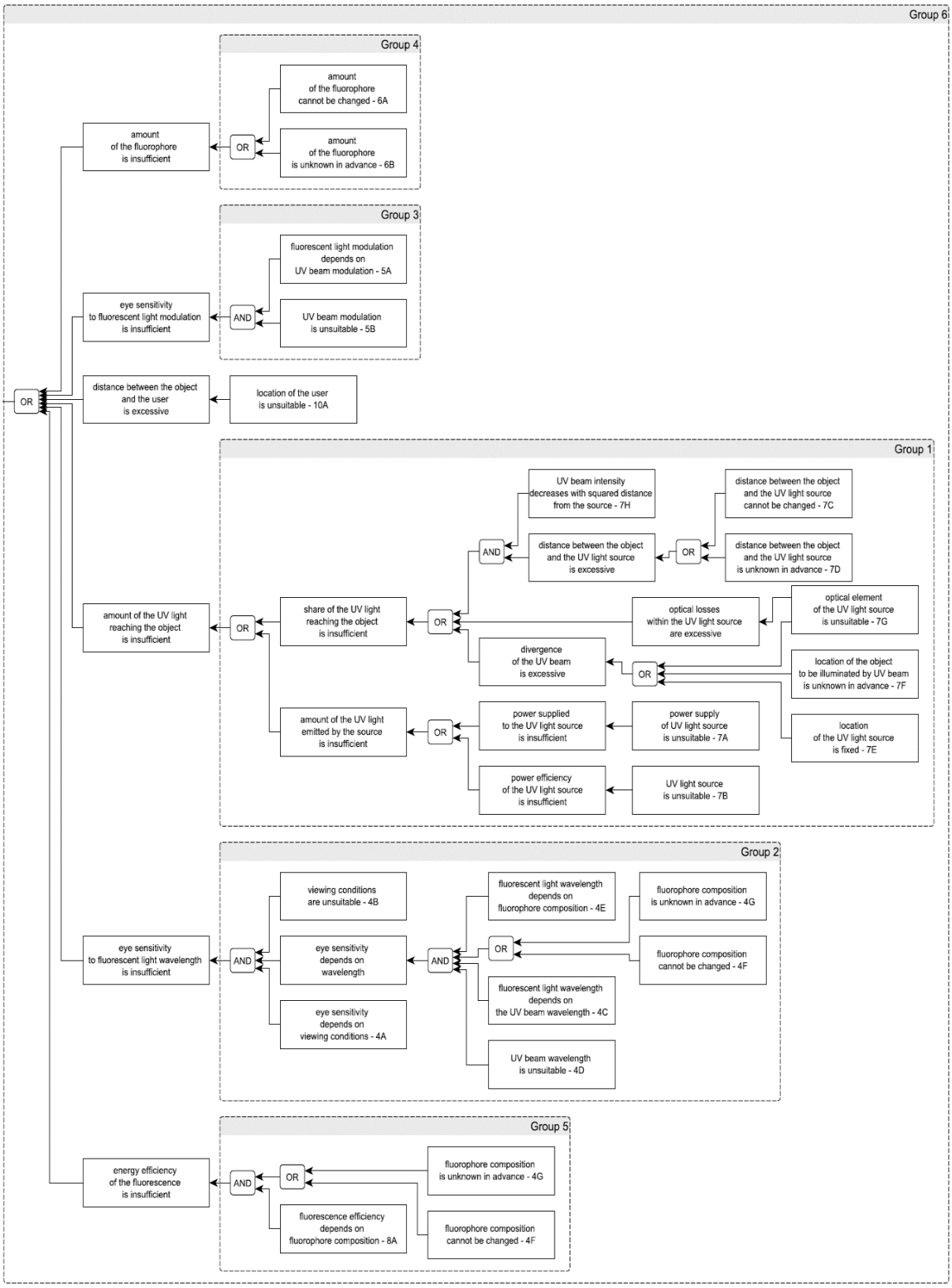



Fig. 5. Expanded folder 6 of the CECA diagram (*brightness of the fluorescent markers is insufficient*)

Also, a few other root causes seem manageable more than the others (although with a supposed increase in system complexity):

- *distance between the object and the UV light source is unknown in advance - 7D,*
- *location of the object to be illuminated by UV beam is unknown in advance - 7F,*

- *location of the UV light source is fixed - 7E.*

Concluding, the following key disadvantages have been selected for further consideration as the most promising since they appeared at least once in each sub-diagram in the context of contradictory demands:

(1) *UV beam modulation is unsuitable,*
(2) *UV beam wavelength is unsuitable,*
(3) *viewing conditions are unsuitable,*
(4) *location of the user is unsuitable,*
(5) *location of the bystander is unsuitable,*
(6) *amount of the UV light emitted by the source is insufficient,*
(7) *amount of the UV light emitted by the source is excessive,*
(8) *user's eyes sensitivity to fluorescent light modulation is insufficient,*
(9) *bystander's eyes sensitivity to fluorescent light modulation is excessive.*

Finally, these key disadvantages have been transformed into key problems enumerated below. The key problems are formulated in such a way that solving any of them would eliminate both target disadvantages (numbers in parentheses show mapping onto key disadvantages).

KP1: *How to make the bystander's eyes less sensitive to fluorescent light and UV beam?*
(1, 2, 3, 9)
KP2: *How to make the user's eyes more sensitive to fluorescent light?*
(3, 8)
KP3: *How to make the UV beam to induce fluorescent light visible only to the user?*
(1, 2, 6, 7)
KP4: *How to set up the locations of people to make fluorescent light visible only to the user?*
(3, 4, 5)

## 2.4 Developing the solution

Approaching KP1, we might think about selective attenuation of the UV light and fluorescent light on their way to bystander's eyes, being similar to shielding against the ambient light used in regular fluorescence detectors (see Fig. 6). Unfortunately, this method appears unusable here because we want the process to be literarily invisible to all but the user, who is aware of the detection. Therefore we must not perform any additional operations on the examined object or the people involved in or witnessing the examination.

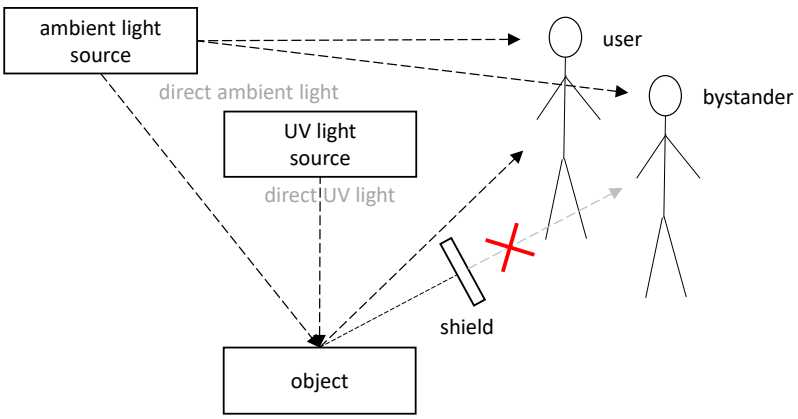



Fig. 6. Shielding cannot be used for solving KP1 because we are not allowed to change the procedure

Because the ambient light, object, and bystanders should not be affected in any way, we may switch to KP2 and apply *the other way around* principle by using weak UV light inducing weak fluorescent light with *selective enhancements* provided to improve users' ability to detect the markers as it is shown in Fig. 7.

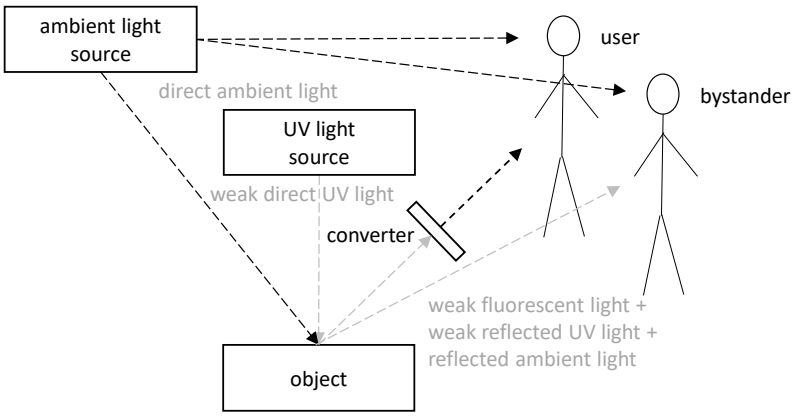



Fig. 7. Detection may use weak fluorescent light, which is converted to be detectable only by the user

## 2.5 System structure and operation

The solution idea described above may be implemented by illuminating the examined object with a low-intensity UV light and then extracting and amplifying imperceptibly small optical changes using a camera, image processing system, and an output device signaling the results of detection (see Fig. 8). To reliably recognize the fluorescent markers, we need to confirm that they are only visible during the excitation and disappear otherwise. Hence the UV beam should be variable (e.g. pulse-modulated).

The processing system monitors the video stream continuously and captures the images acquired by a camera when the object is only illuminated with the ambient light and when it is also temporarily illuminated by imperceptibly weak UV light. Such reference images are subtracted pixel-wise, and the differential image carrying extracted information about fluorescent markers is amplified and further analyzed. The final results of the image processing are sent to the output device, which informs the user.

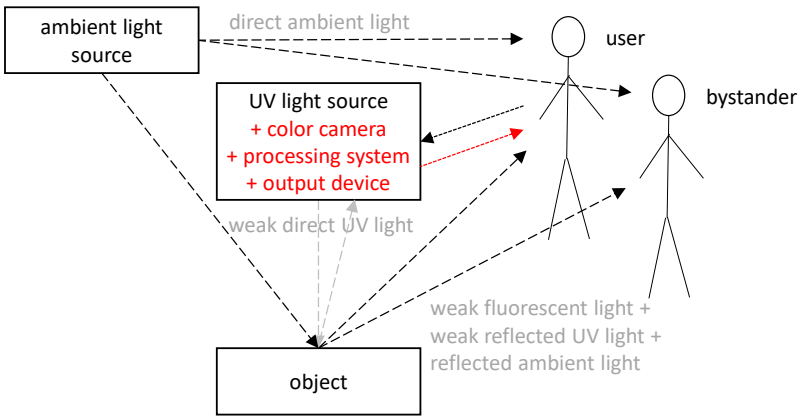



Fig. 8. Imperceptible detection of fluorescent markers in ambient light – modulated UV light induces fluorescent light too weak to be seen with a naked eye, which is acquired by a camera and extracted by an image processing system to inform the user through an output device

An obvious solution would be to use a display to present the processed image of the object to the user, possibly with some additional information. Depending on application requirements,

other output devices may be used to provide e.g. sound notification as in some metal detectors, with intensity, pitch, and cadence related to the parameters of the fluorescent markers detected (and possibly recognized against a pattern collection) by the processing system.

The modified function model from Fig. 3 is shown in Fig. 9.

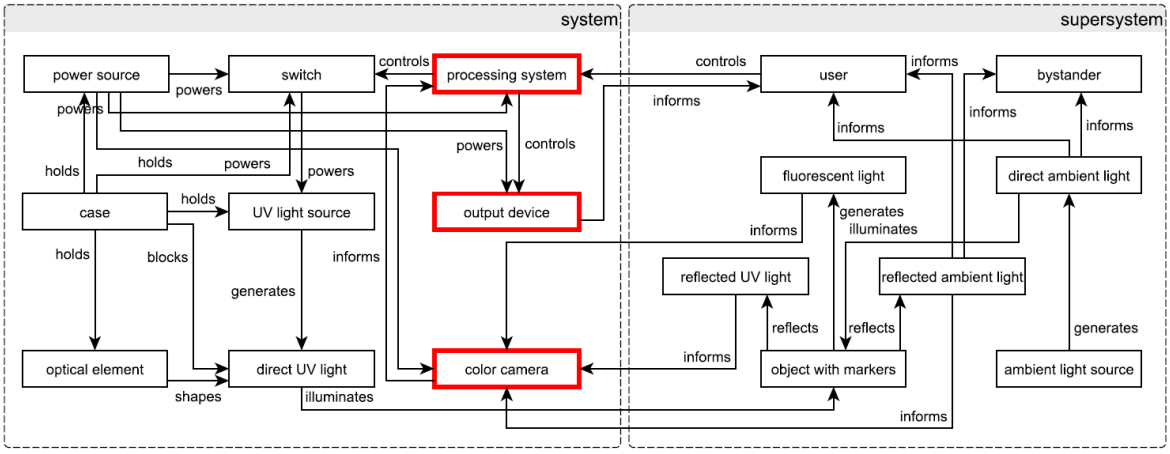



Fig. 9. Function diagram of a detector providing imperceptible detection of fluorescent markers in the ambient light conditions (with the added camera, image processing system, and output device)

## 3 System simulation

The simulation experiments covered selected aspects of the system operation, including:

- image processing with static results demonstrating the influence of the luminescent light on the appearance of the objects in the ambient light and visibility of the fluorescent markers,
- image processing with dynamic results showing how amplitude and pattern of luminescent light modulation change the appearance of the objects in the ambient light,
- prototyping the algorithm of selecting images of minimum / maximum average intensities located possibly close to each other in a video sequence.

Table 2. Selected sample images used in the simulation experiments
– ambient light images and respective UV light images (not to scale)

identity card - back

driving license - front

banknote - front

Image processing experiments were implemented using Adobe Photoshop Elements application and pictures of documents and banknotes available on the website of Polish Security Printing Works (www.pwpw.pl), as observed in ambient light and UV light. Algorithm prototyping was done in Visual Basic for Applications (VBA) using the MS Excel platform. The schemes and results of the selected experiments are presented below.

## 3.1 The experiments

The first group of experiments covered sample documents protected with fluorescent markers. The illumination with UV light of different relative intensities was first simulated by additively mixing the ambient light image with a fluorescent image using weights ranging from 1% to 100%. Then the original ambient light image was subtracted from the mixed image, and the differential image was processed by a histogram correction algorithm providing expansion of the dynamic range of the pixel values to obtain optimal contrast, as shown in Fig. 10.

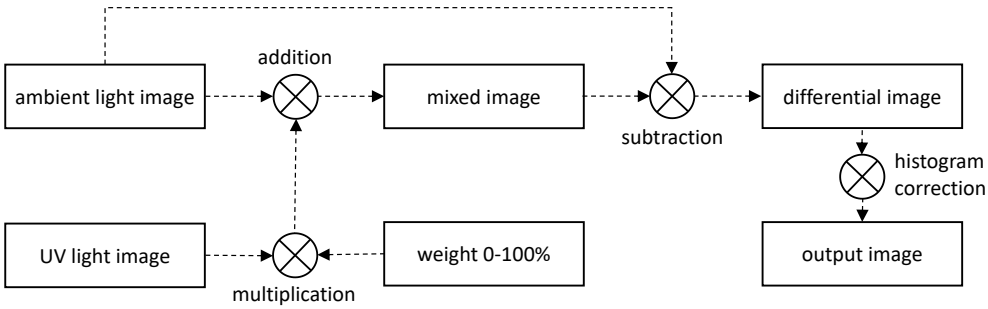



Fig. 10. Experimental setup of static simulation using an original image (ambient light image) and UV light image on the input

Because the image processing application recognizes and refuses to load images of banknotes, samples of this type have been processed using a simplified version of the above scenario. The brightness of the sample UV light images has been decreased in geometrical series by compacting the histogram range by half 7 times, obtaining brightness of 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, and 1/128 of the input image. Such images were processed by a histogram correction algorithm, as in the original scenario (see Fig. 11). Then the same procedure was repeated for the UV light images of documents examined before to compare the results.

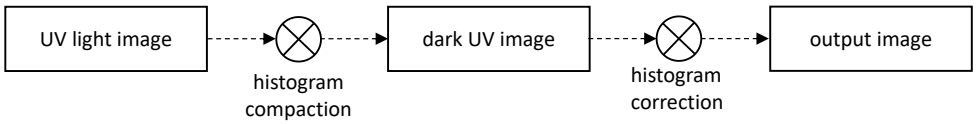


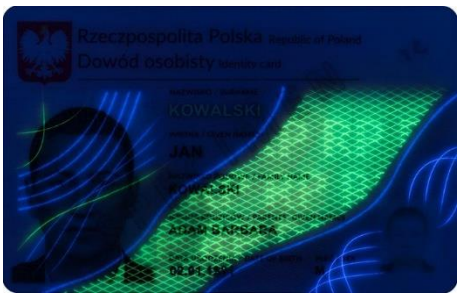
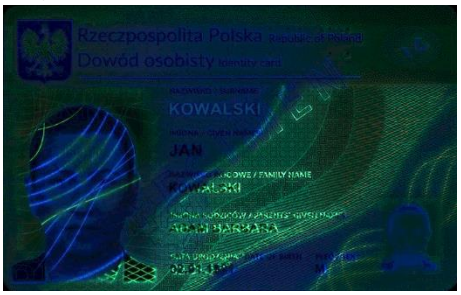

Fig. 11. Experimental setup of simplified static simulation using only UV light image on the input

Another group of experiments was aimed at assessing the noticeability of original image changes simulating time-variable UV light illumination. The effect of dynamic changes has been obtained by stacking the ambient light images of the same object with a gradually increased and decreased share of the UV light image. Several collections of this type have been prepared as animated GIF images with different amplitudes (1÷100% of added UV light image), different numbers of intermediate levels (0÷8 samples), and different intervals of switching between the images (100÷600 ms). Such files were observed in a web browser to evaluate the visibility of blinking. The experiments have shown that even changes as big as 40% may be difficult to spot if they are sufficiently smooth.

## 3.2 Selected results

The results were qualitatively evaluated by visually assessing the similarity of the revealed markers to the UV light image, and average image brightness was also recorded as a synthetic characteristic of a whole image. Due to the image processing scheme, the differential images are not identical with the weighted UV light images used for mixing (even for the 100% share). Nevertheless, the presence, locations, and shapes of the markers may be confirmed even when as small amount as 1% of UV light image is added to the original image, and the results obtained beyond 5% share are visually identical to those obtained for 100% UV light image added.

Table 3. Selected results of image processing simulation for 1%, 10%, and 100% of the UV light image colors added to the ambient light image; the average brightness of differential image (not shown), and the expanded image is given in the right column

| | |
|---|---|
| original ambient light image<br>average brightness 204,06 | UV light image<br>average brightness 42,71 |
| |  |
| ambient light image additively mixed with a weighted UV light image | differential image processed with a histogram correction algorithm |
| | |
| 1% UV - average brightness 204,15 | average brightness 0,12 → 12,17 |
| |  |
| 10% UV - average brightness 206,05 | average brightness 2,03 → 36,30 |
| | |
| 100% UV - average brightness 223,85 | average brightness 19,80 → 34,74 |

## 4 Summary and further work

The contradiction describing the problem has been formulated and successfully resolved using TRIZ tools, resulting in a method and device described in a patent application PL434862 filed

to the Patent Office of the Republic of Poland [5]. The main idea of the solution is to use a low-intensity time-variable UV light source for illuminating the objects and process the objects' images acquired by a camera to detect color changes too small to be noticed with a naked eye. The underlying algorithms have been prototyped by computer simulation using sample images of documents protected with fluorescent markers. The experiments indicated that the markers might be reasonably recognized even for the intensity share of the fluorescent light as low as 1% of the ambient light level.

In addition to *optical changes*, the developed solution employs three other inventive principles, as it inverts the usual approach by decreasing fluorescence intensity instead of increasing it (*the other way around*), provides a selective enhancement to a weak signal (*partial or excessive actions*), and uses a UV beam of variable intensity to activate the markers (*dynamization*).

Expected secondary problems may result from differences between the performed concept substantiation and requirements of real-life applications. The samples used for simulation differ from the marks left by pepper gel in terms of intensity, regularity of shape, and foreseeability of location. Moreover, the verification only employed still images, while the system is expected to detect markers in video sequences, where object tracking will be necessary.

Further work will cover developing a software application to be used on smartphones and other mobile devices together with a standalone UV lamp. Such configuration requires a more complicated approach than when the processing system controls the UV light source because the modulation parameters of the UV beam (in particular the modulation phase) are not known and must be deduced from the video stream. For this purpose, spatiotemporal filtering methods may supposedly be applied, similar to those used to measure heart rate by analyzing invisible changes of skin color caused by blood flow [6].

## Acknowledgments

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## References

1. ISO 21348:2007. Process for determining solar irradiances. www.iso.org.
2. Ultraviolet. Wikipedia. en.wikipedia.org/wiki/Ultraviolet.
3. Lötzsch D., Eberhardt V., Rabe C. "Chromogenic Materials". In: Ullmann's Encyclopedia of Industrial Chemistry, Wiley 2016, pp. 1-26. doi:10.1002/14356007.t07_t01.
4. Fluorescence. Wikipedia. en.wikipedia.org/wiki/Fluorescence.
5. Chrząszcz J. "Detector and method of detection of fluorescent objects", Patent application PL434862, Application date: 2020-07-31 (in Polish).
6. Wu H. et al. "Eulerian video magnification for revealing subtle changes in the world". ACM Trans. Graph. 31, 4, Article 65 (July 2012). doi.org/10.1145/2185520.2185561.

[ all online publications last accessed on June 12th, 2021 ]

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# Introduction of TRIZ at a company by using the distance TRIZ-trainer course and the Solving Mill software (the example of SAMSUNG)

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## Abstract

The use of TRIZ in the innovative activity of a company yields good results both in the patenting dynamics and in the quality of the ideas produced. Of great importance is competent introduction of TRIZ into the structure of the company's innovative subdivisions. This primarily refers to the organization of training specialists in solving inventive problems.

The use of the online TRIZ-trainer system in addition to the traditional forms of study (a series of seminars conducted by a trainer) provides significant advantages. It becomes possible to train the company's employees in several stages by increasing the training material complexity.

This learning system has proved good in teaching University students and post-graduates. As a result, the value of University graduates in the labor market grows significantly. Production companies are provided with specialists already able to solve problems at a patentable level.

## 1 TRIZ in Korea

The world's first experience in the wide systemic application of TRIZ [1,2] to the production process started in 1998 when LG offered a permanent job to Dmitry Kucheryavy from Minsk. The annual number of patent applications filed by LG employees increased almost fivefold in the period between 2000 and 2007 (Fig. 1).

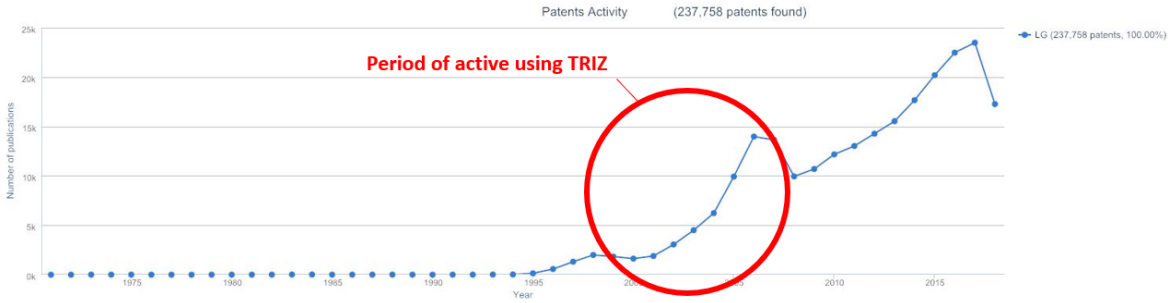


Fig.1. Patenting dynamics at LG (according to the data of the Gold Fire program)

Taking this experience into account, Samsung SDI invited Vasily Lenyashin and Leonid Chechurin to work for the company. They showed good results in solving inventive problems and in 2000 a decision was taken to invite TRIZ experts to Samsung Advance Institute of Technology (SAIT). They were Nikolay Khomenko and the author of this article.

From the very beginning, the SAIT managements wanted to clarify two questions:

1. Is TRIZ a well-elaborated method of invention or are they just dealing with capable engineers?
2. How effectively can TRIZ be applied to the process of new product development and to solving production problems?

To get an answer to the first question, they proposed the TRIZ group to solve problems from different fields of the company's activities. SAIT provides scientific and methodological assistance to all 200 small and big Samsung companies, so the group had to solve problems from the field of medicine and microelectronics, the production of plastics and household appliances, displays and semiconductors, chemistry and power engineering – too many to name. Despite such a variety of problems, the TRIZ group demonstrated fairly good results. On that basis, the SAIT management drew a conclusion that TRIZ was really an effective method which could be formalized to transfer the knowledge and skills in inventive problem solving to the company's specialists.

The effectiveness of TRIZ was checked by constantly recording the economic effect of the TRIZ group's work. The conclusions were as follows - in the first two years of work, the SAIT TRIZ group brought the company a profit of $92 mln. Of course, one should take into account large production volume, but for a group of three, it was a meaningful result.

TRIZ-based systemic invention began to actively develop on Samsung. Experienced TRIZ specialists from the former USSR were invited to all major companies of the corporation, systemic inventions began to produce significant results.

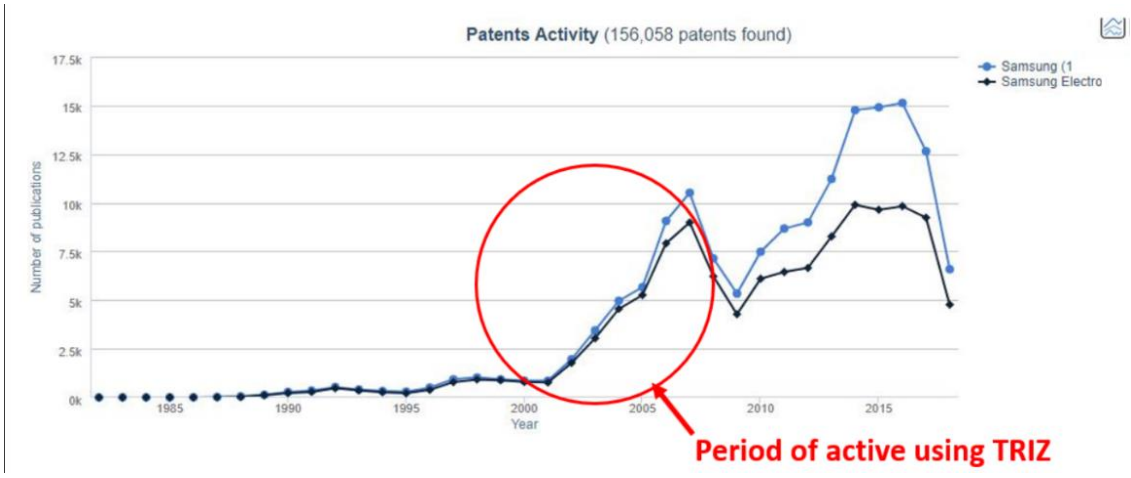


Fig.2. Patenting dynamics at SAMSUNG (according to the data provided by the Gold Fire program)

The results of that work look very well indeed. The period of active application of TRIZ at Samsung lasted from 1999 to 2007. During that time, the number of technical solutions patented by Samsung specialists per year grew by 14 times throughout the corporation and by 11 times at Samsung Electronics (Fig. 2). A serious base of patented ideas formed the basis for the technological and innovative breakthrough of the company, which confidently moved to the leading position in the world.

## 2 Teaching TRIZ

The corporation management studied the obtained results of practical application of TRIZ at SAIT and Samsung SDI and raised the question of introducing TRIZ as one of the standard innovative methods. This implied mass training of employees.

The profit received by a company from the introduction of systemic TRIZ-based invention can be huge if the influence of the following two factors is used to the full extent: the training of problem-solving specialists and the efforts by the company's management to organize systemic invention. While the training of TRIZ specialists is easy to manage, the organization of systemic invention at a company depends entirely on its management. The management must ensure the following things:

- motivation of employees for obtaining patentable solutions to problems,
- selection of problems, the solution to which ensures the maximum economic effect for the company,
- understanding of the TRIZ-training purpose as the development of problem-solving skills and not just obtaining a certificate.

Training of company's employees along with solving real production problems is an important stage in the TRIZ implementation. The main problem here as a rule is the lack of time. TRIZ training at the initial level requires at least two weeks and the full course takes about two months. For this time, it is necessary to free employees from performing their work duties, which means an additional cost.

In addition, the selection of specialists for such seminars is often carried out at random, without sufficient consideration of individual features. At the same time, it is not always possible to select the employees most suitable for consulting work. Often, the suitability or unsuitability of an employee can only be determined on completing a training course, when time and money have already been spent.

The elimination of these problems was considered as a separate managerial task. The fulfilment of that task resulted in a program of step-by-step training of the company's personnel, including the creation of a permanent TRIZ-group led by one of the company's top managers.

The introduction of systemic invention at a company occurs at three levels (Fig. 3).

**1st level.** The dissemination of the methodological knowledge on TRIZ among the company's specialists, formation of a community of inventors. The first, initial stage of training can be completed by all employees of the company. In this case, students receive the basic knowledge of TRIZ and problem-solving skills. At this stage, the student can learn the logic of constructing solutions and consolidate it by solving a certain number of educational problems.

*The goal* is creating an innovative culture at the company. After completing the first level course, the specialist knows about TRIZ, understands its terminology, has an idea of problem-solving tools and algorithms. In the course of training, the initial skill of solving an inventive problem is formed. Experience shows that completing the first level course would be useful for 30-40 % of the total number of the company's employees.

After the initial straining stage, the most capable employees are selected, who can be recommended for further training at teacher-led seminars.

*The method* is distance learning using the TRIZ-trainer computer program, introductory seminars and webinars.

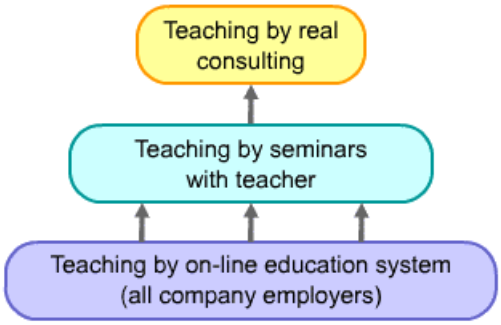


Fig. 3. The three-stage scheme for training company's specialists to solve problems using TRIZ

**2nd level.** Training of inventive problem solvers.

*The goal* is the training of qualified users of invention techniques capable of finding patentable solutions to production problems. The minimum number of trained problem solvers can be 5-10% of the company's specialists involved in the production technology and organization and in the development of new products.

*The method* is training seminars based on solving educational and real production problems under the guidance of an experienced trainer. At the second stage, the student has an opportunity to improve the knowledge gained at the initial stage of training, investigate into the theoretical foundations of TRIZ, gain in-depth practice of solving educational and real problems.

The total duration of such seminars can range from two weeks to a month in blocks of 3-5 days with intervals. During the intervals, the students solve company's problems on their own under the guidance of a trainer.

**3rd level.** The final stage of training is an internship of employees in solving real problems under the guidance of an experienced TRIZ consultant.

Here the students can gain a deeper understanding of the theoretical foundations of problem solving and gain practical skills in identifying problems in a real production situation and solving them. They can learn the targeted search for information when working with the specialists of the customer team, as well as develop skills in assessing and choosing the best solution in a particular situation.

*The goal* is organizing a group of highly qualified invention specialists who would coordinate the work of the company's inventors and solve complex problems given by the company's management. The number of specialists in the company's TRIZ group can range from 3 to 7 persons.

*The method* is conducting master classes for inventors selected at the second stage of training, internship in the course of practical solving of the company's problems and training of employees.

## 3 Peculiar features of inventive problem solving

Major problems relate to the first-level training. It is especially important to organize such training during the initial period of TRIZ implementation in order to popularize systemic invention at the company and remove the unreasonable fear of tackling an inventive problem.

The main problem here is usually the lack of time. The initial training course requires 2-3 days of studies, which at the company level means a significant loss of working time. Therefore, you need to carefully figure out what should be taught to a specialist and how to do it with minimum expense.

First of all, it is necessary to determine what to teach.

The answer here is simple, but often ignored by TRIZ teachers. It is necessary that the trainee not only, and not so much study the theoretical principles of TRIZ, but pay the most serious attention to the practical side of the matter. The most important goal is to develop the skill of solving an inventive problem. That is, the subject should be called "How to solve inventive problems using TRIZ".

To effectively teach problem solving through training, we need a clear problem-solving structure. Then you can repeat the solution process many times, explaining and fixing the peculiar features of performing each action.

In this regard, the approaches of the General Theory of Strong Thinking (OTSM), developed by Nikolai Khomenko [3,4], were attractive. A clearly limited narrowing search space implies at the same time some freedom of action within its boundaries (Fig. 3). In addition, OTSM comprises actions to be performed when solving a problem in accordance with the classical scheme of cognition - "transition from a concrete situation to its abstract models; transformation of these models; building a specific solution", which is more understandable to engineers with traditional education.

Our approach is as follows: to develop the most suitable structure for solving a problem, it is advisable to combine OTSM with TRIZ elements. In this case, TRIZ tools have an auxiliary function, helping to carry out the steps of the algorithm. This can be done by rigidly setting several key points of the solution process, providing for more or less free transitions between them (Fig. 4).

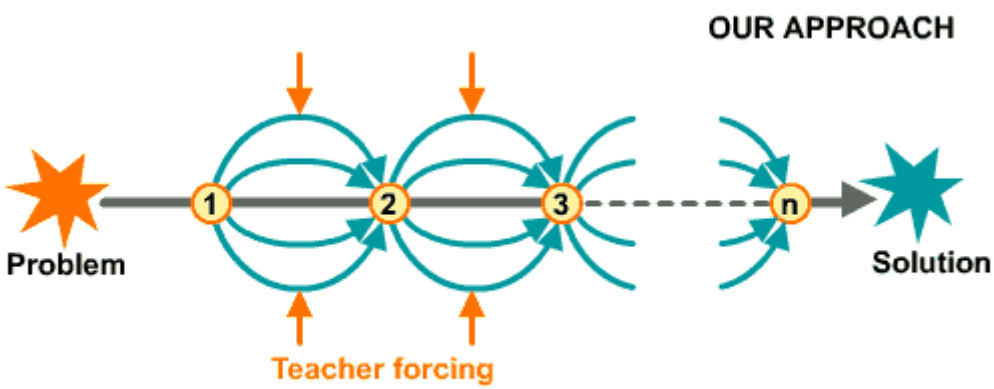


Fig. 4. The proposed approach to problem solving

This structure was developed by Elena Novitskaya and me on the basis of many years' experience in solving real problems and is illustrated by the "Christmas tree" diagram [5] which has now been transformed into the AIPS - the algorithm for correcting problem situations (Fig. 5) [6].

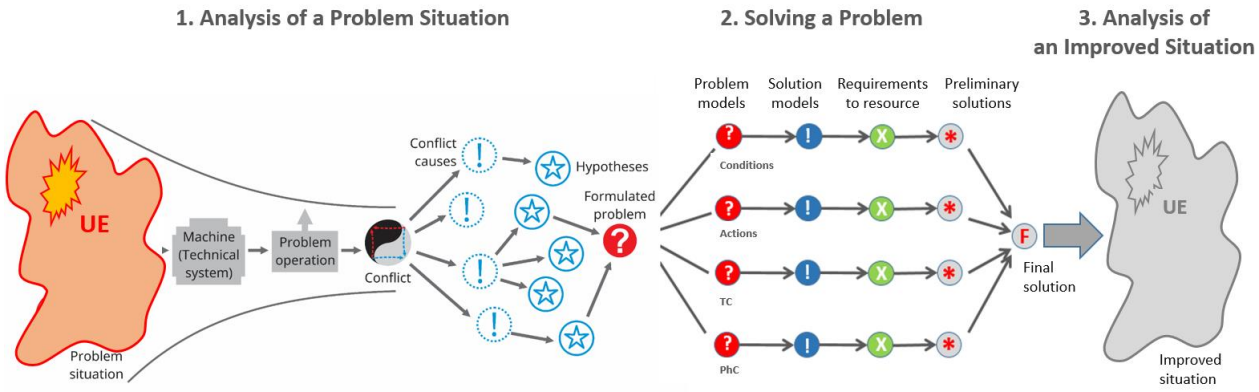


Fig. 5. The scheme of correcting problem situations (AIPS)

Now it is clear what to teach. The TRIZ-training goal should be developing the skills of practical solving of inventive problems. The AIPS algorithm is well suited for this purpose. Now we need to decide how exactly to train a specialist.

Most suitable for corporate training is a system that combines online training and seminars under the guidance of a teacher - a distance learning course. In such a combined training system, basic information and control assignments are presented on electronic media and can be accessed by the trainee at any time, for example, via the Internet or through the company's corporate network. In addition, each student can contact a personal tutor-consultant through a computer network. The teacher accepts and evaluates control tasks and can also answer questions and help the student perform the actions necessary for solving a problem in the most rational way. In this case, personal contact between the student and the teacher is not required. Thus, the advantages of two competing training systems are combined.

Currently, there are many distance learning courses available in TRIZ. However, most of them are focused on software-based learning. The purpose of such training is to give the student knowledge about the subject being studied. However, in order to teach students to solve inventive problems, it is necessary to give them not only knowledge, but, first of all, skills.

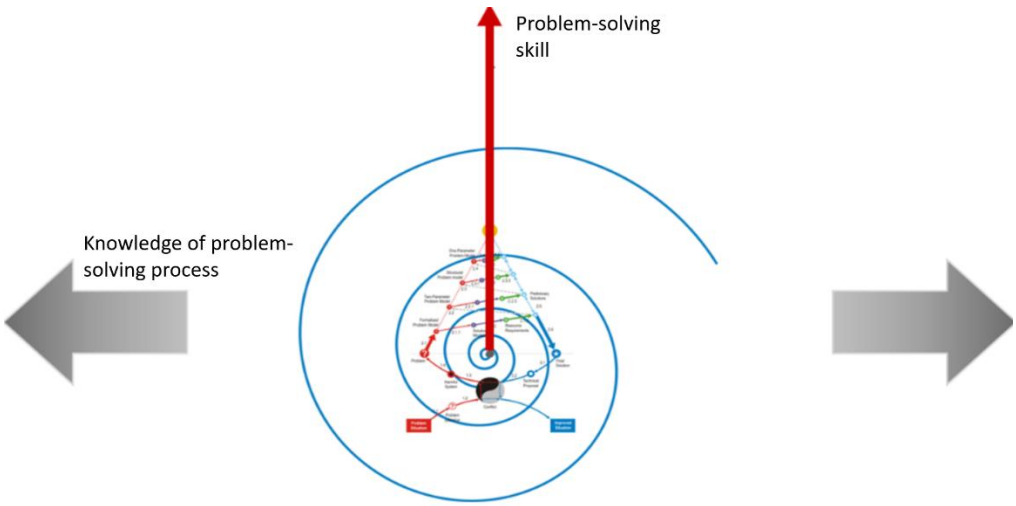


Fig. 6. «Spiral» method of training

Therefore, the most appropriate way to teach TRIZ is through training. In this case, the student is asked to perform some action, and theoretical knowledge is involved when necessary and to the extent necessary. An example would be learning any repetitive activity, such as driving a car or airplane. The purpose of the training is to develop the skill of performing actions. Further training is aimed at a deeper mastery of the theoretical knowledge necessary to understand the meaning underlying the actions performed.

In this case, the training proceeds as if in a spiral (Fig. 6).

One turn of this spiral is a solved and carefully analyzed problem. With each turn, the field of knowledge about the problem-solving process expands and the student gains practical skills. The unfolding spiral is an endless curve, just like the study of TRIZ. After receiving the initial skills, the solver is set free to gain new experience. It is a never-ending process, like, for example, learning a foreign language.

This approach dramatically increases the effectiveness of training, but teacher-led trainings are time-consuming.

## 4 TRIZ-trainer

We have been elaborating this approach to solving real production problems for many years and used it as a basis for developing the "TRIZ-trainer" distance learning system for SAMSUNG. The distance course was tested in training the company's specialists and showed good results. Target Invention has improved the distance course, its version in Russian is available (Fig. 7).

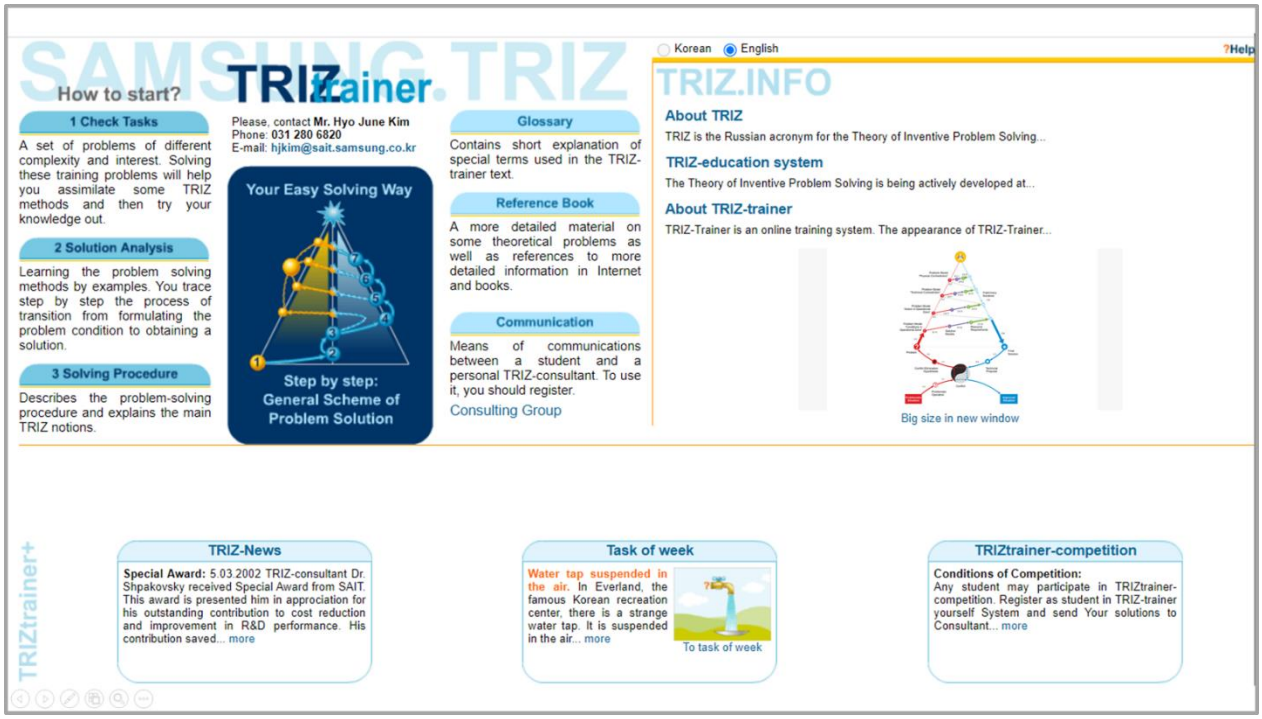


Fig. 7. The homepage of TRIZ-trainer 2001

The information offered to the student in TRIZ-trainer is grouped into several functional blocks, the main of which are the following:

1. *Problems*

The "Control tasks" block offers the students a set of problems with a possible structure of the solving process. The statement of the problem is clarified by animated illustrations.

2. *Analysis* of problems

This block offers a detailed analysis of educational and real production problems built in accordance with the "Christmas tree" diagram.

3. *Solving procedure*

This part of TRIZ trainer contains the necessary theoretical information about the key points of the problem-solving process and transitions between them. In addition, there is a glossary with short definitions of the concepts used in TRIZ-trainer, and links to the literature used and recommended for self-improvement.

The work with TRIZ-trainer is organized in the following way.

In the **"Problems"** section, the student receives a set of problems for solving and solves them, observing the sequence of actions prescribed by the template based of the algorithm for correcting problem situations (AIPS). The produced ideas and problem-solving process itself are sent to the teacher through the communication system. The teacher evaluates ideas and, together with the student, analyzes the solving progress and points out errors and inaccuracies.

To better understand how to solve an inventive problem, the students can refer to the “Analysis of problems” solved by this method and solve their problems by analogy with the presented case studies.

The Solving Process section explains the problem-solving process in more detail. Here you can see the theoretical approaches both to the implementation of each step and to the solution of the

problem as a whole, get acquainted with the tool-application examples. In the theoretical section of the program, a number of control questions are provided, to which the student must answer by choosing the appropriate, in his opinion, answer option.

For additional explanations of terms and approaches, see the **"Glossary"** and recommended sources of information from the **"List of References"** below.

The texts of the program contain a large number of crosslinks which will connect you to the desired section of the theory or glossary.

Important components of the educational process are webinars conducted by a trainer, as well as constant communication between a student and a teacher through the communication section. They provide the student with the opportunity to ask any question at any time, including questions concerning real problems he is working on, and the teacher has the opportunity to assess the individual abilities of each student. This structure allows the teacher to simultaneously work with a group of students and the student has the opportunity to consult with his teacher at any moment.

Fig. 8. The combined program of TRIZ-trainer and Solving Mill

Currently, we have developed an extended version of the TRIZ-trainer program. This program presents the problem-solving process modified to take into account the experience gained through practical consulting and training of specialists. In addition, the solving part has been significantly expanded in the program. It forms a separate block and is named Solving Mill.

TRIZ-trainer and Solving Mill form a modular structure for teaching inventive problem solving and supporting the user's problem-solving process (Fig. 8). The advantage of such a combined program is that its blocks can be used both jointly and separately.

That is, if our goal is to teach students, then we can only use the TRIZ-trainer program. If, on the other hand, we want to focus on solving company's real problems, then it is appropriate to use the Solving Mill program. Another possibility is the joint application of the two programs. In this case, it is possible to organize training of specialists along with practical problem solving.

## 5 Conclusions

- Teaching the problem-solving basics with the help of the "TRIZ-trainer" distance learning system is very effective for companies and universities.
- Tuition fee per student is much lower than in case of teacher-led seminars.
- The TRIZ-trainer distance learning program not only gives knowledge of TRIZ, but, first of all, teaches to solve problems.
- The "TRIZ-trainer" distance learning system is easily integrated into the traditional training structure of company specialists and university students.
- The "TRIZ-Trainer" distance learning system provides methodological unity with the inventive problem-solving software Solving Mill, both software can complement each other.

## References

1. Altshuller, Genrikh. “The Innovative Algorithm. TRIZ, Systematic Innovation and Technical Creativity”. Technical Innovation Center, INC. Worcester, MA. 1999.
2. Salamatov Y. “TRIZ: The Right Solution at the Right Time”. Published by Insytec, 1999.
3. N. Knomenko. “TRIZ as a General Theory of Strong Thinking (OTSM)”. https://otsm-triz.org/ (In Russian).
4. Sebastien Dubois, Nikolay Khomenko, Pilippe Lutz, Ronald De Guio. “Problem formulation– A Key Step in the process of Resolution of Inventive Problem”. World Conference “TRIZ future 2001”.
5. Nikolay Shpakovsky. Using the tools of classical TRIZ in the “Christmas Tree” diagram. Website GENERATOR. http://www.gnrtr.com/Generator.html?pi=202&cp=3
6. Nikolay Shpakovsky. OTSM-TRIZ. Approaches and practice. M. INFRA. 2019 (In Russian)

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# ISO Standards for Innovation and their Impacts to the TRIZ Community

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## Abstract

In 2019, the first set of multiple ISO guidance standards for innovation were released. The ISO 56000 family offers guidance to product and process organizations for defining, adopting and operating innovation management systems, and establishes a common language for innovation practices. Currently, a total of eight ISO innovation standards are in different stages of development, review and publication, including standards for intellectual property management, strategic intelligence management, and idea management. The release of ISO 56002 (Guidance on Innovation Management Systems) in July of 2019 is raising questions from industry leaders and startups alike as to how the standard can be adopted, not only to shape their innovation management systems, but also combine the guidelines with other management system standards such as quality management (ISO 9001), environmental management (ISO 14001), and asset management (ISO 55001). The emergence of ISO's innovation standards presents a unique opportunity for the TRIZ community to provide focused insight and guidance over the next few years which could spark a renaissance in the awareness, enablement, and adoption of TRIZ methods across many industries.

## ISO Background

Founded in 1947, the International Organization for Standardization (ISO) is a standards-setting body composed of technical and industry leaders representing over 160 countries. The original goal of ISO was ensuring that products and services are safe, reliable, and of good quality. For decades, ISO published standards mostly related to manufacturing and units of measure. In 1987, ISO published its first quality management standard (ISO 9001) which has become one of the most recognized and widely adopted standards today. The environmental standard, ISO 14001 followed a few years later in 1996. Since then, ISO branched out into many fields including information security, social responsibility, energy management, and even corporate integrity.

## ISO 56000 Overview

The ISO 56000 series is a family of standards for Innovation Management, with a goal of providing guidance to organizations on how to structure and manage innovation (and related activities) with consistent processes, programs, and metrics. The standards provide baselines

for innovation management as a discipline, which can be easily integrated with widely adopted management system standards, including ISO 9001. The approach to innovation management taken by the ISO 56000 family is a systems approach, which considers numerous interrelated elements that influence each other in the way innovation is managed. The standards are designed to support innovation in organizations of any size, and drive benefits across the organization, its markets and establish a sustainable innovation culture.

At the time of writing this paper, the ISO 56000 family contained or was developing the following standards:

- ISO 56000: Innovation management – Fundamentals and vocabulary (Published in 2020)
- ISO 56002: Innovation management – Innovation management system – Guidance (Published in 2019)
- ISO 56003: Innovation management – Tools and methods for innovation partnership – Guidance (Published in 2019)
- ISO 56004: Innovation management – Assessment – Guidance (Published in 2019)
- ISO 56005: Innovation management – Tools and methods for Intellectual Property management – Guidance (Under development)
- ISO 56006: Innovation management – Tools and methods for strategic intelligence management – Guidance (Under development)
- ISO 56007: Innovation management – Idea management (Under development)
- ISO 56008: Innovation management – Tools and methods for innovation operation measurements (Under development)
- ISO/WD TS 56010: Innovation management – Illustrative examples of ISO 56000 (Under development)

As of September of 2020, four of the ISO 56000 standards listed above have been published, and four others are at various stages of development. An additional standard (ISO 56010) is in the early working draft / technical specification phase.

One standard in the ISO 56000 family establishes a foundation from which the other standards are built. The ISO 56000 standard (Fundamentals and vocabulary) helps organizations use a common terminology for innovation management and enables consistency in communications about innovation processes and outcomes. The standard provides a universal vocabulary, fundamental concepts and principles of innovation management that enable organizations to share their innovation activities in a credible and consistent manner. ISO 56000 is referenced by other standards in this family. Any organization that is looking to adopt one or more of the ISO Innovation Management standards should consider adopting the ISO 56000 standard as a starting point for communicating innovation concepts, practices, and activities.

The TRIZ practitioner has much to gain by reviewing the scope and content of the ISO 56000 standard. Within the standard are fundamental concepts which align to some of the key benefits of TRIZ methods, practices and use cases. In one specific example, section 4.2.5 of the standard outlines reasons an organization would want to adopt practices of innovation management. These reasons include [1]:

- ensuring the alignment of innovation activities and initiatives with the strategic direction of the organization, including resource allocation, indicators, and follow-up
- ensuring that the innovation strategy and objectives are flexible and adaptable to the evolution of promising opportunity areas and innovations

- managing the trade-off between optimization of performance and exploration of new opportunities in the organization
- fostering a culture supporting innovation activities and creating the appropriate conditions to innovate effectively, including securing resources
- removing barriers for innovation initiatives and innovators, e.g. implement processes and provide support to enable innovation activities in the organization
- ensuring that innovation activities are based on an understanding of stated or unstated needs and expectations

The TRIZ practitioner should recognize several alignments of TRIZ methods and use cases that align to the value drivers outlined in this section of the standard. For example, "Ensuring that the innovation strategy and objectives are flexible and adaptable to the evolution of promising opportunity areas" speaks directly to consideration of TRIZ patterns of evolution. As part the adoption of some or all of the ISO 56000 family of standards (notable, and as we'll discuss, ISO 56002), the TRIZ practitioner is right to ask themselves questions which include [2], "What does increased ideality look like for an organization adopting these standards? What are patterns of increasing adoption complexity that could be simplified? What adoption elements have matching or mismatched characteristics? Are there modes of adoption that require less human involvement?".

The ISO 56000 family is not prescriptive. Instead, it sets guidelines by which an organization can incorporate and build their own unique practices that help them achieve standardized innovation goals and parameterized assets. The alignment of TRIZ to concepts, drivers and innovation management use cases described in these standards is significant and presents opportunities for TRIZ practitioners to (re)introduce TRIZ to organizations in a way that is consistent and repeatable across organizations and industries. Among the currently published standards in the ISO 56000 family, ISO 56002 presents the largest opportunity for TRIZ practitioners to have meaningful discussions and repeatable, measurable impacts with their clients.

## ISO 56002

One of the more recent standards in the ISO 56000 family to be published (again, as of the time of the writing of this paper) is ISO 56002 (Innovation management system), and is by far, one of the more comprehensive of the published standards in this track to date. The ISO 56002 guidance standard covers many aspects of innovation management, from ideation through validation (and the culture that sustains the innovation process), commercialization, and protection of a resulting intellectual property

asset in one or more markets. The standard introduces a key driver and justification for all organizations (of any size) to consider implementing an innovation management system:

> *An innovation management system guides the organization to determine its innovation vision, strategy, policy, and objectives, and to establish the support and processes needed to achieve the intended outcomes."* [3]

It is reasonable to assume that audience of this paper would tacitly or explicitly know and agree with the benefits of adopting an innovation management system (and certainly, ISO 56002 gives an exhaustive list). What is of key importance in the introduction of this standard are eight principles which drive the foundations of an innovation management system. The eight principles are considered to be an open set to be integrated and adapted within an organization. The eight principles, as listed in the standard, are:

a) realization of value

b) future-focused leaders

c) strategic direction

d) culture

e) exploiting insights

f) managing uncertainty

g) adaptability

h) systems approach

The TRIZ practitioner should recognize that the methods and tools of TRIZ can align to many, if not all of these principles (some more directly than others). It is an important consideration when discussing the value of TRIZ methods with an organization. It is often too easy to focus a TRIZ discussion on the capabilities of TRIZ methods or tools, instead of the business value that TRIZ can help an organization realize. The principles and guidelines in ISO 56002 will be carefully studied and adopted by many organizations in the coming years. Aligning the benefits and value proposition of different aspects of TRIZ to different parts of the standard will enable TRIZ practitioners to more effectively drive adoption of TRIZ within a standard context (which is focused on sustainable value creation and delivery).

## ISO 56002 and TRIZ Adoption

This paper has already presented some initial observations of where TRIZ and the ISO 56000 series has intersections. Ultimately, it is advisable that each TRIZ practitioner should review one or more of the standards to determine the best areas of intersection for their own practice. ISO 56002 provides a comprehensive set of guidelines for the scope, establishment, culture, operation, leadership roles and objectives of an innovation management system. Within the ISO 56002 standard, there are a number of guideline sections which are highly aligned to the benefits, methods, tools and practices of TRIZ. The following list presents a tiny sampling of these sections with recommendations for how TRIZ practitioners might align and help foster not only the adoption of TRIZ, but also the adoption of the ISO 56002 standard (as well as the ISO 56000 family).

1. Section 4.1.1(b): *"The organization should regularly determine areas of opportunity for potential value realization."*

   TRIZ practitioners often lead teams or workshops that focus on discovering the most valuable problems to solve as a preamble to helping teams identify and validate concepts. As part of a regularly scheduled event within an organization to identify areas of value creation, TRIZ offers benefits that help fulfill this guideline.

2. Section 4.1.2(f): *"The organization should regularly scan and analyze the external context, considering issues related to the potential opportunities and threats, also those that might result from disruptions."*

   Organizations that create products, processes or other forms of intellectual asset value need to be aware of what's coming, and have an ability to project what might be coming, independent of documented insights. TRIZ practitioners are well-aware of the power and value of S-curve analysis, and of methods that examine how technologies and solutions might evolve. Organizations that adopt ISO 56002 are going to commit to resources (and roles) that require this kind of forethought and analysis. TRIZ practitioners have a particularly strong conversation point within this guideline and should consider

asking organizations how they currently track and project future solutions and disruptions to their value streams.

3. Section 5.1.2(a): *"Top management should demonstrate leadership and commitment with respect to value realization by allowing for conceptualization, experimentation, and prototyping, involving users, customers, and other interested parties to test hypotheses and validate assumptions."*

   An organization that adopts ISO 56002 will be committing to principles that will be embraced by leadership roles as well as subject matter experts. The standard maps out significant guidelines for leaders in terms of fostering, developing, and maintaining an innovation culture that is a critical part of an effective innovation management system. The TRIZ practitioner has every reason to have conversations with top management about their current methods for creating new ideas, solutions and how they are validated (as well as considerations such as freedom to operate). TRIZ offers unique and powerful ideation methods and systematic approaches to problem-solving. Top management that is investing in the adoption of the ISO 56000 family should be very receptive to discussions that provide practical, prescriptive means for meeting the guidelines set forth in the standards. This is a unique opportunity for TRIZ practitioners to drive high-value, high-impact conversations across organizations and industries that proposes the adoption of TRIZ methods as key components of meeting ISO 56000 series guidelines.

4. *Section 7.6(b): "The organization should consider creating awareness of, ensuring access to, and providing training for, the available (innovation) tools and methods."*

   Section 7.6 of the ISO 56002 standard focuses on the tools and methods that necessary for the development, maintenance and continuous improvement of an innovation management system. Tools and methods can focus on ideation, scenario planning, idea management, design strategies, business model templates and many other topics related to managing innovation. The form and formats of such tools and methods can include (and are not limited to) guides, presentations, software, presentations, and live services. Section 7.6 of the ISO 56002 is perhaps the easiest point of entry for a TRIZ practitioner to start a conversation with an organization regarding the adoption of TRIZ tools and methods as part of an ISO 56000 adoption strategy. Combined with other alignments to the ISO 56002 standard and the ISO 56000 family, the TRIZ practitioner can create tailored and effective roadmaps to help organizations achieve ISO 56000 adoption through the adoption of TRIZ methods and tools.

## Recommendations

The ISO 56000 family of standards is a framework designed to address high-degrees of variations in communication, uncertainties and processes for managing innovation that have existed for decades. The current publication roadmap and schedule for the standards track comes at a time when demand for innovation initiatives will grow exponentially in the coming years. As an innovation method and platform, TRIZ has been minimally adopted by small teams in companies and institutions of various sizes for years. TRIZ is often considered a "niche" discipline, and without dedicated sponsorship, is rarely adopted as a sustainable program by even the largest of organizations. The awareness by governments and industry of the ISO 56000 family is growing, and is raising questions by organizations as how to best adopt the standards. It is recommended that TRIZ practitioners become aware and well-versed in the ISO 56000 family, and keep a watchful eye on the continuing development and upcoming releases of additional standards in this track. It is also recommended that TRIZ organizations work with their memberships to develop alignment strategies of TRIZ methods to the ISO 56000 family, and create materials and services promoting the adoption of the ISO 56000 family through leveraging of TRIZ tools, methods and insights.

By aligning the business value proposed by the ISO 56000 family with TRIZ, the TRIZ community has a unique opportunity over the next few years to significant increase mindshare and adoption of TRIZ tools and methods in the name of driving value through the adoption of innovation management standards.

## References

1. ISO 56000:2020(E), Innovation management – Fundamentals and vocabulary, Section 4.2.5
2. Michael S. Slocum, "Use the Eight Patterns of Evolution to Innovation", The TRIZ Journal
3. ISO 56002:2019, Innovation management – Innovation management system - Guidance, Section 0.1

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# Modern Tools for Business TRIZ

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## Abstract

In the early 1990s, first attempts were made to examine if a systematic approach used in TRIZ can be used beyond engineering: in particular, to assist supporting solving innovative problems and challenges within the areas of business and management. The experience gained since helps with drawing conclusions regarding the applicability of the approach as well as which parts of TRIZ can be directly used in the areas of business and management; which parts cannot be used or must be adapted; and what new knowledge is needed. The paper summarizes state-of-the-art of modern TRIZ tools for different types of innovative projects in business and management.

Keywords: *TRIZ, Business Innovation, Innovation Training*

## 1 Introduction

For a long time, engineering innovation has been among the most important factors driving the progress of human civilization. Today it is obvious that business innovation is not less important to successfully compete and becomes the necessity. Modern business environment is extremely dynamic and fast, information technology and global networking eliminate borders, which used to keep businesses in their comfort zones, the market continuously demands better services, competition even between small companies moves to a global scale.

At the same time there was no solid and proven method that would support business innovation. In search for a solution, more and more businesspeople turn their attention to TRIZ. While TRIZ nowadays is primarily known and used in technology and engineering, applications of TRIZ in business and management areas have been practically unknown. It should not be surprising: TRIZ was created by engineers for engineers. The vast majority of TRIZ professionals work in the areas of engineering rather than business due to historic reasons.

In addition, most of TRIZ experts working in the technology areas are vaguely familiar with specifics of business environments. It became obvious that a separate version TRIZ for Business and Management was needed.

Relatively recently, TRIZ developers started to expand application of TRIZ to business and management areas [1, 2, 3, 4, 5, 6].

The results appeared to be rather encouraging: a number of seemingly unsolvable business and management problems were solved quite effectively and efficiently. Such situation triggered further development of TRIZ for Business and Management, which has been actively evolving during recent years. A major step in further promotion of "Business TRIZ" was made by introduction of Darrell Mann's book "Hands-On Systematic Innovation for Business and Management" [7] in 2004. It triggered performing further experiments by business professionals in academia and industry.

In contrast to engineering innovation which occurs either in a technical product or in a manufacturing or a production process, innovative solutions in business and management have a broader scope and can occur at different places of a specific business ecosystem (Fig. 1). Red spots in the figure demonstrate where such innovations can usually take place.

Note that sometimes, to achieve improvement of collaborative efforts within the value network, innovation of a business system of a supplier can be demanded.

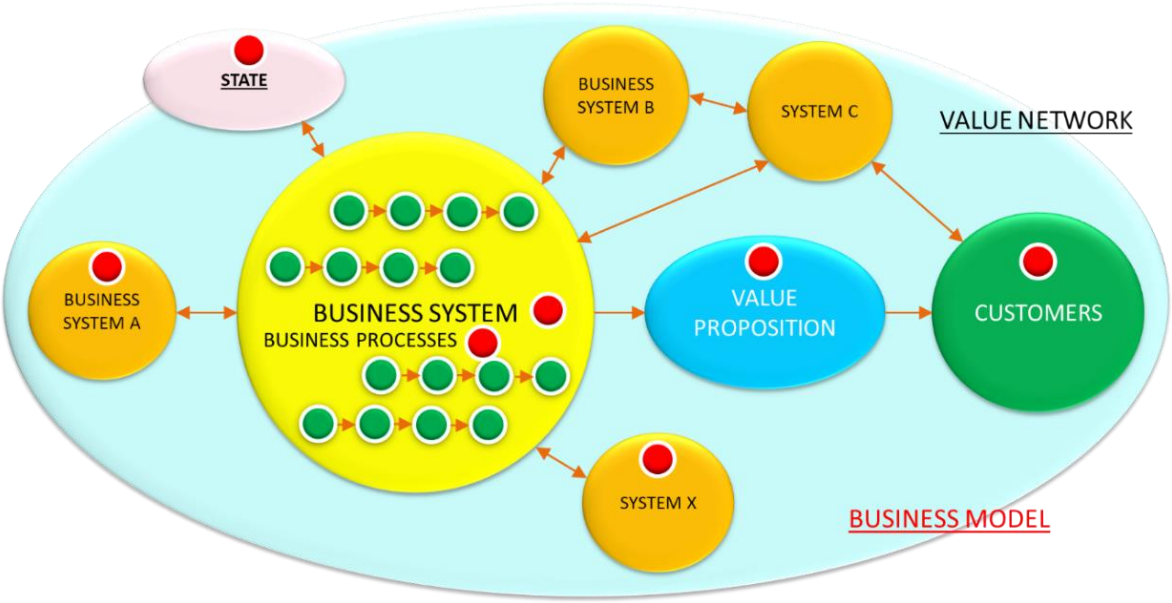



Fig 1. Red spots mark places where business and management innovation can take place.

As we all know, modern TRIZ is based on the assumption that all technical systems evolve according to certain regularities. Once we know these regularities, we are capable of predicting future evolution of systems and considerably lower the risks when choosing the direction of innovative changes. This assumption is based on the basic model of a technical system proposed in the early times of developing TRIZ by the author of TRIZ G. Altshuller (Fig 2).

It becomes obvious that the same assumption – evolution of applies to business systems, but with its own regularities. To unify business systems and to extract the patterns of evolution of business systems, a TRIZ-based model of a business system was suggested (Fig 3) [8]. Currently such a model is considered as fundamental and is used as a basic during the development of different TRIZ tools for business and management.

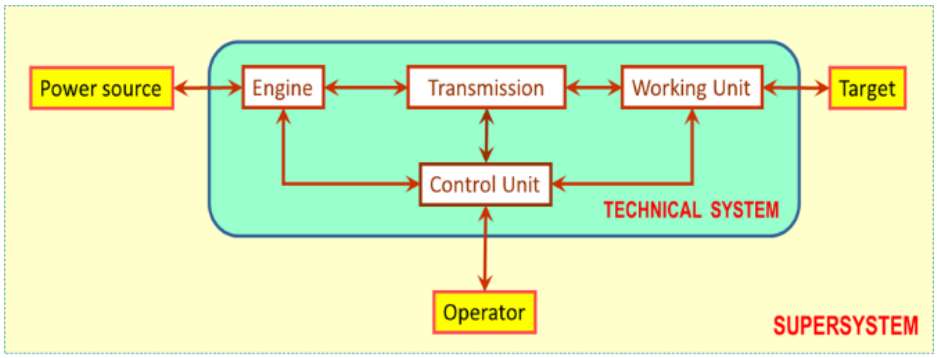



Fig. 2. Models or a Technical System in TRIZ

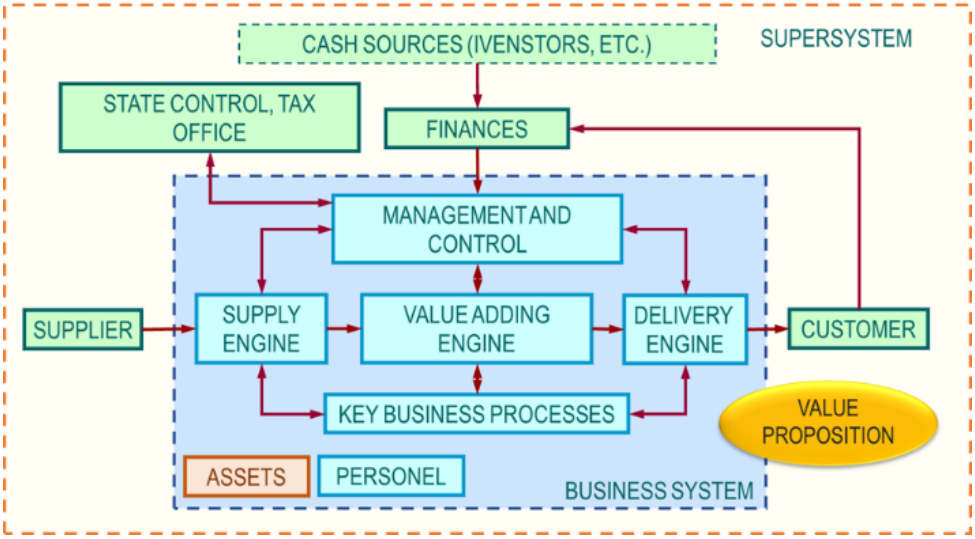



Fig. 3. Model of a Business System in TRIZ

A business system is a model of an organization which converts some input to a certain output by adding value. As seen, a model of a business systems resembles a technical system although includes different parts. Nevertheless, a conceptual similarity at a functional level helps to establish analogies and conduct many parallels. First of all, both technical and business systems are utilitarian systems, which are created artificially to satisfy some human goals and meet certain demands.

However, numerous attempts in the past to directly apply technical TRIZ to create business innovations or solve business problems mostly failed.

One of the reasons is a cognitive bias. When we explain TRIZ principles with the help of technical examples, non-technical people will understand the examples, but they will hardly connect it with their own area of competence and therefore will not capture these principles and incorporate them to their own practice.

To solve this problem, during a number of years, studies were conducted to understand which and how some parts of TRIZ can be adapted to business language and business tasks.

As a result, it was proposed to distinguish a different direction within TRIZ for systematic applications of TRIZ principles for business innovation, which is today known as “Business TRIZ”.

## 2 Modern Business TRIZ

Modern Business TRIZ is a result of 20 years of adaptations and developments. Its tools are smilar to the tools of technical TRIZ, including classical ones. They are structured to the curricula accordingly three large areas of competence (Fig. 3):

1. Tools for solving specific stand-alone problems.
2. Tools for analysing systems and processes, and extracting and ranking of problems. Disruptive innovations and process/systems cost cutting.
3. Tools for future forecast, breakthrough innovations, and antcipating failures.

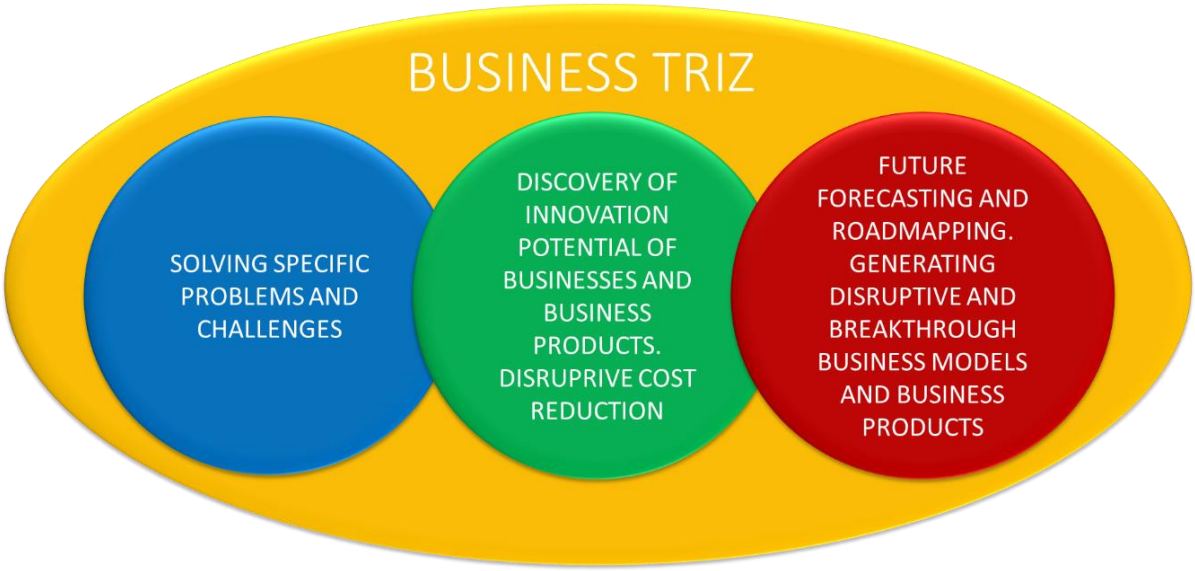



Figure 3. Three levels represent the current structure of Business TRIZ

Table 1 shows tools which are included to a modern training program for Business TRIZ. Similar to MATRIZ curricula for technical TRIZ, it consists of three competence levels.

Table 1. Tools of Business TRIZ in the current Business TRIZ Curricula

| LEVEL 1: SOLVING A SPECIFIC PROBLEM / CHALLENGE | LEVEL 2: INNOVATION OF SYSTEMS AND PROCESSES, PROBLEMS DISCOVERY, DISRUPTIVE COST CUTTING | LEVEL 3: FUTURE INNOVATION ROADMAPPING |
|---|---|---|
| • Problem Perception Mapping.<br>• Ideal Solutions.<br>• Root Conflict Analysis (RCA+).<br>• Principles of Separating Conflicting Requirements.<br>• 40 Innovation Principles for Business and Management.<br>• Contradiction Matrix for Eliminating Business Contradictions.<br>• Ideas Portfolio.<br>• Multi-Criteria Matrix of Solution Ideas. Integral Ideas Landscape. | • Business Model Assessment.<br>• Function and Cost Analysis. Problems Discovery.<br>• Function Idealization (Trimming) for Systems and Processes.<br>• Object-Field Modeling.<br>• Standard Inventive Solution Patterns for Business and Management.<br>• Merging Alternative Competing Systems (Feature Transfer).<br>• Function Oriented Search (FOS).<br>• Main Parameters of Value (MPVs).<br>• S-curve Analysis and Assessment. | • Value-Conflict Mapping (VCM).<br>• Multi-Screen Analysis (MSA).<br>• TRIZ Laws and Trends of Evolution.<br>• Line of Functionality Evolution.<br>• Trends and Lines of Business Systems and Products Evolution.<br>• Systematic Services Evolution.<br>• Subversion Analysis.<br>• Anticipatory Failures Analysis.<br>• Business Models Navigator.<br>• Diversification of Business Models and New Markets Discovery.<br>• Business Innovation Roadmapping. |

Today, these levels of competence are implemented in a training and certification program developed by the International Business TRIZ Association (IBTA) [9].

Currently, the following three groups of tools are in the program:

1. Tools of classical TRIZ which remained unchanged.
2. Adapted tools: classical and modern tools of technical TRIZ which were incorporated to Business TRIZ but underwent slight or serious adaptations.
3. New tools which were developed for Business TRIZ.

## 2.1 Adapted Tools

As mentioned above, adapted tools represent the largest group of TRIZ tools. They are listed in Table 2.

Table 2. Adapted tools of TRIZ

| TOOL | CHANGE |
|---|---|
| 40 Inventive Principles | Adapted version of 40 Inventive Principles for Business and Management |
| Contradiction Matrix by G. Altshuller | Business Matrix 3.0 (D. Mann)<br>Innomation Matrix (D. Conley) |
| Cause and Effect Chain Analysis (CECA) | Root Conflict Analysis (RCA+) |
| Resources | Classification of resources for business and management |
| Function Analysis | Extended version: intangible objects; function formulation, etc. |
| Substance-Field Model and Standard Inventive Solutions | Object-Field Model; New classification of standard solutions; New system of standard solutions. |
| Function Oriented Search (FOS) | Updated a way a function is identified in business |
| Laws, Trends and Lines of Systems Evolution | Adapted version for business systems and products |
| ARIZ | Problem Solving process supported by different tools replaces ARIZ |

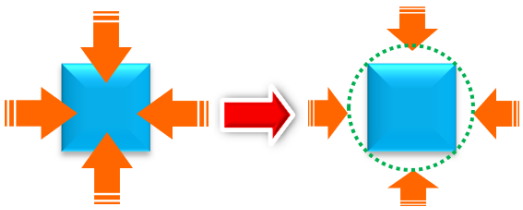
To illustrate the changes, let us take a look at two most known problem solving tools of TRIZ: 40 Inventive Principles and 76 Standard Inventive Solutions.

In particular, a modified version of the most famous TRIZ tools - 40 Inventive Principles for eliminating technical contradictions, contains the following changes:

- Partly changed the content of each principle to adapt it to business terminology.
- Completely changed contents of Inventive Principles 8, 9, 12, 14, 18, 19, 28, 29, 30, 31, 36, 37, 38
- Changed the titles of Inventive Principles 12, 14, 18, 28, 29, 30, 31, 32, 36, 37, 38.
- In each principle were changed the quantity of subprinciples, and currently the system includes of 192 recommendations.

An example of an updated inventive principle #12 is shown in Fig. 5.

**#12: TENSION REMOVAL**



**Strategies and recommendations**

- Create conditions to eliminate or compensate for possible tensions that occur or might occur within your system or between a system and its supersystem.
- Create conditions to eliminate or compensate for possible tensions that occur or might occur within your process or between a process and its supersystem.
- Integrate different subsystems or systems to remove tension.
- Introduce a new subsystem or a process activity to decrease possible tension.
- Eliminate or replace a subsystem or process activity that creates tension.
- Break a process to smaller steps to remove possible tension.

**EXAMPLES**

- A manager tunes presentation to best suit audience of, for example, workers and directors.
- Making "horizontal" career changes to broaden skills.
- Trust building exercises.
- Increasing customer's loyalty by organizing customer groups meetings, events and supply of information.
- Team members distribute their own merit award money (rather than management).
- Force-Field Analysis: group discussion of the phrase "forces push in various directions" - teambuilding/problem-solving technique.
- Conducting job interview in a café rather than in the office.
- Online FAQs help to clarify many issues before engaging to a purchase.
- Ensuring equal handling of different customer groups.
- Hiring a third-party independent mediator for resolving conflicts.
- "Go/No Go" clauses in contracts.

Fig. 5. An Inventive Principle for Business and Management.

Similarly, the new matrix of contradiction elimination for business and management is available and consists of 45 business parameters [10].

The same applies to what is known as "Standard Inventive Solutions". A classical TRIZ System of Standard Inventive Solution is based on a so-called "su-field" (substance-field) analysis and consists of 76 standard solutions. Although the approach can be effectively used for solving business and management problems, using the word "substance" would be obscure. Therefore a model was changed: rather that "substance-field", an "object-field" analysis is used.

Examples of two modified and adapted Standard Inventive Solutions for business and Management are shown in Fig. 6.

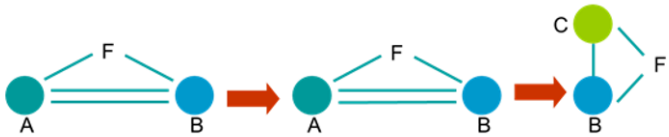
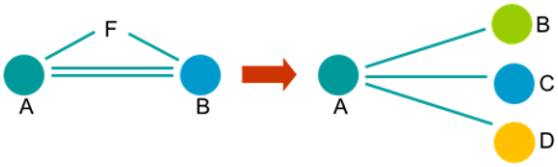
| | | |
|---|---|---|
| 2-3 | **If a precise effect of interaction between two objects A and B is required while the excessive interaction must be maintained, and it is difficult or impossible to achieve it under the conditions given, use the maximum action, while the excess of the action is then removed.**<br>  <br><br>Explanation: Often we cannot obtain optimal result directly. In such cases it is possible to use maximum action and then remove the excess. | *Example: If it is difficult to predict in which specific methods (A) to train employees (B), then train them in general methods which can be later adjusted to the specific needs of an organization (C).* |
| 2-4 | **If there is an excessive result of interaction between the objects A and B, introduce several objects instead of object B and redistribute action between these newly introduced objects. New objects can be identical or with biased parameters.**<br>  <br> | *Example: Too much diverse information (A) can make work of a business analyst (B) ineffective. Rather than using a single analyst with broad competence, several analysts with different narrow competences can be used.* |

Fig 6. Two examples of Standard Inventive Solutions for Business TRIZ.

In addition, the inventive standards are grouped differently than in technical TRIZ. While in technical TRIZ they are grouped according the line of evolution of technical systems, in Business TRIZ, standard inventive solutions are grouped according to the type of problems they solve. In total, there are 5 groups of problems [11] (Fig. 7).

**GROUPS:**

- **Group 1: Improving insufficient effect of an interaction**
  - Standard 1-1: Transition to internal complex model
  - Standard 1-2: Transition to external complex model
  - Standard 1-3: Introducing intermediary
  - Standard 1-4: Using existing resource
  - Standard 1-5: Using modified or new environment
  - Standard 1-6: Transition to dual model
  - Standard 1-7: Transition to periodic action
  - Standard 1-8: Introducing selective protection
  - Standard 1-9: Introducing selective amplification
  - Standard 1-10: Segmentation of objects and processes
  - Standard 1-11: Increasing the degree of segmentation
  - Standard 1-12: Dynamization of objects and processes
  - Standard 1-13: Increasing the degree of dynamics
  - Standard 1-14: Transition to bi- and poly-systems
  - Standard 1-15: Increasing differences in bi- and poly-systems
  - Standard 1-16: Paradigm change
- **Group 2: Improving excessive effect of an interaction**
  - Standard 2-1: Introducing filtering
  - Standard 2-2: Modified environment
  - Standard 2-3: Action maximizing
  - Standard 2-4: Removing excess of action
- **Group 3: Improving poorly controllable effect of an interaction**
  - Standard 3-1: Introducing intermediary
  - Standard 3-2: Transition to external complex model
  - Standard 3-3: Replacing paradigm
  - Standard 3-4: Outsourcing to supersystem
  - Standard 3-5: Transition to chain model
- **Group 4: Eliminating negative effect of an interaction**
  - Standard 4-1: Introducing intermediary
  - Standard 4-2: Introducing modified intermediary
  - Standard 4-3: Neutralizing
  - Standard 4-4: Distraction by a new field
  - Standard 4-5: Introducing antipodal action
  - Standard 4-6: Modified object in advance
  - Standard 4-7: Withdrawing effect
  - Standard 4-8: Periodic action
  - Standard 4-9: High speed
  - Standard 4-10: Paradigm change
- **Group 5: Organizing or improving measurement and detection**
  - Standard 5-1: Problem change
  - Standard 5-2: Using a copy
  - Standard 5-3: Successive detection
  - Standard 5-4: Indirect resource measurement
  - Standard 5-5: Transition to a dual model
  - Standard 5-6: Transition to bi- and poly-systems
  - Standard 5-7: Measuring derivative

Fig 7. Current structure of a System of Inventive Standards

## 2.2 New Tools

In addition, new tools for Business TRIZ were developed. Some of them appear to be universal and can be applied to both technical and Business TRIZ [11]. They are listed in Table 3.

Table 3. New tools of TRIZ

| TOOL | DESCRIPTION |
|---|---|
| Value-Conflict Mapping (VCM) | Enables extracting barriers to further evolution of a system or a service with regard to existing and forthcoming market trends and demands and presenting them in form of a contradictions tree |
| Multi-Screen Analysis (MSA) | Systematic comparison of previous and current generations of systems or processes and extracting future problems to solve related to Ideality-Value Formula |
| Root Conflict Analysis (RCA+) | Decomposes a problem given to a tree of interrelated causes and contradiction |
| Business Models Navigator | Identifies specific business models capable of eliminating typical business contradictions |
| Ideas Landscaping | Multi-criteria Decision Matrix and a set of layers to evaluate and select most promising solution ideas |
| Business Innovation Roadmapping | Approach to strategically plan a timeline of future innovations consisting of a number of layers (based on Dr. R. Phaal approach) |

Descriptions of most of these tools are presented in [12].

Specifically, we can outline the tool "Business Model Navigator" which was developed to eliminate contradictions by replacing business model [13].

## Summary

This paper was supposed to give a short overview of tools included today to the training and certification program of the International Business TRIZ Association (IBTA) which set up a goal to develop the top quality standards of training in TRIZ for Business and Management.

Taking to account relatively short time of implementing the program, IBTA looks forward to expanding its activities, in particular, accreditation of new trainers, thus gathering more customer feedback to improve its training program.

## References

1. Zlotin B. & Zussman A. "Evolution of Organizations". Materials of TRIZ Course, Kishinev, Moldova, 1991. (in Russian)
2. Mann D. & Domb E. "40 Inventive (business) principles with examples", The TRIZ Journal, September 1999.
3. Souchkov V. "M-TRIZ: Application of TRIZ to Solve Business Problem", Insytec white paper, June 1999.
4. Ishida Atsuko. "Using TRIZ to Create Innovative Business Models and Products". In *Proceedings of International Conference TRIZ Future 2003*, November 12-14, 2003, Aachen, Germany.
5. Averboukh E. "I-TRIZ for Six Sigma Business Process Management", The Online TRIZ Journal, December 2003.
6. Smith H. "P-TRIZ Formulation", #2 in a series, BPTrends.com, March 2006.
7. Mann D. "Hands on Systematic Innovation: For Business and Management". Edward Gaskell Publishers, 2004

8. Souchkov, V, "Typical Patterns of Business Model Innovation". In *Special Issue: Selected papers presented at the 15th International TRIZ Future Conference "Global Structured Innovation",* Berlin, 26.-29.10.2015. pp 121-127
9. Website of the International Business TRIZ Association (IBTA), www.biztriz.net . Last seen September 10, 2021.
10. Mann, D. "Business Matrix 3.0. Solving Management, People and Process Contradictions", IFR Press., 2018.
11. Souchkov V., Roxas J.P. "A System of Standard Inventive Solution Patterns for Business and Management problems". In *Proceedings of the 12th International Conference TRIZfest 2016. The International TRIZ Association - MATRIZ*. July 28-30, Beijing, China. 2016. pp 22-35.
12. Souchkov V. "Materials of Training for TRIZ and Systematic Innovation for Business and Management: Levels 1-3". ICG Training & Consulting, Enschede, The Netherlands, 2007-2021.
13. Kuryan A. & Rubin M. "TRIZ-Navigator for Business Models". In *Proceedings of the 13th International Conference TRIZfest 2017.* The International TRIZ Association - MATRIZ. September 14-16. 2017. pp 514-525.

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TRIZ*fest*-2021

# Patent Circumvention and Strengthening in Wind Turbine Blade Noise Reduction

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## Abstract

In wind turbine, serrated trailing edge is a well-known method to reduce the noise produced by the rotating wind turbine blades. This paper tries to circumvent one competitive patent and also try to make our own new patent stronger.

Keywords: *patent circumvention, TRIZ, DFP*

## 1 Project

With the large-scale construction of wind farms and the large-scale development of wind turbines, the noise problem of wind turbines is becoming more and more prominent. At present, the application of serrated trailing edge is an effective way to suppress trailing edge noise of blades by various machine manufacturers and blade manufacturers. The schematic diagram is shown below in Fig.1[1].

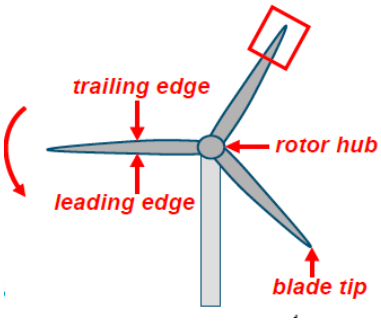



Fig.1. Wind turbine blades

Noise may be generated at the trailing edge of an airfoil by one distinct processes: turbulent boundary layer trailing edge noise, or “TBL-TE” noise.

TBL-TE noise, referred to hereafter as “trailing edge noise,” is caused by scattering of turbulent fluctuations within the blade boundary layer at the trailing edge, resulting in radiation of broadband noise (see Fig.2[2]).

Incident unsteady pressure fluctuations in the turbulent boundary layer are scattered at the sharp trailing edge, causing some of the fluctuation energy to be radiated as sound. The radiated noise is loudest for an incident pressure wave that is aligned with the edge and traveling normal to the edge. As this pressure wave passes over the edge, it encounters a sudden change in acoustic impedance, resulting in the scattering of noise. The serrations can be viewed as a means of distributing this sudden change in impedance over a finite distance, thereby reducing the strength of the scattering process.

Fig.2. Wind turbine blades

## 2 TRIZ relation

Through the analysis of the competitors' valid patents, we can see that patent US20190113019A1 has the best effect and has a very good market prospect.

The independent claims are shown below in Fig.3.

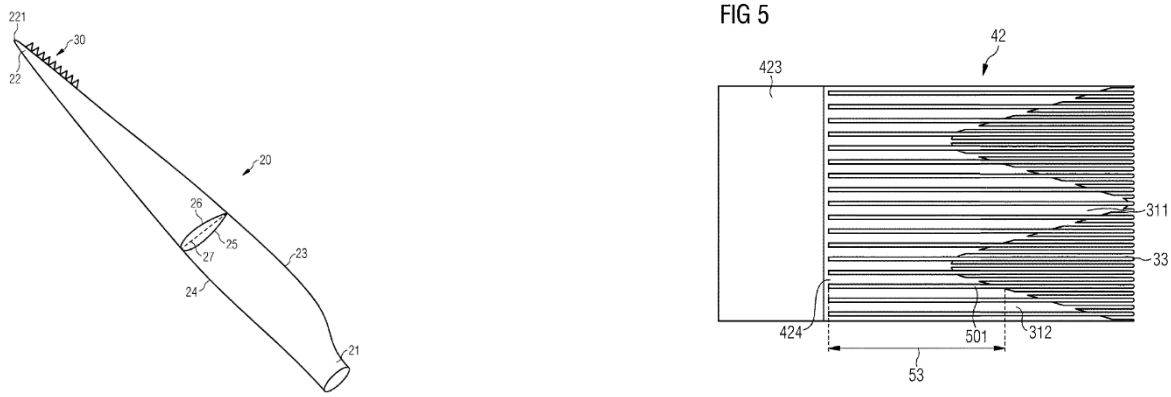



Fig.3. US20190113019A1

There is provided a rotor blade for a wind turbine, wherein the rotor blade comprises serrations along at least a portion of the trailing edge section of the rotor blade. The serrations comprise a first tooth and at least a second tooth, wherein the first tooth is spaced apart from the second tooth. The area between the first tooth and the second tooth is at least partially filled with a plurality of comb elements, wherein the comb elements are arranged substantially parallel to each other and in substantially chordwise direction of the rotor blade such that generation of noise in the trailing edge section of the rotor blade is reduced. The rotor blade is further characterized in that it comprises a plurality of ridges, comprising a first ridge and at least a second ridge for manipulating an airflow which is flowing along the ridges.

According to the independent claim of patent US20190113019A1, the functional model was established (see Fig.4).

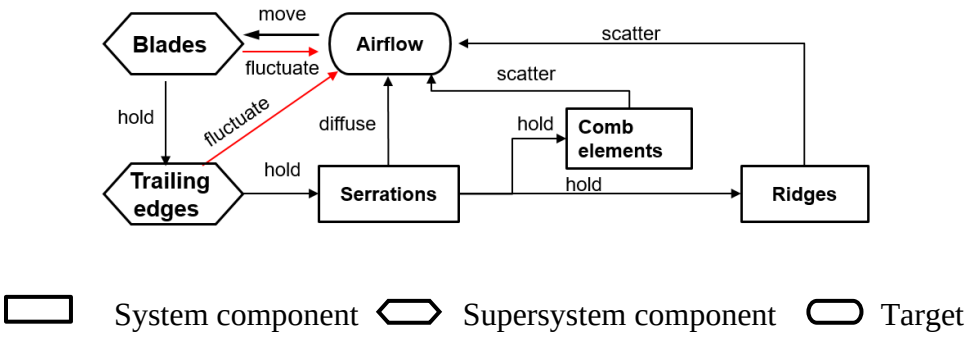



Fig.4. Functional Model

According to the rules from DFP [2], we build the following table, see Table 1.

Table 1

14. Table 1. Attributes Analysis

| System component | Function | Attributes (component has details on position, shape, orientation, etc.) | For what |
|---|---|---|---|
| Serrations | To diffuse airflow | along trailing edge; tooth spaced apart each other | |
| Comb elements | To diffuse airflow | Within two teeth; parallel to each other; in chordwise direction | To reduce the noise |
| Ridges | | | |

## 3 Application of Trimming

Remove the ridges, and redistribute its useful function to component serrations. We can replace the serrations with notch grooves or pits (see Fig.5).

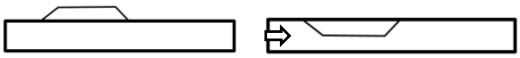


Fig.5 Original design and new design

Also, we can redistribute its useful function of ridges to the supersystem component airflow.

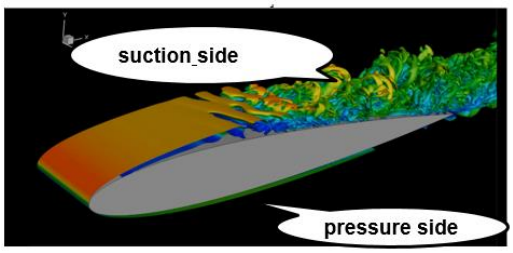



Fig.6 Suction and pressure sides of blades

We can make through grooves at the position of the original ridges, so the airflow in the pressure side will go through the grooves and generate 'air ridges' (see Fig.6).

## 4 Application of PC:

Comb elements should be in chordwise direction to reduce the noise effectively

BUT

Comb elements should be downward against chordwise direction for increasing the lifting force

Here seperation in space is applicable(see Fig.7).

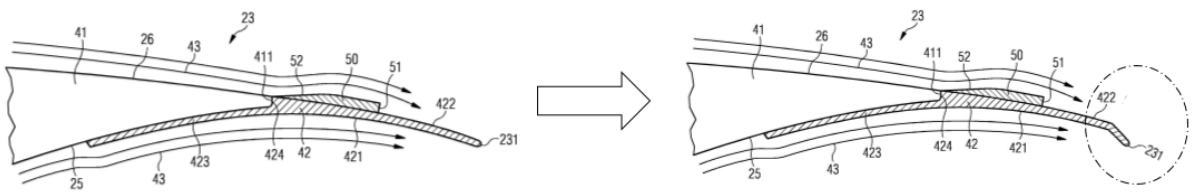



Fig.7 Original design and new design

## 5 Application of Super effect analysis:

We know the method of  Serrations have a good effect to reduce the noise, and the edge of the serrations are resources without causing much attention before. So we can apply multiple serrations or pits to the edges of each tooth (see Fig.8).

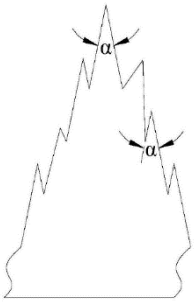



Fig.8 Tooth with multiple small serrations

## 6 Application of MPV analysis

Though the result of competitive patent is perfect, but in the course of testing, we found that serrated trailing edge is easy to drop from the trailing edge of blades and hurt objects around the wind turbine. So in this aspect, we also need to solve it. Again, we build the function model to identify the hidden function disadvantages (see Fig.9).

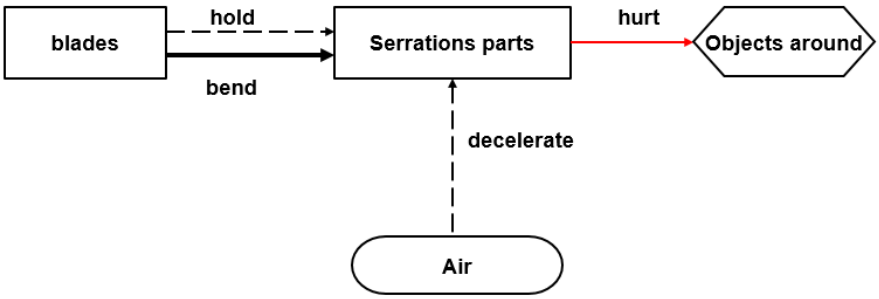
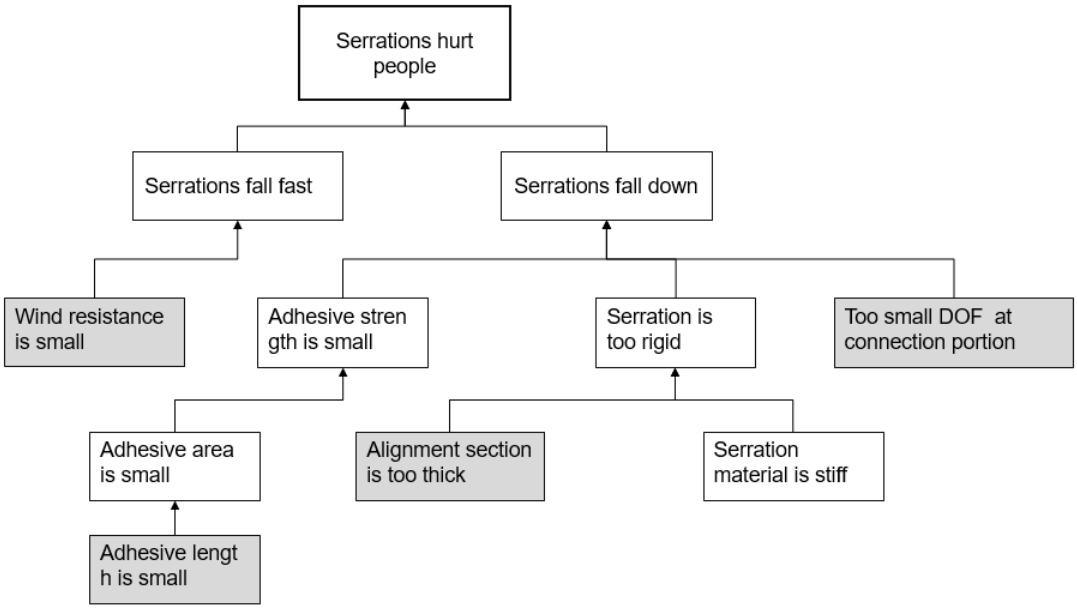



Fig.9 Function model

After that, CECA model is built to identify more hidden disadvantages (see Fig.10).




key disadvantages

Fig.10 CECA model

Then we select several key disadvantages to solve by TRIZ problem solving tools.

## 3 Application of PC

The adhesive length should be big in order to get bit adhesive force,

But

The adhesive length should be small in order to reduce the bending stress.

We can solve it by separation in relation. It means that the adhesive length is small for the blades, but for the glue, it is big.

So the solution is as follows, the adhesive part of the serrations is wavy to improve the adhesive force and reduce the bending stress (see Fig.11).

Fig.11 Wavy serrated trailing edge

For the key disadvantage of ‘wind resistance is small’, it's designed to be heavy on one side, so It swirls slowly through the air as it falls, falling slowly (see Fig.12).

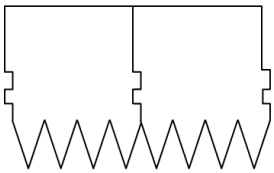


Fig.12 Spinning falling serrated trailing edge

## 4 Conclusions

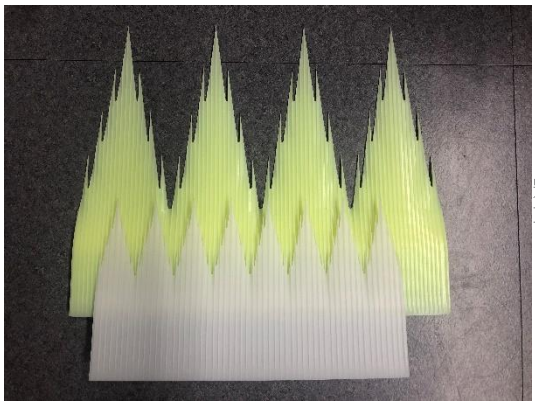


Fig.13 serrated trailing edge with multiple small teeth

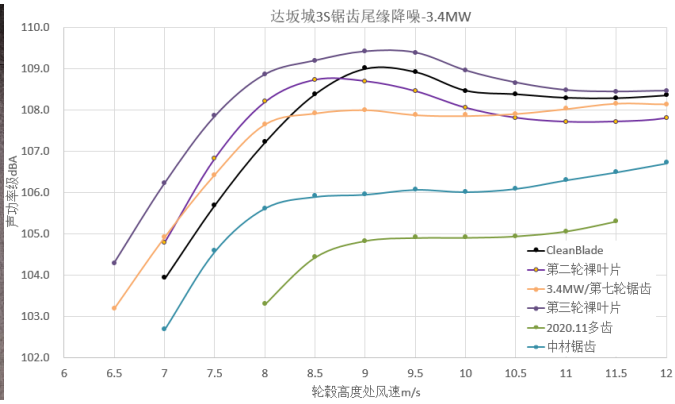



Fig.14 Result comparison of noise value

The serrated trailing edge with multiple small teeth (see Fig.13) was patented and tested in GW155, and the noise reduction effects (see Fig.14) was compared with the competitive patent. The effect was surprisingly good.

## Acknowledgements

Many thanks to Dr. Sergei Ikovenko and Alex Lyubomirskiy, Their patient instruction are very helpful for my understanding and using of TRIZ in my project.

## References

1. Low-noise wind turbine design http://www.ewea.org/events/workshops/wp-content/uploads/2012/12/EWEA-Noise-Workshop-Oxford-2012-1-1-Stefan-Oerlemans.pdf
2. Serge Ikovenko, Design for Patentability Level 1 online Training, 2019

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TRIZ*fest*-2021

# Pockets of Knowledge (PoK) – TRIZ

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## Abstract

This study investigates current training trends and their implication for training in TRIZ. It proposes to use the concept of "Pockets of Knowledge" (PoK), a short on-demand video format to deliver various modules of the TRIZ methodology. It is aimed initially at start-ups but could soon see its remit expand. The authors believe this new format can help the further democratization of TRIZ in the world.

Keywords: *Pockets of Knowledge (PoK), start-ups.*

## 1. Introduction

TRIZ has been developing in the world for the last 65 years. Its power to help companies tackle difficult and varied technical challenges is evident and proven. What's more, TRIZ continuously evolves. Over the years, its tools improve and new tools emerge. Also, TRIZ adapts to a growing number of new areas and new applications, e.g. to business and organization, patent management, and education, to name just a few.

Despite its undeniable success, many companies which are aware of the existence of TRIZ, large companies or SMEs, do not wish to use it. One major objection expressed is its complexity. For them, this alleged disadvantage has two consequences: it necessitates too much time to learn, to master and to apply to a specific project.

Based on our respective experiences, we believe that:

- To completely learn (e.g. to MATRIZ level 3) and master TRIZ can take years.
- TRIZ is not complex in itself, but it contains many tools.

- Which TRIZ roadmap (some well-chosen TRIZ tools arranged in a certain order) to use for a given challenge is not obvious, mostly because of a lack of publications on this important topic.
- Many difficult projects or challenges require a significant part of (or the complete) TRIZ toolbox.
- Most less difficult projects or challenges do not require many TRIZ tools; rather the application of a minimum number of well-chosen tools can be sufficient.
- The name TRIZ can give an impression of complexity, since TRIZ stands for the Theory of Inventive Problem Solving and the term "theory" is normally associated with something very complex which requires a lot of time and effort to understand.

Additionally, there are some contexts in which companies or individuals have very limited time, financial and human resources. This is particularly the case among start-ups. By definition, the services or the products of start-ups are at stage 1 or stage T on their respective S-curves, and therefore have many challenges of different natures to tackle. Some of these challenges can potentially be addressed with the use of TRIZ. However, in practice, start-ups usually cannot learn the complete TRIZ toolbox. Also, assumedly, for many of their challenges where TRIZ might be useful, the application of *all* TRIZ tools is unnecessary. Start-ups are ready to learn very quickly and immediately afterwards apply the necessary tools to the challenge at hand. So, what shall be proposed to them, and how?

## 2. Current training trends

For both the private and public sectors, clear training trends emerge. Along with the digitalization of the world, which has been accelerated by the COVID-19 pandemic, training has also become more digital. Today, the most advanced digital training has the following characteristics:

- It is organized in modules.
- Modules contain videos and quizzes: videos capture the attention of the trainee, while quizzes consolidate the integration of knowledge.
- Videos have a short format (from 3 to 15min).

The short format of videos corresponds to the concept of Pockets of Knowledge (PoK).

## 3. Pockets of Knowledge TRIZ

A new format of TRIZ training service named PoK TRIZ is proposed. The initial target market of this new service is the world of start-ups. The value proposition is to offer on demand, segmented modules to meet an immediate need and ensure development and innovation is done at pace. Its structure is as follows:

- A typical situation encountered by the start-up is chosen, e.g. cost reduction (This is one of the general recommendations at stage 1 of evolution [1].).
- For this chosen situation, the minimal, customized TRIZ roadmap is proposed, with a corresponding set of tools.
- Each tool of the customized roadmap is taught online in small progressive modules. Each module contains PoK TRIZ video(s). Videos show illustrative examples for which the TRIZ tools algorithms are applied.

As a result, start-ups can learn quickly and immediately apply their learning to the challenge at hand.

## 4. Comparison with project management

If we consider the building of the pyramids (c. 2540 BC) and the Great Wall of China (c. 212 BC), we can say that project management has been practised for thousands of years. However, over the last 50 years or so, it has evolved rapidly to respond to changing customer requirements and a greater need to deliver at pace and to manage more risk and uncertainty in the environment.

Methodologies have evolved to accommodate these different needs, from full design upfront methodologies to partial design upfront to no design upfront. Waterfall, hybrid and Agile methodologies have emerged. For instance, waterfall methodologies have evolved to become more adaptable to Agile environments. PromptII (1975) was a response to a need to deliver on time and budget. This was followed by Prince (1989), which added progress assurance, and PRINCE 2 (1996), which made the method more generic and applicable to any project, with tailoring as a key principle. More recently, PRINCE 2 AGILE (2015) was created to be adaptable to Agile environments.

Just as project management methodologies have tailored their tools to suit the needs of particular projects and users, can TRIZ offer a more accessible, modular approach to some users?

## 5. Case study A: Design simplification

This is a “virtual case study” created using information available in the public domain.

Usually, ice cubes are not transparent and have a milky aspect, because air bubbles germinate and grow ahead of the water crystallization front and get trapped inside the ice cube because the crystallization front first forms at the upper water surface.

An imaginary start-up company A has designed an ice tray which produces transparent ice cubes. The concept is shown below on Figure 1 (in reality it was developed by a Japanese company in 1994 [2]). The functioning principle of this ice cube tray is as follows: air bubbles can escape through the holes 5 and 5’ and accumulate in a secondary tray 12. As a result, the ice cube 4 is transparent. This design has been tested on a prototype with success.

However, while this product is still at stage 1 of its S-curve, the start-up considers that this ice cube tray design is rather complex and costly, and it wants to simplify it. The company thinks it has found a good functioning principle and it is out of question to change it.

Company A goes to the PoK website and registers. Its typical situation is identified: design simplification. The following roadmap is proposed:

- Short Function Analysis
- Trimming
- Physical Contradictions and their Resolution Principles
- Function-Oriented Search

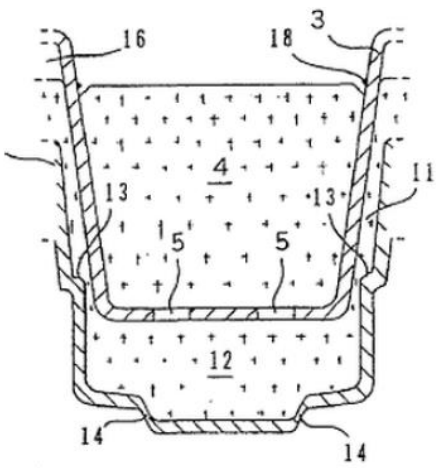


Fig. 1: Initial design of ice cube tray for the production of transparent ice cubes

After the short PoK TRIZ Function Analysis video course, company A composes the Function graphical model shown on Figure 2.

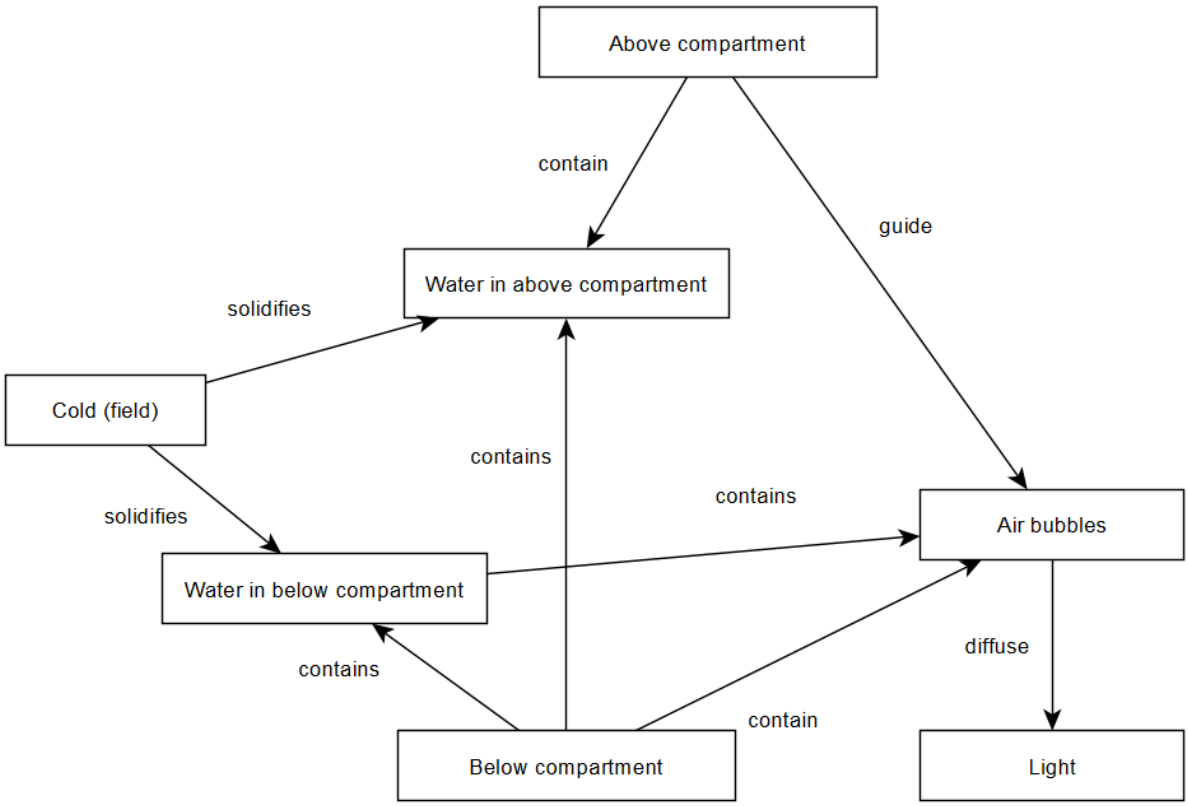


Fig. 2: Function graphical model of the initial ice cube tray design

After the PoK TRIZ Trimming video course, company A recognizes readily that the most direct way to simplify its initial ice cube tray design is to trim the below compartment. Then the Trimming model appears as on Fig. 3.

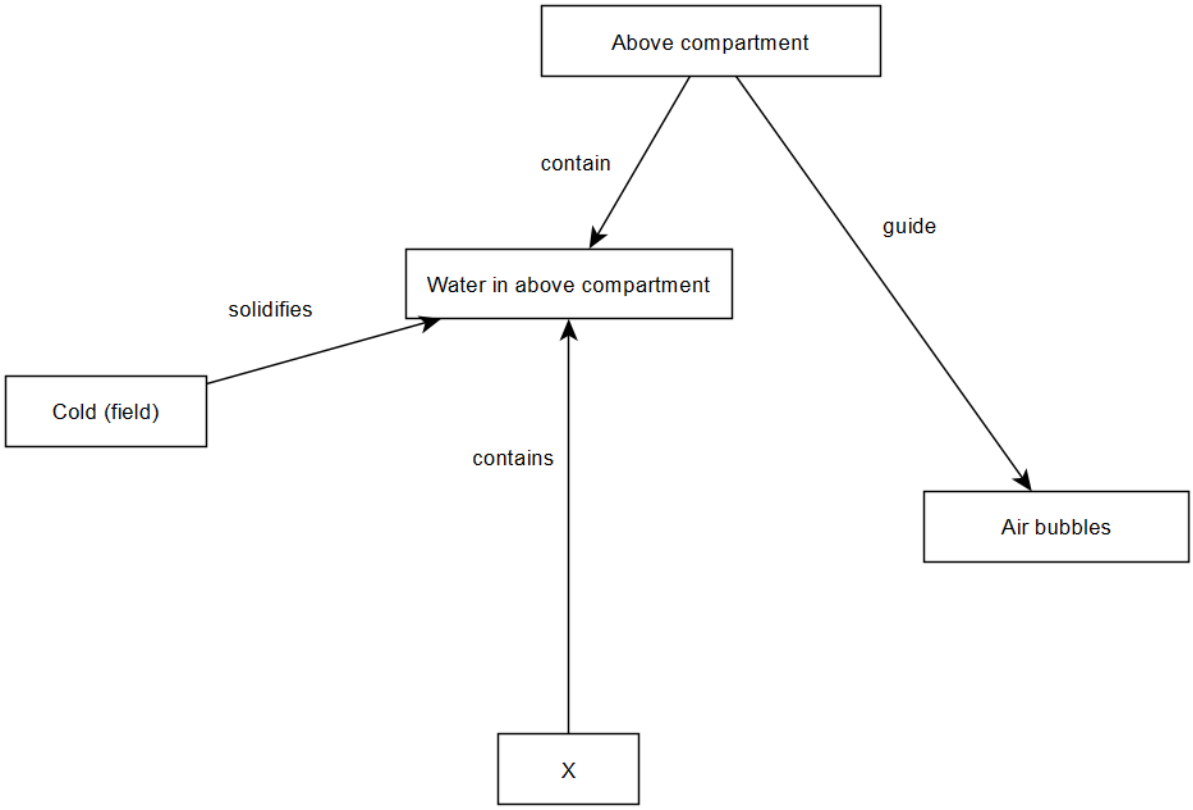


Fig. 3: Trimming model after having trimmed the below compartment

After having trimmed the "below compartment", company A understands that "water in below compartment" is superfluous and therefore eliminated. As air bubbles escape in the ambient air, the "light" component becomes superfluous. However, one very important function that was fulfilled by the below compartment, namely "contains water" shall be fulfilled by one of the remaining components of the system or by components of the supersystem. There is only one reasonable possibility that arises: the above compartment must contain water. But as it is initially, water flows through openings 5 and 5'. Therefore openings 5 and 5' must be modified.

As a result, company A defines the following Trimming problem: openings 5 and 5' must stop water and let air bubbles go through.

After the PoK TRIZ Physical Contradictions (and their Resolution Principles) video course, company A understands that the Trimming problem can be further transformed into the following Physical Contradiction: The openings (5 and 5') must be open to let the air bubbles go through BUT the openings must be closed to stop water. Obviously, this Physical Contradiction can reasonably only be solved by Separation in Relation: this is a tautology. Among the recommended Inventive Principles to fulfil this method [3], one of them seems promising: the use of Porous Materials. In practice, there is the need to replace the openings 5 and 5' by a porous material that stops water and lets air go through. With a porous material having hydrophobic or super-hydrophobic properties, this might be feasible.

Similarly, after the PoK TRIZ Function-Oriented Search video course, company A could search for a technological material that repels water and lets gases pass through. A leading area is constituted by winter sport clothes that should be impermeable to water (from outside) and be permeable to evaporated water from perspiration (from the body). The GoreTex® technology could be easily identified. The new design is depicted in Figure 4 [4].

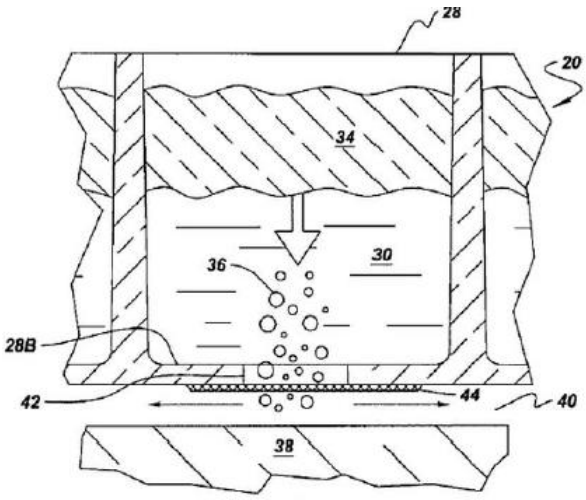


Fig. 4: Ice cube tray for the production of transparent ice cubes after design simplification

This virtual case study shows how company A could have simplified the initial design of its product while being at stage 1 on its S-curve with the help of a Design Simplification specific training module. This training module would contain PoK video courses of the different tools to be used consecutively for this situation, namely Function Analysis, Trimming, Physical Contradictions and their Resolution Principles and Function-Oriented Search.

## 6. Case study B: Design simplification

Function Analysis [5] is one of the most powerful analytical tools of Modern TRIZ. It is an essential part of any project. At the same time, in comparison with other tools, function analysis requires significant time and effort to learn and apply. Moreover, function analysis has some limitations associated with its applicability for analyzing information systems and software. Data, information and fragments of codes cannot be considered as legitimate components of any function model since these are neither substances nor fields.

There are two objectives of the case study below: 1) to demonstrate the applicability of function analysis for describing information systems; 2) to propose a way to pack function analysis into the “Pockets of Knowledge” format.

The case study is taken from a TRIZ project performed for a Russian company which was building an online marketplace for customers in Dubai, United Arab Emirates. This marketplace represents a typical B2B model where the customers are restaurants and food suppliers. The main idea behind this service is to provide the customers with a convenient online platform for purchasing and selling food products for restaurants.

A simplified function model, which is a small fragment of the real one, is shown in Fig 5.

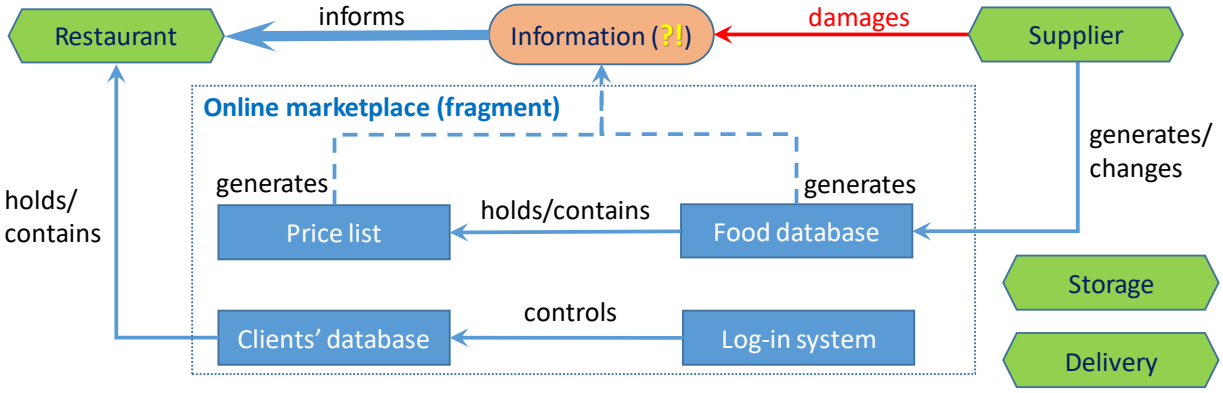


Fig 5: Simplified function model of online marketplace (fragment)

As can be seen from the model, "Information" is included and treated as a component. Moreover, "Information" is considered as the Product of online marketplace and the Main Function is defined as "Marketplace generates information". It is a serious exception to the rules of Function Analysis that the project team decided to introduce. Now, when the analytical part of the project is completed, it is fair to mention that such an exception was critically important in terms of understanding how the online marketplace works and what its main function is.

In terms of Pockets of Knowledge, this exception also plays an important role. It allows either the learner or the TRIZ facilitator to exclude from the explanation of function analysis a significant part about material objects, substances and fields. Instead, only the difference between a component and a parameter was explained.

## 7. Conclusions

A modern, online, video-based format for the delivery of TRIZ tools to start-ups is proposed. The delivery will be modular, accessible and immediately applicable to a particular situation. It will appeal to users who lack the resources to complete longer training courses. This approach is called "Pockets of Knowledge (PoK) TRIZ".

Beyond start-ups as the initial target users, this approach could be helpful in several other situations:

- An individual or a group in a SME or a big company who wants to tackle a challenge without any former knowledge of TRIZ.
- An individual who wants to discover TRIZ and possibly learn it, and who might have a specific, personal challenge to tackle.
- An individual who has been trained in TRIZ to any level in the past and who wants to refresh his/her knowledge.
- Students at university or engineering school who want to apply TRIZ tools quickly on their projects.

In a world where remote training has become the norm, PoK could have a bright future for the training of individuals and groups and it could be adapted for different target users. As such, this new format can help the further democratization of TRIZ in the world.

## References


1. Trends of Engineering Systems Evolution (TESE). TRIZ paths to innovation. Alex Lyubomirskiy *et al*. (2018). Editor: Peter Ward.
2. Ice cube tray. Nishimura *et al*. US Patent 5,346,063 A. Nov. 15, 1994.
3. 40 Inventive Principles. Robert Adunka. TRIZ Consulting Group.
4. Clear ice tray. Shapiro et al. US Patent 6,357,720 B1. Mar. 19, 2002.
5. Sergei Ikovenko, et al, "State-of-the-Art TRIZ, Theory of Inventive Problem Solving", A guide for Level 1 certification by the International TRIZ Association (MATRIZ), 2019, Novismo Ltd.


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# PRACTICAL RESEARCH ON THE ENTERPRISE ORIENTED INTEGRATION OF MULTIPLE METHODS

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## Abstract

With the in-depth promotion, application and practice of TRIZ in enterprises, the high-quality, agile, and coordinated development of enterprises sets higher requirements for the innovation methodology. This article will explore ways to efficiently solve enterprise technological innovation problems from the perspective of multi-method integration and enhance enterprise innovation ability. DMAOVC is a methodology that integrates a variety of innovative technologies to solve the practical problems of enterprises. It has a complete set of processes of definition, analysis, problem solving, substantiation, implementation, control, optimization, and improvement. DMAOVC has achieved great results through practice in enterprises by handling technical problems, improving productivity and product quality, and enhancing the company's market competitiveness. The article is an introduction to the practice of the method. I hope that engineers and experts who are interested in it can read this article and provide valuable opinions.

*Key words: innovative method, integration of multiple methods, DMAOVC, promotion strategies, practical cases*

## 1 Introduction

The innovative method is the technology that uses one or more scientific thinking, scientific methods and scientific tools to realize innovation. As its core content and important tool, TRIZ, with the application and promotion of innovative methods in enterprises, has been widely recognized and highly valued by enterprises, and has achieved gratifying results. But then came some noise:TRIZ method can do anything， any method is not omnipotent. It has its own advantages and disadvantages. How to Develop strengths and avoid weaknesses is our concern. TRIZ method is useless. For beginners, they feel at a loss because of their lack of professional ability, lack of deep theoretical learning and difficulty in applying it in combination with problems. For experts in some fields, due to their solidified thinking mode and strong professional perspective, they think that the obtained plan is too ambitious and difficult to implement, and the method is of little value to them.

In the face of the above problems, we should promote the integration of various innovative methods, realize the innovation system of the integration of multiple methods with the technology innovative methods as the leading, lean R & D, lean production, quality control as the means, efficient management, intelligent operation and strategic transformation as the purpose,

and promote the improvement of the overall innovation ability of the enterprise. The integration of various innovative methods is the general trend. To achieve cross-border development and integration innovation, in a sense, is not only the only way for enterprise development, the drive of market trend, but also the internal needs of the internal innovation development of the enterprise.

# 2 Integration of multiple methods is the most urgent need for the transformation and development of the enterprise

## 2.1 The development of the enterprise has reached a bottleneck

The enterprise is a complex integrated organization. It is difficult to solve the existing problems with a single method. It is difficult for a single method to meet the numerous demands in the business production chain, which forces the birth of the integration of multiple methods.

## 2.2 Application of innovative methods into deep water area

With the popularization and promotion of innovative methods, the combination of methodology with production practice and scientific research is the focus. It is urgent to improve the R & D efficiency of enterprises and achieve a qualitative breakthrough in core technology, product development, process improvement and production operation.

The single feature innovative method is used to solve the problem. The factors considered are few and lack of systematicness. In the process of implementation, the generated plan will appear to take a part for the whole. Therefore, the integration of multiple methods is a very urgent and arduous task.

## 2.3 Value of the integration of multiple methods

The practice of innovative methods has entered the deep water area, and the development of enterprises has entered the transition period. In order to improve the quality and efficiency, it is necessary to explore a practical methodology system for enterprise problems.

# 3 Methodology of the implementation of the integration of multiple methods

## 3.1 3.1 Proposal of methodology

Establish and sort out the application logic route of methodology, comprehensively extract the essence of multiple innovative methods, precipitate wisdom, and integrate and build methodology system. Establish the innovative methodology of the integration of multiple methods DMAOVC.

## 3.2 Tool system of methodology

DMAOVC consists of six stages: D Definition stage - M Measurement stage - A Analysis stage - O Optimization stage - V Verification stage - C Control stage

**D Definition stage**: define the problem, define the project, define the current situation, define the goal

- Project source
- Acceptance criteria

- Approval of project

**M Measurement stage**: quantitative indicators (data, improvement focus), clear objectives and promotion proportion

- Problem decomposition
- Measurement method
- Objective verification

**A Analysis stage**: system analysis, three-axis analysis, plan generation and resource planning

- System analysis
- Three-axis analysis
- Problem solving
- knowledge library analysis
- Implementation plan

**O Optimization stage**: Technology prediction, product planning, drawing technology roadmap, and Evaluation and summary

- Concept list
- Solution selection
- Process optimization

**V Verification stage**: collaborative simulation, system verification, knowledge management and promotion strategy

- Test verification
- Result evaluation
- Project verification

**C Control stage**: reduce fluctuation, solidify effect, control rebound, form standardization, and verify the target improvement results.

- Standardization
- Continuous improvement
- New topic verification

# 4 The promotion strategy of the practice of the integration of multiple methods

## 4.1 Implement the overall architecture

The multiple methods implementation strategy is vertical leadership and level by level implementation to link leadership and lower levels, report to leadership and make known to lower levels. Attention need to be paid to the pain point, profit point, survival and development point of the enterprise, and concentrate efforts. Strategies, projects and systems need to form a virtuous circle.

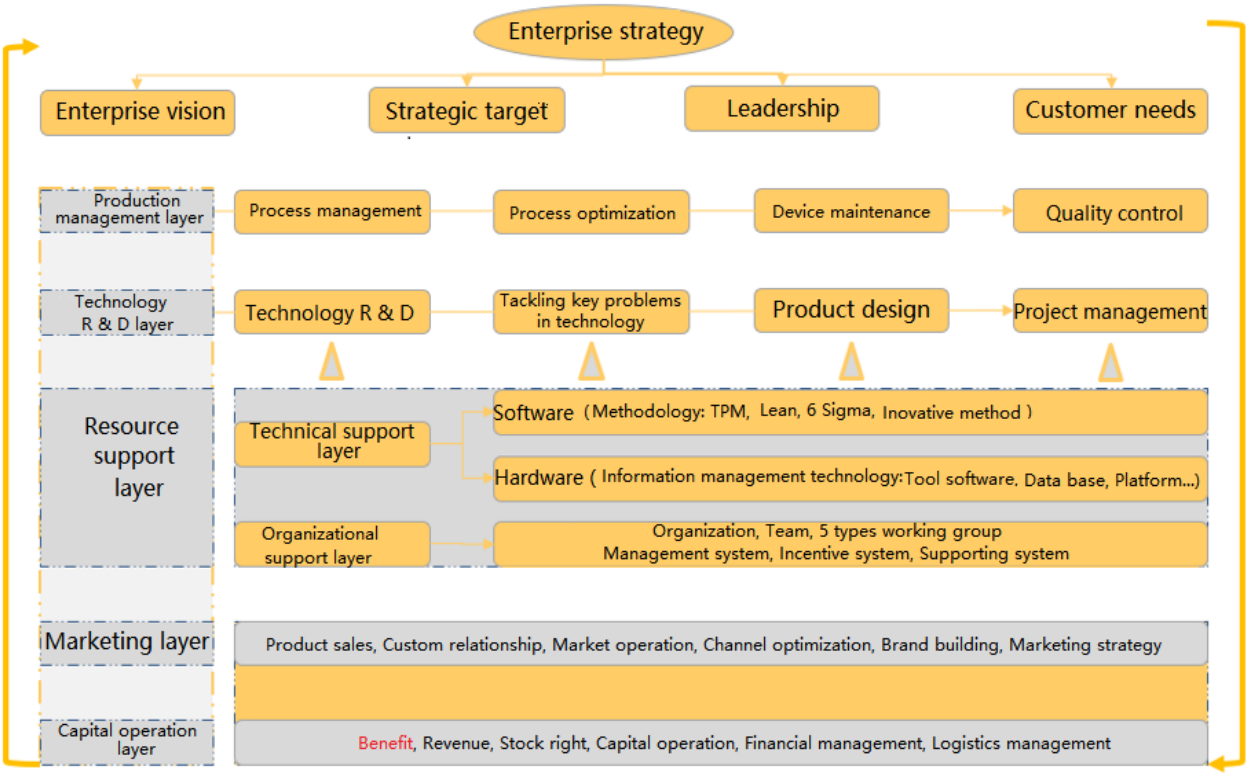


Fig 1. Enterprise strategy

## 4.2 Implementation steps and Strategies

### 4.2.1 Implementation steps

- Enterprise research
- Clarify problems and enterprise needs
- Formulate plan and project plan
- On site implementation and plan verification
- plan implementation and result evaluation
- Achievement promotion and experience precipitation
- Continuous improvement and project tracking

### 4.2.2 Implementation strategy

Strategic drive and continuous improvement

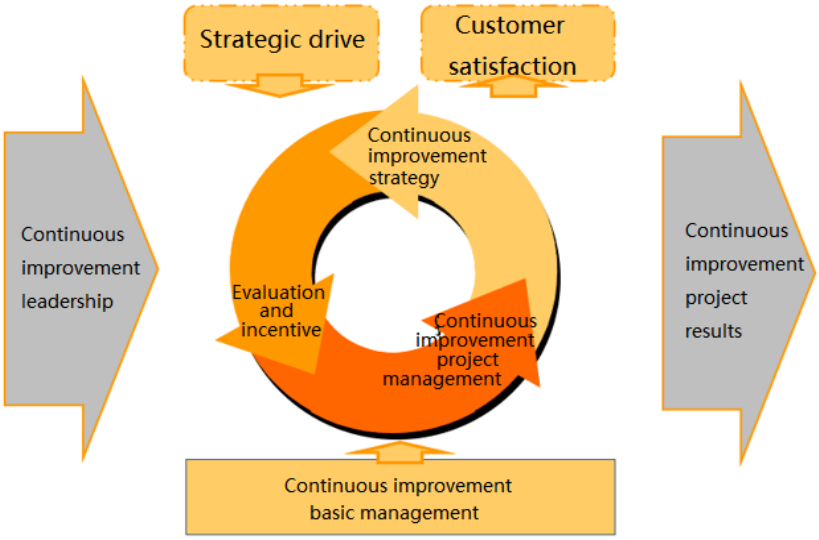


Fig 2. Implementation strategy

## 4.3 Implement plans and plans

Careful plan is the condition for DMAOVC implementation. The step-by-step implementation plan of the project is needed.

## 4.4 Establish organization and system

Good organization is the guarantee of DMAOVC implementation, and cross department cooperation is the only way to DMAOVC project success.

Fig 3. Organizational structure pyramid model

## 4.5 Establish milestones and risk control

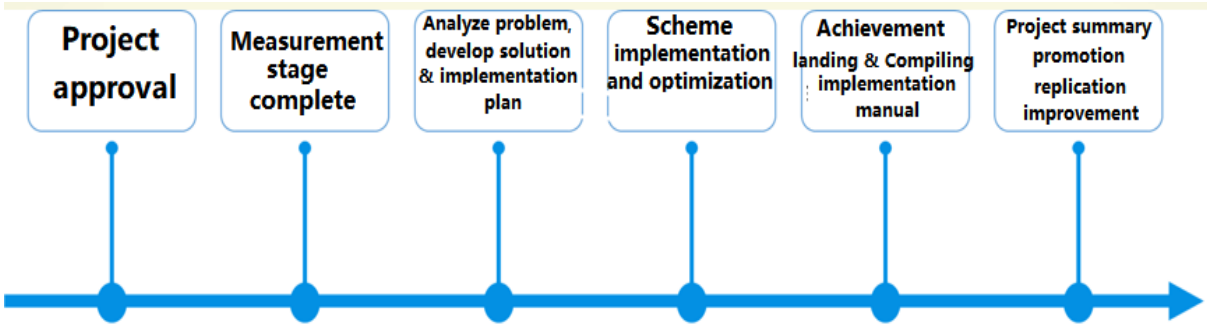


Fig 4. Project implementation milestone

## 5 Application case of the integration of multiple methods practice

### Case Sharing of DMAOVC Practice "Reduce the single consumption of PVC resin calcium carbide"

*Production management department of Ordos chemical business division*

**D Definition stage**:

**Project Description**: chlor alkali chemical industry is based on the heavy chemical industry circular economy mode of large chemical industry, large project, large cycle and high technology, realizing the optimization of resource utilization, industrial structure, environmental protection and energy saving, and moving forward with a modern heavy chemical ecological enterprise. The group is committed to the comprehensive development and utilization of resources, relying on local coal, limestone and other advantageous resources, developing circular economy, and being the leader of comprehensive energy consumption per unit product in the industry.

**Formed capacity**:

| Calcium carbide | PVC Phase 1 | Caustic soda | Cement | Limestone |
|---|---|---|---|---|
| 1.2million tons/year | 0.45million tons/year | 0.3million tons/year | 1million tons/year | 1.4million tons/year |

Fig 5. Formed capacity

The key factor affecting the production cost of PVC lies in the consumption level of calcium carbide, that is, the unit consumption of calcium carbide. Carbide cost and PVC manufacturing cost account for 91.42% of the total, and carbide cost accounts for 66.09% of the total production cost of PVC.

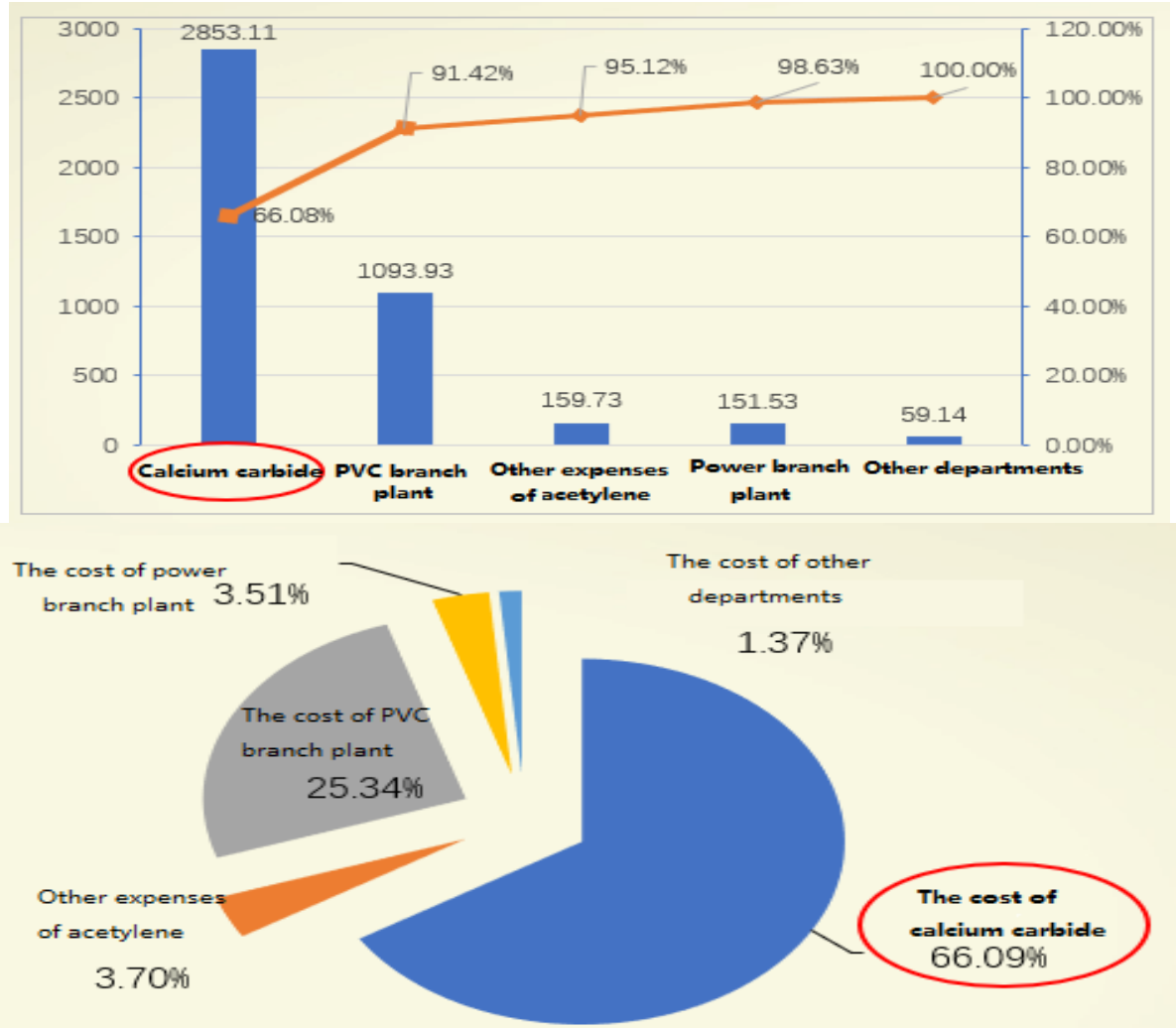


Fig 6. The production cost of PVC

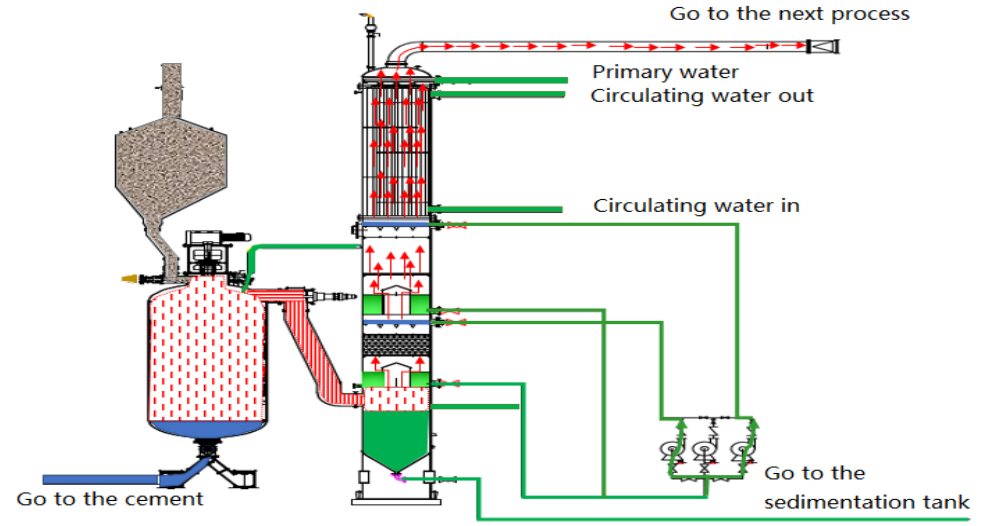


Fig 7. The system in which calcium carbide is located is an acetylene generating system

**Voice of Customer(VOC):**

The lower the carbide consumption, the better the actual production control and equipment operation. The more thorough the reaction of calcium carbide, the less the residue of calcium

carbide slag screen, and the safer the conveying system of calcium carbide slag.

**Voice of Business(VOB):**

Reduce the unit consumption of calcium carbide, which is the most important production and operation index of PVC industry. It is directly reflected in the production cost of PVC, improves the position and voice in the industry, and meets the national requirements for energy consumption per unit product.

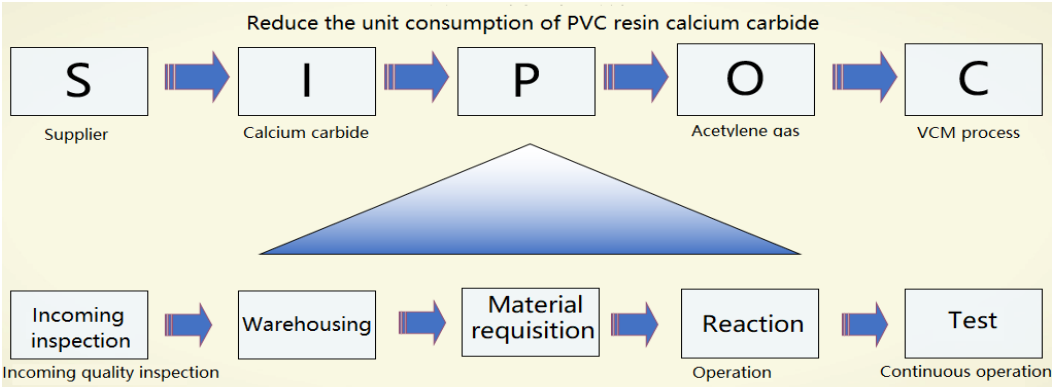


Fig 8. SIPOC analysis

| Weight | | MFPV | | | | | |
|---|---|---|---|---|---|---|---|
| ⊙ ○ △ | | Degree of differentiation | Calcium carbide pulling | Calcium carbide damage | Gas evolution | Conversion rate | Importance degree |
| 9 3 1 | | | | | | | |
| MSPV | Safety | 3 | 9 | 3 | 1 | 9 | 9 |
| | Automatic control | 1 | 1 | 1 | 1 | 1 | 9 |
| | Unit consumption | 9 | 9 | 9 | 9 | 9 | 9 |
| | Hign running rate | 1 | 1 | 1 | 9 | 9 | 9 |
| | Easy operation | 1 | 1 | 1 | 9 | 9 | 1 |
| Total score | | 15 | 21 | 15 | 29 | 37 | |
| Sorting | | 4 | 3 | 4 | 2 | 1 | |

Fig 9. MPV analysis

**Conclusion**: the conversion rate of calcium carbide is the key to acetylene production system, which needs to be solved urgently.

**Project objective**: to reduce the unit consumption of calcium carbide by 0.25% (1.3354t calcium carbide / tpvc) on the basis of 1.3388t calcium carbide / tpvc.

**D Measurement stage**

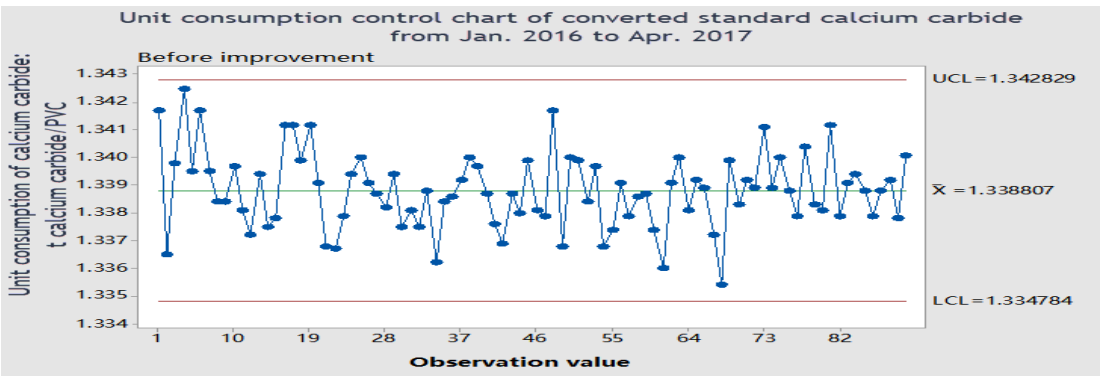


Fig 10. Historical data of unit consumption of calcium carbide

As shown in the figure above, it is the control chart of unit consumption of converted standard carbide from January 2016 to April 2017. The average unit consumption of converted standard carbide in 16 months is 1.3388, but there is a certain gap between the value and the expected value of 1.3354 required by the company, so it needs to be improved.

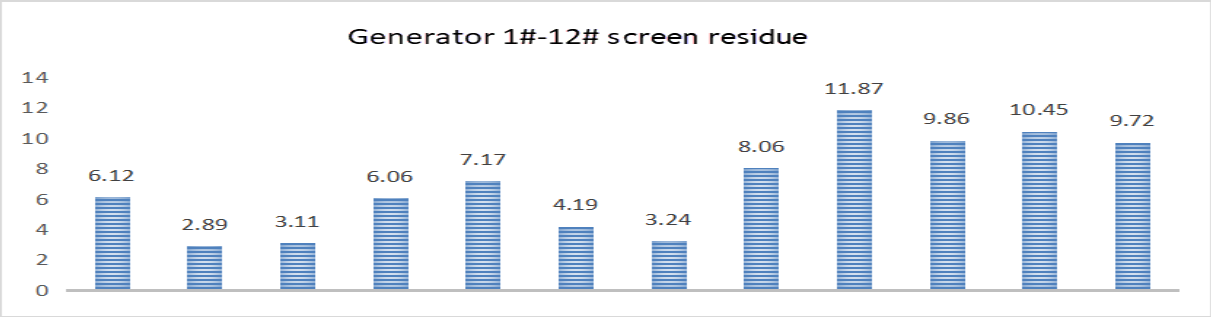


Fig 11.Statistical table of screen residue

**Illustration**: the source of acetylene injection is divided into settling tanks 1 and 2, in which settling tank 1 is used for generators 1-8, settling tanks 2 is used for generators 9-12. Through noise analysis, it is found that generator 9-12 screen residue weight is generally high, the main reason is that the solid content in water is high, then the nozzle is blocked seriously, resulting in incomplete reaction. We improve it by adding filter screen.

## A Analysis stage

### 1. System function analysis

Form the system thought, master the system method, build the system function model, and clarify the system function problem.

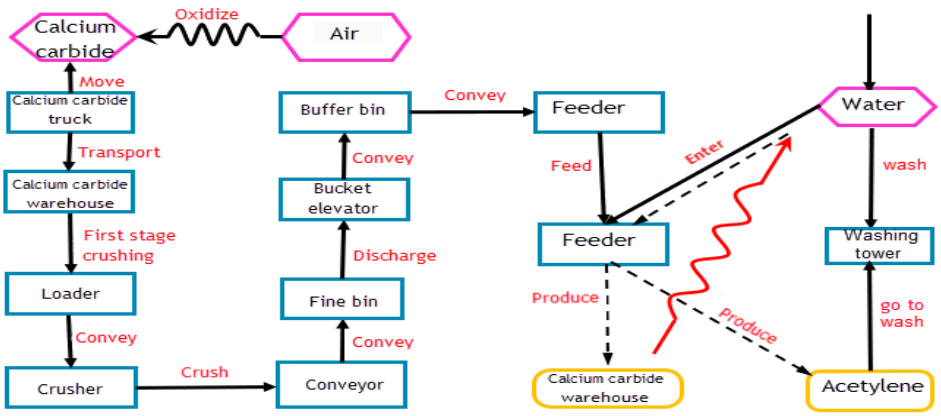


Fig 12. System function analysis

Through functional analysis, it is found that: the water in the air is harmful to calcium carbide, the water is useful but insufficient to acetylene generator, the generator is useful but insufficient to calcium carbide slag and acetylene, calcium carbide slag is harmful to water.

### 2. Cause-Effect Chain Analysis

Use Cause-Effect Chain Analysis to confirm the causes of production process problems:

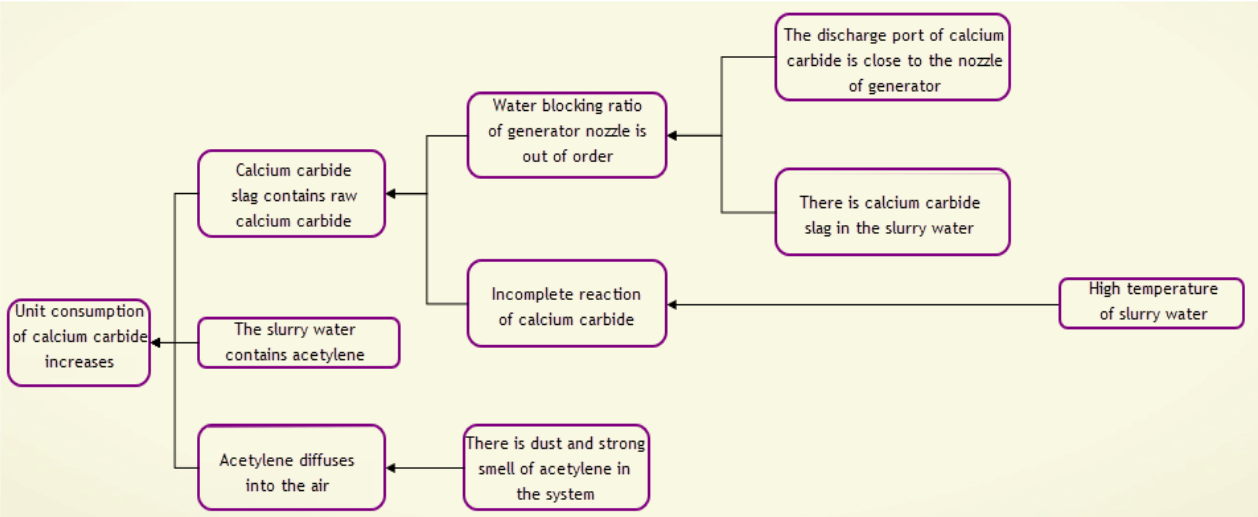


Fig 13. Cause-Effect Chain Analysis

**Plan 1**

Change feeder position. The carbide feeder moves down to the elliptical surface of the generator barrel, which solves the problem of nozzle blockage.

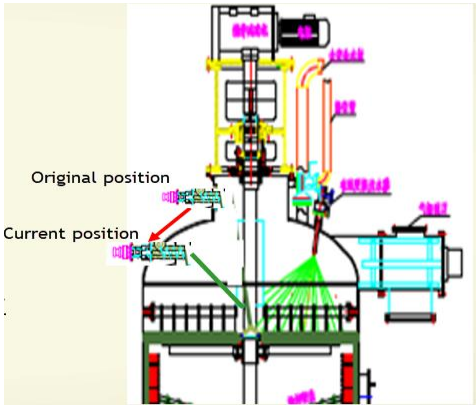


Fig 14. Plan 1

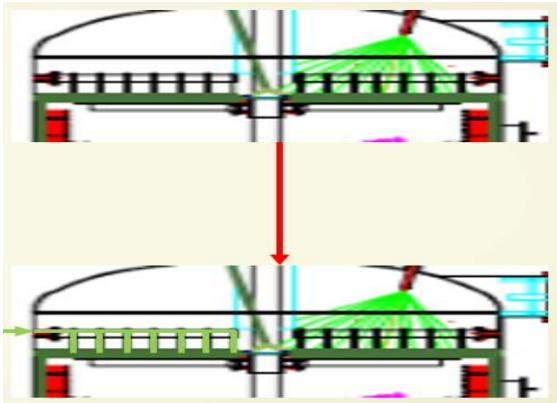

Fig 15. Plan 2

## 3. Resource analysis

| | Resource name | Category | Usability |
|---|---|---|---|
| System internal resources | Mixing rake ruler | Substance resource | Usable |
| | Water | Substance resource | Usable |
| | Reaction process | Space resource | Usable |

| | Resource name | Category | Usability |
|---|---|---|---|
| System external resources | Moisture meter | Information resource | Usable |
| | Air | Substance resource | Unusable |
| | Gravity | Energy resource | Usable |

Fig 16. Resource analysis

**Plan 2**

Increase the reaction area (make full use of the space resources of the reaction field in the sys-

tem, from the original one water injection, the fifth tower tray contacts with water for one reaction, divided into two water injection, two reaction areas)

## 4. Contradiction analysis

In order to reduce the "calcium carbide containing raw material in carbide slag", it is necessary to reduce the particle size of calcium carbide, improve the loss of calcium carbide, but thus extend the pretreatment time of calcium carbide.

**Plan 3**: According to “physical or chemical parameter changes” of the inventive principle of No.35 , the solution is as follows: reduce system resistance.

$$CaC_2 + H_2O \rightarrow C_2H_2 + Ca(OH)_2 \quad (1)$$

**Plan 4**

According to “Preliminary action” of the inventive principle of No.10, the solution is as follows:

water injection nozzle is installed between the carbide feeding and the fifth tray, and the gravity process of carbide feeding is used to make the water play a role in the first time.

**Plan 5**

According to “Dynamization” of the inventive principle of No.10, the solution is as follows:

Choose the fluidized bed reactor, that is, reduce the size of the carbide particles, use pneumatic conveying to feed, change the feeding position to between the fifth layer of rake teeth and the fourth layer of rake teeth, and remove the fifth layer of rake teeth.

**Plan 6**

According to “Mechanical vibration” of the inventive principle of No.18, the solution is as follows:

Install the vibrator to the fifth rake ruler of the generator to make the carbide in the local motion state, so that the reaction can be carried out thoroughly.

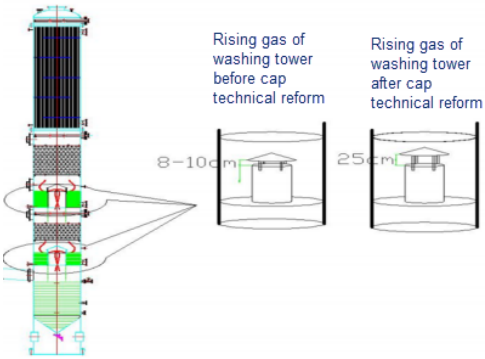


Fig 17. Plan 3

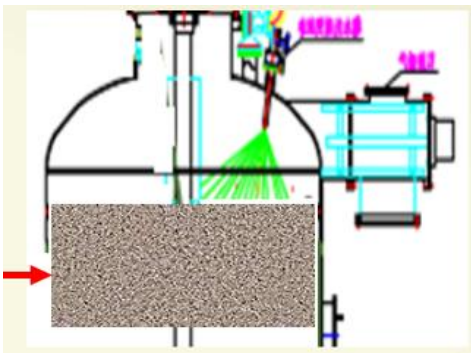

Fig 18. Plan 5

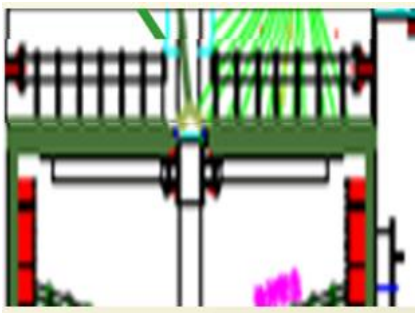

Fig 19. Plan 6

## 5. Field-field analysis and standard solutions

According to the Substance-Field model of the problem, the standard solution system is found, and the standard solution S 1.2.1 is obtained. $S_3$ is introduced to eliminate the harmful effect.

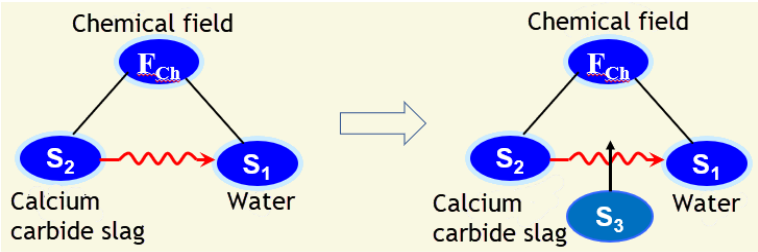


Fig 20. S3 is introduced to eliminate the harmful effect

**Plan 7**

A filter is added to the water injection pipeline of the generator to eliminate carbide slag carried in the settling water.

According to the Substance-Field model of the problem, the standard solution system is found, and the standard solution s 1.2.4 is obtained. $F_2$ is introduced to eliminate the harmful effect.

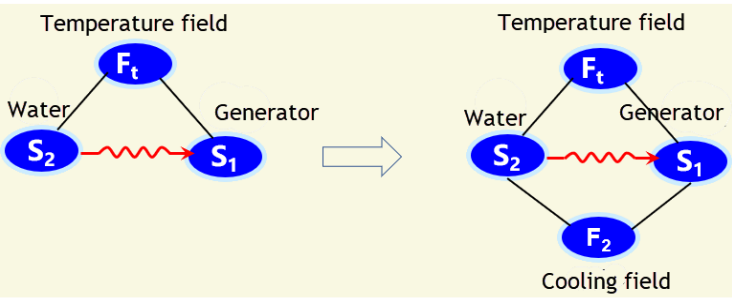


Fig 21. S3 is introduced to eliminate the harmful effect

**Plan 8**

Add a cooler (field) on the water injection line of the generator to reduce the reaction water temperature.

Fig 22. Plan 7

Fig 23. Plan 8

6. **Scientific effect**

**Determinate function:** control the flow of aerosols (suspended particles in gas, such as smoke, fog, etc.).

**Search effect:** mixture separation, absorption, cooling

**Plan 9**

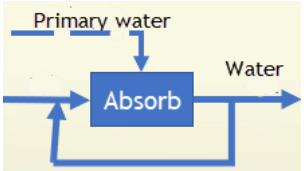


Fig 24. An absorption device is added at the top of the slag bin

**O Optimization stage:**

**Evolution analysis**

By analyzing the evolution process of the existing technology system, we choose the law of technology evolution: "the law of micro evolution".

Wet acetylene → dry acetylene → wet acetylene new process → plasma cracking coal to acetylene process

According to the selected technology evolution route, the position of the existing technology system in the evolution route is judged, and then the potential state is determined.

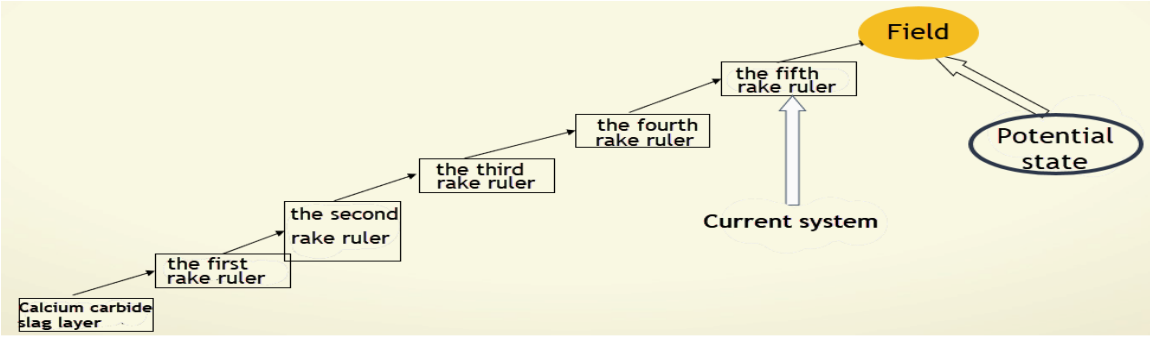


Fig 25. the law of micro evolution

**Plan 10**

Changing the reaction field is suitable for both dry acetylene and wet acetylene, which not only ensures the consumption of water, but also ensures the low water content. Carbide slag process, namely wet acetylene process.

$$CaC_2 + H_2O \longrightarrow \uparrow H_2C_2 + Ca(OH)_2 \quad (2)$$

## V Verification stage

### 1. Establish evaluation model and plan

| No. | Scheme | Safety | Possibility | facility value | Easy to verify | Total score |
|---|---|---|---|---|---|---|
| 1 | Increase reaction area | 9 | 9 | 5 | 6 | 29 |
| 2 | Change feeder position | 6 | 8 | 6 | 8 | 28 |
| 3 | Reduce system resistance | 7 | 8 | 7 | 8 | 30 |
| 4 | Pre-reaction during calcium carbide discharging | 9 | 2 | 3 | 3 | 17 |
| 5 | Select fluidized bed reactor | 2 | 1 | 1 | 2 | 6 |
| 6 | Install vibrator to the fifth rake ruler | 3 | 2 | 1 | 4 | 10 |
| 7 | Add filter to water injection line of generator | 7 | 8 | 7 | 9 | 31 |
| 8 | Add cooler to water injection line of generator | 8 | 8 | 8 | 7 | 31 |
| 9 | Add absorption device at the top of slag bin | 6 | 7 | 8 | 9 | 30 |
| 10 | Wet acetylene process | 9 | 9 | 1 | 1 | 20 |

Fig 26. Evaluation plan

### 2. Plan for implementation of the plan

The current optimal plan: the plan 1, 2, 3, 7, 8 and 9 in the plan evaluation are combined to improve the system, and the plan 2, 3, 7, 8 and 9 have been implemented.

### 3. Plan planning

- Prototype production: the sample production is expected to be completed within 3 months.
- Test verification: after the completion of the prototype, it is expected to be completed in 2 weeks.
- Patent application: At least 1 patent application shall be completed in plan 1 or plan 9 within one year

### 4. Benefit analysis

Direct economic benefit: the unit consumption of calcium carbide is reduced from 1.3388t calcium carbide / tpvc to 1.33636t calcium carbide / tpvc. The annual output of our company is 460000t PVC, which can save 1122.4t calcium carbide. If the per ton calcium carbide is calculated as 2550 yuan, it can save 3122000 yuan per year. Acetylene gas can be reduced by 200 * 3 * 0.049 * 8000 = 235200 m 3, converted to 784t of 100% basis calcium carbide, saving 1.2694 million yuan.

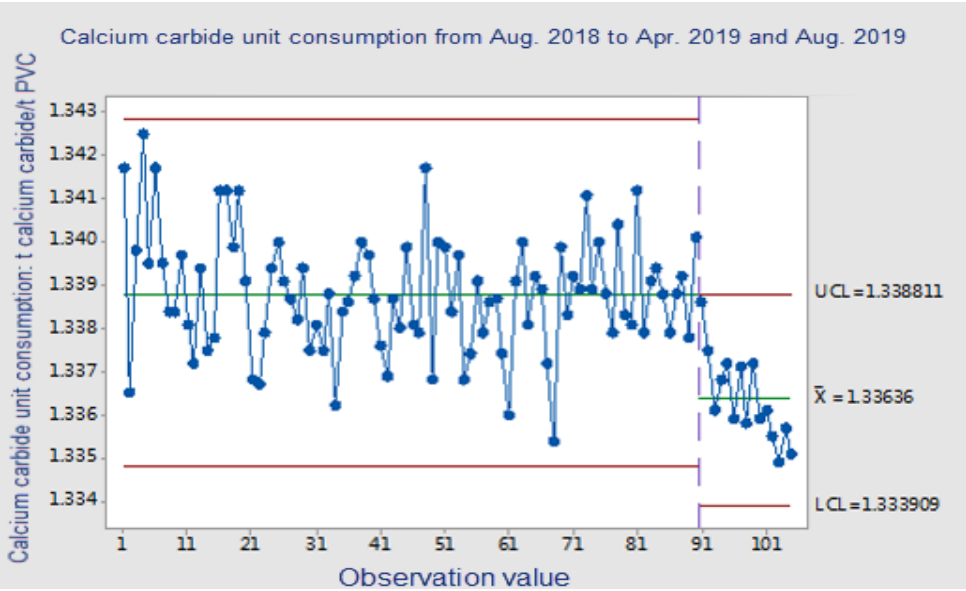


Fig 27. Direct economic benefit

| Name of index | Reduce the volume of filter mud transported abroad | Annual cost saving of filter mud (Ten thousand yuan) | Cost saving of water (Ten thousand yuan) |
|---|---|---|---|
| Accumulated benefit during the implementation period | 52631.69 | 178.7372 | 10.2105 |
| Predicted average annual benefit | 59231.8 | 201.1512 | 11.491 |

Fig 28. Indirect economic benefit

Total benefit: 6.33282 million yuan

Environmental protection benefits: solve the problem of calcium carbide sludge stacking, reduce the content of calcium carbide slag dust, improve the working environment, reduce the environmental protection risk, reduce part of the environmental protection pressure for the group, and its benefits are more obvious.

**C Control stage**

1. Control plan
2. Continuous improvement

## 6 Conclusions

Innovative methodology DMAOVC of integration of multiple methods is an innovative methodology system that integrates system theory, contradiction theory, resource theory and knowledge theory, and integrates TRIZ, lean production, industrial engineering, six sigma and other tools and methods to summarize, practice and extract. It has achieved very good results in more than 20 projects of CGNPC, Ordos and other enterprises. It has achieved breakthrough growth in terms of the quality of project completion, the effect of field implementation, the experience of project team, the improvement of management ability and the growth of enterprise benefits.

However, with the application and promotion of DMAOVC in enterprises, there are also some

problems. First, the implementation samples of enterprises are few at present, and the data support for extracting common laws is insufficient; second, the process needs to be further sorted out, and the tools need to be further optimized; third, how to achieve flexible learning and use for the adaptability of methodology of different types of enterprises It still needs to be strengthened; fourthly, there is a slight lack of support for the solution of system problems in the overall business activities of the enterprise; fifthly, it needs to be further explored theoretically for the solution of disorder, dispersion and mutation problems, and for the integration of various methods and tools, it needs to be intimate, glued and traceless. Facing many problems, it needs to be explored hard, and there is no strong road and a long way to go.

## References

1. Robert B. Stewart. Fundamentals of Value Methodology. Publishing House of Mechanical Industry
2. Kevin N.Otto & Kristin L.Wood Product design. Publishing House of Electronics Industry
3. Tian Feng. Lean R & D. Publishing House of Mechanical Industry
4. Nikolai Shpakovsky. Evolution Trees. Science and technology of China press
5. Cao Fuquan. Introduction to innovative thinking and methods. Heilongjiang Education Press
6. Eliyahu M. Goldratt. Critical chain. Publishing House of Electronics Industry
1. Eliyahu M.Goldratt & Efrat Goldratt-Ashlag. The choice. Publishing House of Electronics Industry

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# Semantic Web Modelling of TRIZ System Evolution Concepts

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## Abstract

Since Altshuller's formulation of eight evolution laws of technical systems [1], the topic has developed into a weighty TRIZ tool, primarily on a speculative-empirical basis [3,4], to classify or predict development directions of technical systems. In [6], Shpakovsky presents a systematic attempt to assemble such development germs into the more complex structure of an evolution tree. In this paper, we report on the transformation of these approaches and results into a formal syntax based on RDF. The required formal remodelling especially of concrete examples clarifies the strengths and weaknesses of the concepts developed in [6]. The modelling project is part of our contribution [10] to the TRIZ Ontology Project [11].

Keywords: *Evolution of Technical Systems, Evolution Tree, Semantic Web, TRIZ Ontology Project*

## 1 Aim of the work

The aim of this paper is to present an ontological modelling of the areas of *TRIZ System Evolution Concepts* based on the approaches in [4] and [6] and further own considerations. The work fits into the activities of the TRIZ and WUMM Ontology Projects [10,11] to model core TRIZ concepts using modern Semantic Web means. We provide two kinds of result – a formally described SKOS based body of notions and formal models of three examples taken from the literature (available in the github repository [8]), and this paper, in which the background and motivation of the modelling decisions are informally described in more detail. Due to space restrictons, we can only take up some essential moments of the modelling and discuss some aspects of two of the three examples. For a more detailed version of the material see the seminar paper [9].

## 2 *Evolution* Concepts for the Development of Technical Systems

### 2.1 TRIZ and the Evolution of Technical Systems

The basic practical approach of TRIZ is the development of technical systems (TS) through transformation in the course of problem solving. These practices of changing real-world systems (including their design, implementation and reconstruction) for dedicated special purposes generate a spectrum of highly contradictory real-world developments, for the systematisation of which appropriate principles must be developed. With the formulation of *8 development laws* of TS [1], Altshuller proposed principles of such a systematisation, which have largely resulted

from the study of patent documents and other practical engineering experience on the background of system-theoretical approaches. The authors of [4], where further developments of this approach are discussed, are more cautious and call the laws *trends* in view of their low theoretical foundation. 10 trends are discussed in [4] based on a wealth of examples, where each of the trends is related on a one-dimensional *less-more* scale of a "trend direction". Assuming the possibility of quantifying each of the scales, a 10-dimensional "development space" emerges with multiple questions not addressed in [4], of which the following is one of the simpler ones: Can progression in one of these 10 dimensions be related with regression in another?

## 2.2 Evolution Trees

Similarly argues Shpakovsky in [6]. He also extracts – largely from experience of the differences in the usefulness of TRIZ principles in practical inventive projects – 10 basic patterns of evolution of TS. Each of these basic patterns is further refined into a sequence of modification subpatterns of graded intensity (see [6: ch. 3]), and this conceptual toolkit (*basic evolution tree*) is applied as a *methodological basis* to the systematisation of real-world technological development in the form of *special evolution trees*.

Unlike [4], in [6: ch. 4] a clear principle is proposed according to which TS are brought into an evolutionary context in such considerations: The basis for any such investigation is a sufficiently general *elementary technical function* (ETF) [6: ch. 4.1]. Only those (sufficiently generalised, [6: p. 122]) TS are included in the investigation that realise this ETF as an emergent function. I refer to this selection in the following as *class of technical systems* (CTS). Its elements are called *objects* in [6]. Each CTS delimited on this basis is doubly contextualised by the choice of the ETF and the degree of generality of the technical systems under consideration. The delimitation should fulfill the following conditions [6: p. 122]:

1. To organise information, a tree-like structure is used that allows visual presentation of descriptions of *all basic* known versions of an object under examination.
2. The evolution tree is an organized set of objective evolution patterns based on the analysis of the evolution of many technical systems. Hence the construction of evolution trees suggests use of an *objective classification criterion*.
3. Every evolution pattern includes a set of generalized descriptions of transformation versions and transitions between them and may be illustrated by a transformation example of a specific technical object. Hence the *requirement of generality and specificity is satisfied*.
4. Information presentation in the form of a tree-like structure allows a designer to see all the basic transformation versions simultaneously and to distinctly *trace their structure*.
5. The availability of the basic tree allows foreseeing all *significant transformation versions* even if the information available on the versions of a system under consideration is scant or fragmentary.

This delimitation is the first step in a sequence of 8 steps [6: ch. 4.3] that Shpakovsky proposes to base his construction of evolution trees on.

1. Determining the elementary function performed by the object of interest, clarifying and formulating its role in the performance of this function.
2. Collecting information on similar objects which either are known to perform the same role in the realization of the same elementary function, or can be adapted to the performance of this function. Making a short description of each modification of the object,

paying special attention to the essence of the transformation which resulted in the appearance of this modification. Finding the initial transformation version of the object, the simplest one in terms of the technological evolution.

3 Selecting the main evolution pattern — the trunk of the future tree. It may be any of the evolution patterns, but using those patterns where transformations of components are especially significant, such as «Segmentation of Objects and Substances» or «Mono-Bi-Poly» would be more convenient. Building the main evolution pattern, the frame of the future Tree by placing cards with the description of corresponding versions of the object under consideration.

4 Constructing of second-order evolution patterns keeping to the following rule: constructing dynamization patterns of object modifications if possible; if it is impossible to obtain dynamization resources, first building the patterns which provide resources — «Mono-bi-poly», «Segmentation» and «Expansion».

5 Checking whether it is possible to build second-order patterns which describe transformations of object's shape, surface and internal structure. These patterns are: «Geometrical Evolution», «Internal Structure Evolution» and «Evolution of Surface Properties». To optimize the tree structure, it is better to add these patterns only if they reflect object transformations which are important for subsequent analysis.

6 Checking whether it is possible to build third-order patterns — «Dynamization» — after the «Mono-Bi-Poly», «Segmentation», «Expansion» patterns. Constructing these patterns in significant and indicative places of the tree.

7 Constructing the «Increasing Controllability» patterns placing them after the Dynamization patterns. These patterns should only be built for characteristic and significant cases of controllability. For all other cases, the controllability of objects is clarified by analogy. Building the «Increasing coordination» patterns in characteristic and indicative places of the Tree.

8 Carrying out an additional information search, supplementing and specifying the tree structure.

### 2.3 Objective of our work

Shpakovsky thus proposed a systematic-methodical approach to the study of the evolution of TS, which goes beyond previous approaches, and demonstrates the practical performance of this approach in a number of examples.

The aim of the work presented here is to prepare this methodological approach for a Semantic Web formalisation within the scope of the WUMM Ontology Project [10]. With regard to the explanations in [2], we limit ourselves to a formalisation of the taxonomy (conceptualisation, basic tree as *evolution tree ontology* – ETO) and show how this can be used in the formalised representation of special evolution trees. In [2], also the reasons are explained in more detail why we base this work on SKOS as meta model and not on OWL.

## 3 Conceptualisation

The conceptualisation to be developed follows the basic assumptions and settings that are explained in more detail in [2]. In particular, the following namespace prefixes are used:

- ex: – the namespace of a special CTS to be modelled.
- tc: – the namespace of the TRIZ concepts.
- od: – the namespace of WUMM's own concepts.

Furthermore the SKOS ontology is used to model labels and definitions of the object.

Our central task is to model the nodes and edges of a given CTS evolution tree. The full graphical representation of that evolution tree as an edge-marked graph then can be reconstructed from that set in the usual way (actually, the two representation forms are equivalent to each other.).

The interaction between the special CTS modelling and the basic constructs of the ETO is explained here using code from the CTS *DisplayDevelopment*. An edge in a CTS evolution graph has the typical shape of an RDF sentence, e.g.

```
ex:TVWithLargePixels ex:decreasePixelSize ex:TVWithMediumPixels .
```

This sentence addresses the development from *TV with large pixels* to *TV with medium pixels* that have a better performance in brightness and sharpness of images. The code of the two nodes is not presented here, we only note that the introduced URIs have nothing directly to do with the semantics of the represented TS except that – following the modelling recommendations of the Semantic Web – "speaking names" are used. To the RDF predicate ex:decreasePixelSize further information is attached.

```
ex:decreasePixelSize a rdf:Property, skos:Concept ;
        od:usesPattern tc:SegmentationPattern ;
        skos:prefLabel "Decrease pixel size"@en ;
        skos:definition """Decrease pixel size by segmentation of one
                big pixel in several smaller ones"""@en .
```

SKOS label and definition describe the transformation in the CTS in more detail, od:usesPattern refers to the pattern from the ETO that was applied in this transformation.

Although RDF graphs are an important RDF concept and multiple RDF graphs can be stored in and retrieved from an RDF store, it is difficult to represent graphs as delimitable objects at the level of RDF triples. We therefore store each specific CTS graph in a separate file. The file contains the description of the nodes and edges of this graph as well as an instance of tc:EvolutionTree with the global properties of the graph. Each such graph also has its own namespace, which can also be used to identify the parts of the graph.

## 4 Modelling the Evolution Tree Ontology (ETO)

This section describes how the concepts from [6] are modelled in our ETO.

The input of an ETO modelling of a CTS is the CTS itself, which is delimited according to contextual parameters (*goal* and *scope* of the modelling, determination of the *ETF*, determination of the *level of abstraction* of the TS to be included in the CTS, see 2.2) and the given methodology [6: ch. 4.3]. This delimitation is taken as given in our modelling. Essential context parameters can be stored in the global object of the graph file.

```
Ex:DisplayEvolution a tc:EvolutionTree;
        rdfs:label "Evolution of TV and Computer Displays"@en;
        dcterms:source "Shpakovsky's book"@en ;
        od:hasETF "visualize information"@en ;
        rdfs:comment """A display is an artificially created object
                specially designed as a tool to realize the function
                «To visualize information»"""@en .
```

## 4.1 Evolution Patterns and Modification Subpatterns

As essential structuring elements for evolution trees, ten *basic evolution patterns* and modifying subpatterns were introduced in [6]. These ten basic patterns are:

1 Mono-Bi-Poly
2 Trimming
3 Expanding-trimming
4 Segmentation

Geometrical evolution

5 Object structure evolution
6 Evolution of surface properties
7 Dynamization
8 Increasing the controllability
9 Increasing the coordination of the elements

For each of these basic evolution patterns, a sequence of more specific *modification subpatterns* is specified. The state of the development along the basic evolution patterns 1–4 constrain the application of other evolution patterns. For example, there is no possibility for dynamization on an unsegmented monolith. The structure of the object is addressed by patterns 5–7. Patterns for dynamization, controllability, and coordination are applied at points that seem reasonable. It is not required to follow the sequence of modification subpatterns of a basic pattern to its end before applying a different basic pattern.

In [6] it is mentioned several times that evolution deals with the development of an object from the CTS. We follow the usual approach in TRIZ ontology modelling that distinguishes between old and new object instead of working with object modifications. All evolutionary transformation steps are therefore modelled according to the pattern

OldObject → isTransformedInto → NewObject.

Note that the concept of an evolution tree is a self-similar concept. An evolution tree thus can be related to an evolution tree with of one of its objects as root expanding this object to another CTS at a different abstraction level. E.g. the evolution tree of the display can be related in such a way to the evolution tree of a plasma screen, which could be analysed further.

## 4.2 Modelling Evolution Tree Concepts

The file *EvolutionTree.ttl* [8] contains the formal description of the basic evolution patterns and thus the basic evolution tree as developed in [6], which is in a second step – as application of the formalization and proof of concept – applied to create formal models of three special evolution trees.

Each basic pattern and modification subpattern is represented by a special URI. Conceptual relations between these patterns and subpatterns are modeled using the (inverse to each other) predicates od:subConceptOf and od:hasSubConcept. E.g. the segmentation pattern is represented by the URI tc:SegmentationPattern and has the following code in Turtle notation.

```
tc:SegmentationPattern a skos:Concept, od:AdditionalConcept ;
        od:subConceptOf tc:BasicEvolutionPattern ;
        od:hasSubConcept tc:Monolith, tc:TwoParts, tc:ManyParts,
                tc:Granules, tc:Powder, tc:Paste, tc:Liquid,
                tc:Foam, tc:Fog, tc:Gas, tc:Plasma, tc:Field,
                tc:Vacuum, tc:IdealObject ;
        skos:prefLabel "Segmenting objects and substances"@en ;
```

```
        skos:example "Segmentation of an aircraft propulsion unit"@en .
```

In the given example tc:SegmentationPattern is a subconcept of tc:BasicEvolutionPattern. Different modification patterns like tc:Liquid are also formalised in that way.

```
tc:Liquid a skos:Concept, od:AdditionalConcept ;
        od:subConceptOf tc:SegmentationPattern ;
        skos:prefLabel "Liquid"@en .
```

Different to [6] certain subpatterns as tc:FlatSurface and tc:CylindricalSurface of the generic evolution pattern tc:GeometricalEvolutionPattern are not put in a mutual subconcept relation since transformations in both directions appear in specific examples. E.g., some modern monitors use curved displays instead of flat ones, whereas older CRT displays have a cylindrical surface due to constrains in manufacturing. Using better glass newer CRT displays have a flat surface. Shpakovsky also introduces the MATChEM-Operator from the wider TRIZ context as extra pattern, not listed in the basic ones.

## 4.3 Construction of Evolution Trees

Shpakovsky emphasises in [6] that the construction of an evolution tree is mostly an iterative process in the course of which the goal, ETF, scope and degree of abstraction of modelling the CTS are gradually refined. Our tools for formal descriptions support this iterative process, as new objects can easily be added as nodes and transformation steps can be added or modified as edge descriptions.

With the description elements presented so far, some of the more advanced concepts from [6] cannot yet be adequately represented. This is especially the case for the concepts *trunk* and *branch* of a CTS tree, which, however, remain vague not only from a graph-theoretical perspective.

The concepts *trunk* and *root* attempt to address the development in a CTS from simpler to more complex forms, which is mainly oriented towards the unfolding of the ETF and associated with the basic patterns 1–4. However, since the modification sequences for each basic pattern define *branches* in the tree, even in such a linear context it is unclear which of these branches is the trunk. In the ETO, a language element can easily be added that identifies transformation edges as belonging to the trunk. However, it is not clear that this results in a linear rather than a branched structure.

However, this is a general conceptual problem – the basic constructs only guarantee that the evolution is described by a *directed graph*. Even the property that the emerging graph is *acyclic* requires additional preconditions. An acyclic graph is characterised by the fact that its nodes can be placed in a linear order that coincides with the edge directions. This can be achieved, for example, assigning timestamps to the objects, but this poses restrictions on the abstraction principle applied in the constitution process of the objects of the CTS.

It also remains largely unclear why evolution graphs should necessarily be *trees*. Major advances in general technical development are characterised precisely by the fact that there meet *several* lines of development. Such phenomena cannot be conceptualised with a pure tree based approach alone.

## 4.4 Determination of yet Unknown Versions

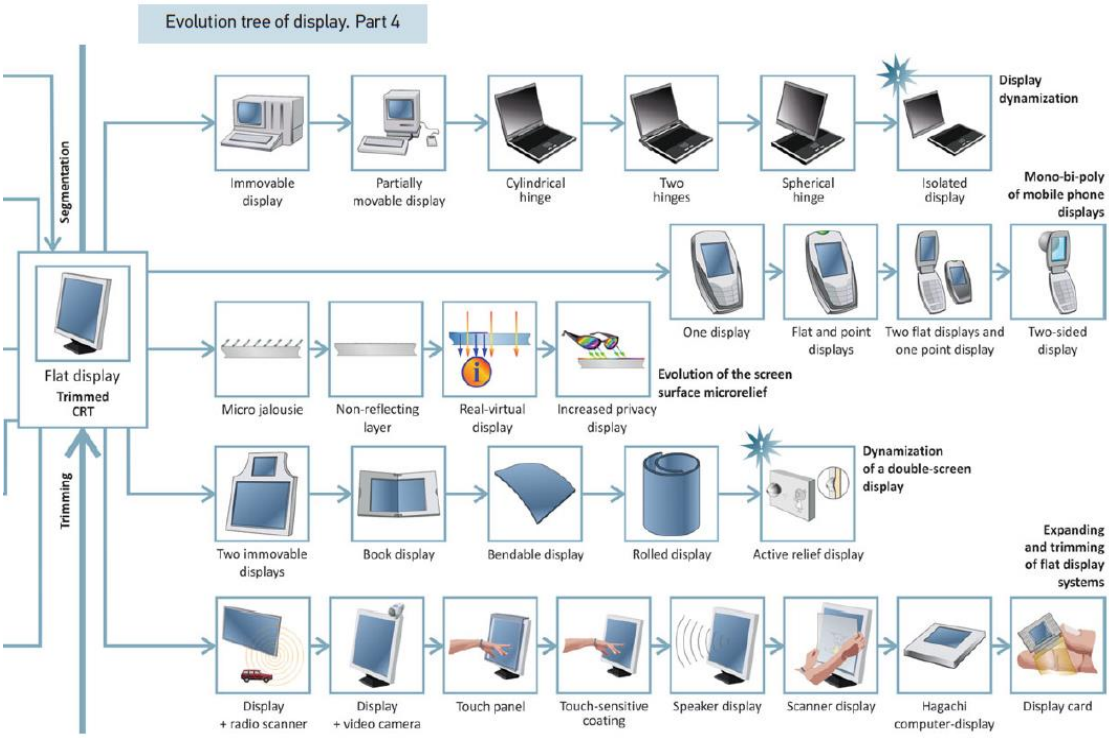


Figure 1: Section of the specific tree of *DisplayEvolution* [6].

For the analysis of a CTS, both the basic (see [6: Fig. 4.78]) and the specific evolution tree (see Fig. 1) must be created. By comparing the two trees, gaps as well as not yet realised evolution patterns can be discovered.

The highest modification level of the dynamization pattern is a complete decoupling of the individual components. For a laptop, this means to separate display and peripherals. Around 2002, at the time the evolution tree of the display [6] was created, this version did not yet exist in the CTS but the gap could be identified and the evolution option formulated. Nowadays, complete dynamization is achieved integrating the computing technology into the display and connecting the peripherals via Bluetooth. This shows that evolution tree analysis is in principle capable to predict such future technological developments.

# 5 Modelling Examples of Specific Evolution Trees

## 5.1 Modelling the Evolution Tree of the Display

Shpakosvky modelled the evolution tree of the display with *To visualize information* as ETF. The abstraction level to include objects in the CTS is given by the definition of a display as an *artificially created object specially designed for the role of a tool in the realization of the elementary function* [6], thus ruling out a sheet of paper with information written on it. The main axis of development, i.e. the trunk of the tree, runs along trimming transitions from the cinematographer, trimmed cinematographer, CRT TV set to the flat display. Further transitions apply the segmentation pattern. The evolution tree trunk is marked adding a

od:usesPattern tc:EvolutionTreeTrunk

statement to the corresponding transition edges. As the granularity of this specific evolution tree is very finegrained some transition patterns can be applied multiple times for object transformations.

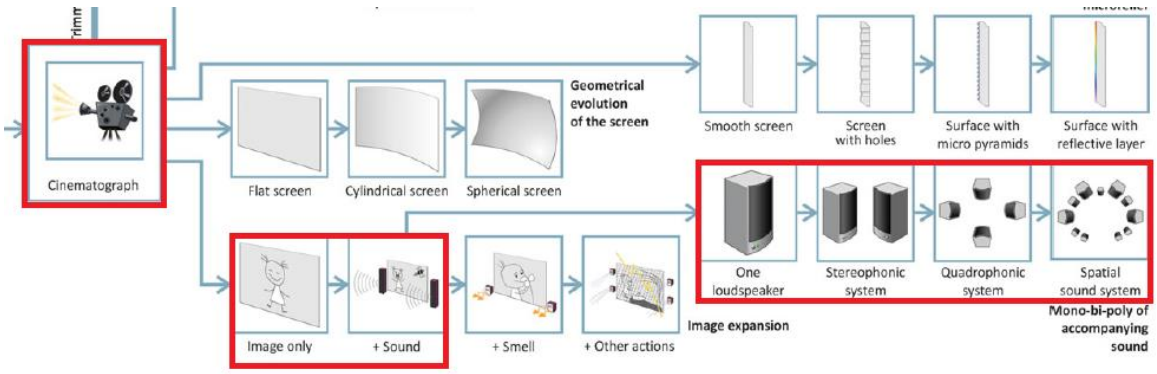


Figure 2: Pattern of adding audio [6]

We describe the code of the transformation for adding sound to the display (see Fig. 2) as an example for the structure of the modelling done in *DisplayExample.ttl* [8]. ex: is used as the namespace because a real-world example is described. We choose the cinematographer from the evolution tree trunk as the starting point of our example.

```
ex:Cinematograph a ex:Screen ;
        ex:transitionsTo ex:ImageOnly, ex:FlatScreen,
                ex:SmoothScreen, ex:ImmovableScreen ;
        ex:trimCinemaBuilding ex:MechanicalTVSet ;
        skos:prefLabel "Cinematograph"@en .
```

A word about the Turtle notation used here, which compactly combines all RDF triples containing the RDF subject ex:Cinematograph. This code contains, among other things, the transition triples starting at the cinematograph object which describe the transitions into the different branches in Figure 2. They expand into the RDF triples

```
ex:Cinematograph ex:transitionsTo ex:ImageOnly .
ex:Cinematograph ex:transitionsTo ex:FlatScreen .
ex:Cinematograph ex:transitionsTo ex:SmoothScreen .
ex:Cinematograph ex:transitionsTo ex:ImmovableScreen .
```

The transitions are all described by ex:transitionsTo and represent the transition of the same object *cinematograph* into the initial positions of the different branches. A uniform predicate is used here, since the respective transformation does not change the object, but only its perception for the further development in the respective branch – the ImageOnly perception is extracted for merging with audio, the FlatScreen perception for further development of curved surfaces, the SmoothScreen single-layer perception for the addition of further layers and the ImmovableScreen perception for further development towards portable units (not shown in figure 2).

Each of these transformations defines a new object in the CTS that may serve as root of a evolution subtree, so that we can also interpret the situation as merging four evolution trees into one with the new root in the *cinematograph*. However, such transformations of whole evolution trees and thus also of the contextualisations given by their CTS are neither discussed in [6] nor so far conceptually supported by our semantic modelling.

Somewhat different is the fifth transformation

```
ex:Cinematograph ex:trimCinemaBuilding ex:MechanicalTVSet .
```

of the cinematograph into a mechanical TV, which also includes a transformation of the technical object itself.

Further development in the addSound branch of the tree is described by the transformation

```
ex:ImageOnly ex:addSound ex:ImageSound .
ex:addSound a rdf:Property, skos:Concept ;
        od:usesPattern tc:MonoBiPolyPattern, tc:BiSystem ;
        skos:prefLabel "Add sound"@en .
```

adding to the image a sound track thus transforming the ex:ImageOnly object into the ex:ImageSound bisystem. The further development yields another branching

```
ex:ImageSound ex:addSmell ex:ImageSoundSmell .
ex:ImageSound ex:transitionsTo ex:OneLoudspeaker .
```

adding a smell track to the bisystem on the one branch and joining bisystem with the audio development track thus refocussing on audio development on the other. However, the latter is problematic for the concept developed in [6], because it softens both the ETF and the contextualisation.

In a similar way the whole evolution tree of the display is transformed into a formal model. One particularity must be explained concerning the further segmentation of the display. Shpakovsky uses in that example not only generic evolution patterns but also specific ones. This was modelled introducing additional model-specific patterns (ex:ManyParts, ex:Sand etc.) in the ex: namespace and the model-specific ex:segmentation predicate.

## 5.2 Modelling the Ship Propulsion Evolution Tree

Souchkov describes in [3] another evolution tree using the example of the boat evolution, see Fig. 3. The terms boat and ship are used interchangeably here even if a ship is assumed to have some other characteristics as a boat, e.g. being ocean-going and having a higher displacement.

This graph representation of an evolution tree differs from the example in 5.1 in that it was not created on the special conceptual basis [6]. Nevertheless there was no problem to prepare the material according to Shpakovsky's principles, enriched and transferred into a formal model (see *BoatExample.ttl* in [8]). The nodes labelled in Fig. 3 in italics are “dead ends” whose development was not continued and which are no longer in active use today. They are marked model-specific as ex:DeadEnd in our modelling.

A *main axis of development* is already given by the nodes labelled in bold, which thus forms the *tree trunk*. The tree heavily branches and also contains parts in which the boat function is no longer dominant, but is used in combination with other functions in bi- and polysystems. The end of the development line *Mono-Bi-Poly* is the transition to a “monosystem on a higher level” [6: p. 184] through integration of the partial functions in the polysystem to a new emergent ETF on the level of the supersystem (listed as T*rend of Transition to the Supersystem* in [4: ch. 4.4]). Such developments, for example from the boat to the military boat in Fig. 3, are not modelled in this complexity in [6], because from the specific context perspective of the CTS, it is not the emergent new ETF that is of interest, but only the contribution that the old ETF makes to it. However, Souchkov's diagram has probably also to be understood in this way, because in that context only the boat property of the military boat is of interest, but not its combat properties, which emerge from the interaction of many sub-functions. However, this is only our assumption; details are not explained in [3].

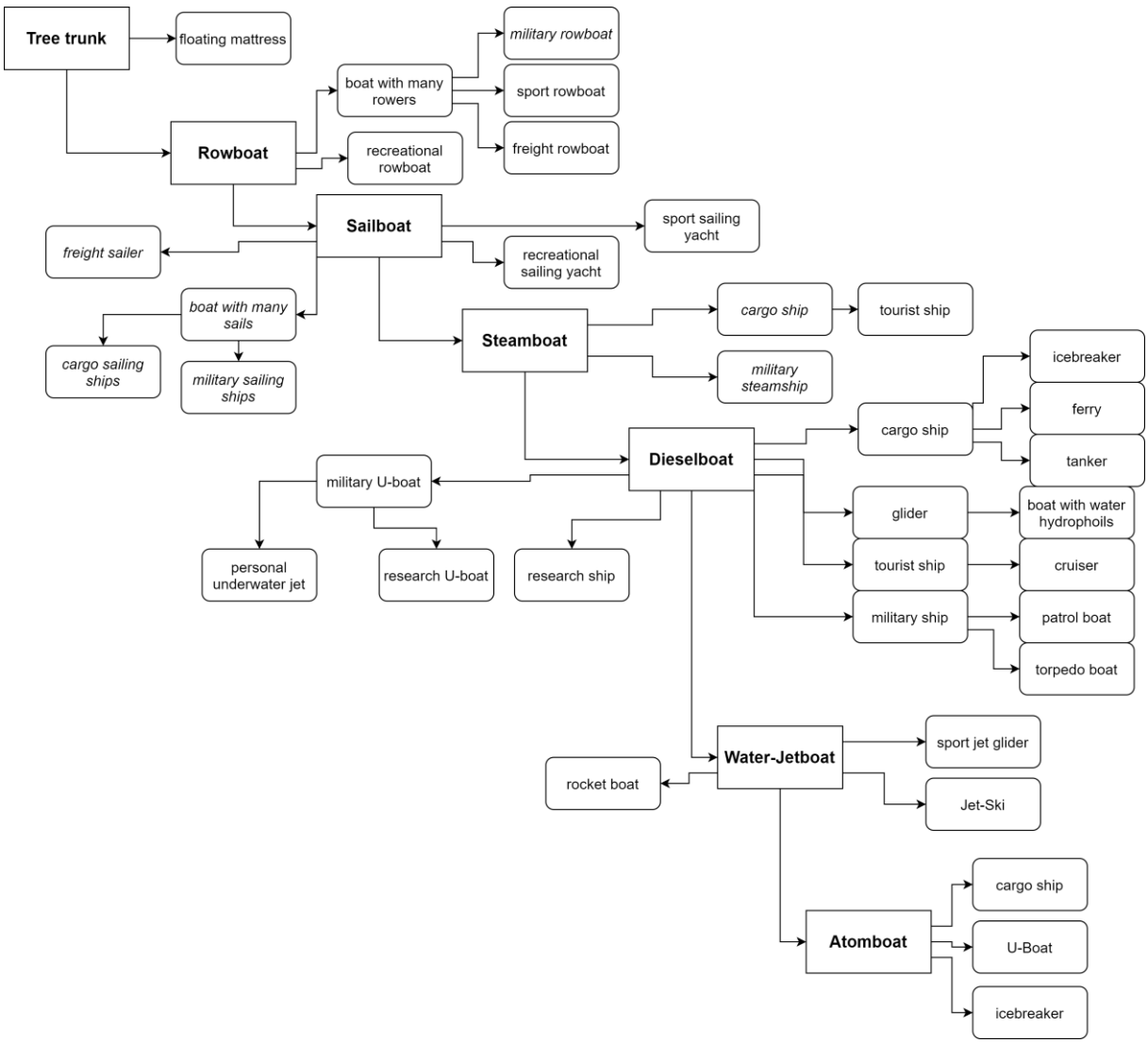


Figure 5: Souchkov's boat evolution tree [3: p. 162], own diagram

The next step is to *specify the ETF* of the CTS model. The objects grouped in this CTS cover a wide range of functionalities and transformations, making it difficult to identify the goal, scope and ETF of the modelling. Souchkov splits the transformations into three categories: New transformations for delivering the main function, existing transformations that could be developed further and completed or discontinued transformations. We are interested in the new transformations for delivering the main function as this defines the main axis of development – tree trunk, rowboat, sailboat, steamboat, dieselboat, waterjetboat and atomboat. Hence we define the ETF as to *provide the boat with engine and power source* since all these transformations, with one exception, focus on the engine and power source. A tree trunk has no power source, a rowboat uses muscle power, a sailboat the wind, a steamboat a steam machine and so on. As the waterjet is a means of propulsion and thus the transformation does not focus on the power source, but how the power is used for propulsion (e.g. propeller, paddle wheel), it should probably be skipped from the evolution tree trunk and a direkt edge between dieselboat and atomboat should be added.

The granularity of this tree is very coarse thus imposing a high degree of abstraction in the definition of the objects of the CTS. This abstraction is also not oriented towards temporal sequences (even in the age of atomboats, there are still rowboats), hence a timestamp based acyclicity condition as mentioned above cannot be implemented in such a context. Moreover,

branching from the trunk does not necessarily follow Shpakovsky's modelling rules, because, for example, the transition steam boat → cargo ship seems to be more as a taxonomic relation general → special than a real technological evolution (according to the Mono-Bi-Poly pattern; the boat receives the additional function "transport of goods", but this is a function from the supersystem). We can already see from these considerations which problems arise with the specification of an initially vague CTS modelling of an evolution tree, as it is given with Figure 3 alone ([3] does not contain any further explanations on the background of the modelling decisions). In the many repetitions of nodes with label "U-Boot" (probably better translated as "submarine") or cargo ship in fig. 3, another complex evolution pattern becomes evident: The evolutionary lines of TS, which are components in a common supersystem, are closely connected through synergy effects, resulting in a close interrelation structure between the evolutionary trees of these two TS, whose specific networking effects cannot be grasped from the perspective of one of these trees alone. This requires new conceptual approaches of an integrative view of technology development.

A particular difficulty is the modelling of the transformations on the trunk of the evolutionary tree, as different new propulsion technologies are introduced in each case and this technological development does not take place at the level of the boat, but at the level of one of its components. The change within the component is accompanied by a complete reorganisation of the way how the interaction between the sub-functions of the different components of boat components works to deliver the emergent ETF of the boat. A corresponding complex reconstruction pattern is missing in Shpakovsky's list. We therefore again use a model-specific pattern

```
ex:BoatMATChEMOperator a tc:SpecificEvolutionPattern ;
        skos:prefLabel "Boat specific MATChEM operator pattern"@en .
```

at this point. The details cannot be presented here, see [9]. It is quite possible to generalise such a suitably defined model-specific pattern, to adopt it for addition to the ETO in the course of further ontology development and to declare the model-specific pattern as subconcepts of such a more general pattern.

## 6 Summary

In this paper we have shown how the concepts of building and refining evolution trees presented by Shpakovsky in [6] can be formalised and transformed into a Semantic Web format. We restricted ourselves to the formal modelling of the tree structure, the process dimension of the methodological system proposed in [6] remains informal. The reasons for this are explained in [2] in more detail.

Nevertheless, this processual methodological dimension is also to be applied in the formal remodelling of concrete examples. The strict requirements of formal modelling are predestined to reveal inconsistencies and weaknesses in the conceptual system of evolution trees. This is demonstrated by two examples from [6] and [3]. In particular, the formal refinement of the vague specifications in the latter example, which is given as a graphic only and was (presumably) not created according to Shpakovsky's methodology, proves both the applicability of Shpakovsky's methodology to problems from other sources and shows which detailed questions have to be solved in the systematic design of coherent evolution trees if one wants to go beyond the limits of purely speculative compilations.

## References

1. Genrich Altshuller (1979). Creativity as an exact science (in Russian). English version: Gordon and Breach, New York 1988.

2. Hans-Gert Gräbe (2021). The WUMM Project on a TRIZ Ontology. Basic Concepts. https://wumm-project.github.io/Texts/WOP-Basics.pdf.
3. Karl Koltze, Valeri Souchkov (2017). Systematic innovation methods (in German). Hanser, Munich. ISBN 978-3-446-45127-8.
4. Alex Lyubomirsky, Simon Litvin, Sergei Ikovenko et al. (2018). Trends of Engineering System Evolution (TESE). TRIZ Consulting Group. ISBN 9783000598463.
5. Nikolay Shpakovsky (2003). One of the evolution trends of an aircraft propulsive device. http://www.gnrtr.com/Generator.html?pi=211&cp=3.
6. Nikolay Shpakovsky (2016). Tree of Technology Evolution. English translation of the Russian original (Forum, Moscow 2010). https://wumm-project.github.io/TTS.html
7. SKOS – The Simple Knowledge Organization System. https://www.w3.org/TR/skos-reference/.
8. Tom Strempel (2021). Code of the RDF Modelling of Evolution Trees. Directory Ontologies/EvolutionTrees in the github repo https://github.com/wumm-project/RDFData.
9. Tom Strempel (2021). A Proposal for Modelling TRIZ System Evolution Concepts. https://wumm-project.github.io/Texts/WOP-EvolutionTrees.pdf.
10. The WUMM Project. https://wumm-project.github.io/.
11. The TRIZ Ontology Project. https://wumm-project.github.io/Ontology.

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# TO IMPROVE TEACHING BY FUNCTIONAL ANALYSIS AND INVENTIVE STANDARDS OF TRIZ FOR BUSINESS AND MANAGEMENT

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## Abstract

There are rare papers to deal with teaching problems by BizTRIZ (TRIZ for Business and Management). This paper tried to apply Functional Analysis and Inventive Standards of BizTRIZ to teaching problems in class. Thought the analysis of Functional Analysis and Binary Problems Ranking, "Teacher's poor-control" was the most important problem in this paper case. "Students' inefficient learning" is the second important problem. "iPhone's interfering" was the third important problem. Then, Inventive Standards for Business and Management Group 3 generated four ideas. And then, Multi-Criteria Decision Matrix and Estimating Time to Implement were used to Comparing and Evaluation those ideas. Finally, the best idea was "Make students group discuss cases and report them". Next, Inventive Standards for Business and Management Group 1 generated nine ideas to improve Students' learning efficiency. Third, Inventive Standards for Business and Management Group 4 generated eight ideas about iPhone's interfering.

Keywords: *TRIZ for Business and Management, Teaching problem, Functional Analysis, Inventive Standards*

## 1 Introduction

Usually, the problem in class is about teacher's experiences and teaching skills. It is rarely generate idea by use create skill. This paper tried to use TRIZ to deal with the problem about Teacher's poor-control in class.

## 2 Literature Review

The TRIZ techniques for Business and Management is different from the original TRIZ tecniques. The techniques and adaptation of TRIZ to business and management applications by ICG T&C. (Valeri Souchkov. 2015).

## 3 Methodology

The TRIZ techniques For Business and Management was used in this paper.

## 3.1 Problem Situation

Teacher asked students do more practices relating innovative skills for knowing skills well. But, students didn't follow the request to practice much due to much more charming internet network. They feel the practice are hard. So they were interested in playing iPhones instead of practice. In this case, the teacher controlled students poorly. And so on, air conditioner is cooled the air but noisy.

## 3.2 Functional Analysis for Business and Management

### 3.2.1 Selected System component

There are 7 components in this system of the problem: Teacher, students, iPhone, network, interesting thing, Air conditioner, and Air.

### 3.2.2 Matrix of interactions

Table 1 Matrix of interaction

| | Teacher | students | iPhone | network | interesting thing | Air conditioner | Air |
|---|---|---|---|---|---|---|---|
| Teacher | | X | | | | X | X |
| students | X | | X | | | X | X |
| iPhone | | X | | X | | | |
| network | | | X | | X | | |
| interesting thing | | | | X | | | |
| Air conditioner | X | X | | | | | X |
| Air | X | X | | | | X | |

### 3.2.3 Function Model

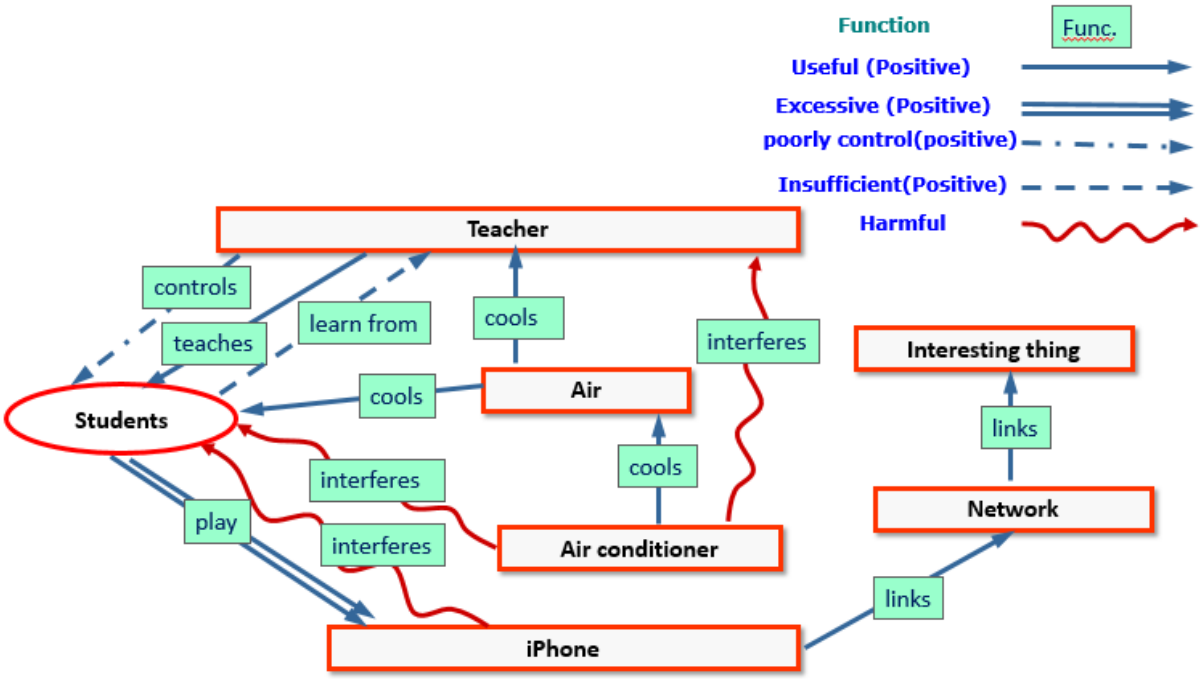


Figure 1. Function Model Diagram

### 3.2.4 Binary Problems Ranking

Table 2 Binary Problems Ranking Table

| # | Problem | 1 | 2 | 3 | 4 | 5 | 6 | Total Score |
|---|---|---|---|---|---|---|---|---|
| 1 | iPhone interferes students | | -1 | +1 | +1 | +1 | -1 | +1 |
| 2 | Students' inefficient learning | +1 | | +1 | +1 | +1 | -1 | +3 |
| 3 | Students play iPhone much | -1 | -1 | | +1 | +1 | -1 | -1 |
| 4 | Air conditioner interferes students | -1 | -1 | -1 | | +1 | -1 | -3 |
| 5 | Air conditioner interferes teacher | -1 | -1 | -1 | -1 | | -1 | -5 |
| 6 | Teacher's poor-control | +1 | +1 | +1 | +1 | +1 | | +5 |

### 3.2.5 Ranked Problems

Table 3 Ranked Problems Table

| # | Problem | Rank |
|---|---|---|
| 1 | Teacher's poor-control | +5 |
| 2 | Students' inefficient learning | +3 |
| 3 | iPhone interferes students | +1 |
| 4 | Students play iPhone much | -1 |
| 5 | Air conditioner interferes students | -3 |
| 6 | Air conditioner interferes teacher | -5 |

### 3.2.6 The Most Important Problem

- Problem 1. Teacher's poor-control
- Problem 2. Students' inefficient learning
- Problem 3. iPhone's interfering

## 3.3 Inventive Standards for Business and Management

I use Inventive Standards Solutions for Business and Management Applications, Group 3. "Improving poorly controllable effect of an interaction" to generate idea for problem 1. Teacher's poor-control, the most Important Problem.

### 3.3.1 Inventive Standards solution 3-1

If there is a poorly controllable effect of interaction between two objects A and B, then introduce a new object between the two which possesses the property to enhance the control over the interaction or the control over an effect produced by the interaction. (Valeri Souchkov. 2015)

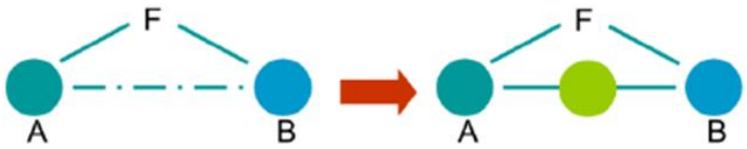


Figure 2. Inventive Standards solution 3-1 Diagram (Valeri Souchkov. 2015)

Generate idea: Demo real innovation products to attract students

### 3.3.2 Inventive Standards solution 3-2

If there is a poorly controllable effect of interaction between two objects A and B, then attach a new object C to object B which possesses the property to create or improve the control over the interaction and an effect produced by the interaction. (Valeri Souchkov. 2015)

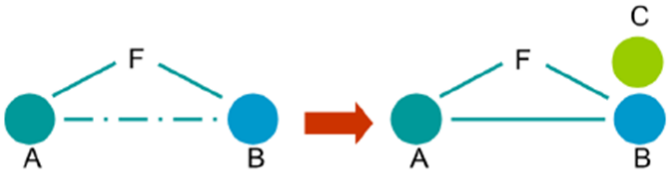


Figure 3. Inventive Standards solution 3-2 Diagram (Valeri Souchkov. 2015)

Generate idea: Give gifts to students for learning well

### 3.3.3 Inventive Standards solution 3-3

If there is a poorly controllable effect of interaction between two objects A and B, then consider replacing a method (principle) of interaction with a new method (principle) which improves the controllability. (Valeri Souchkov. 2015)

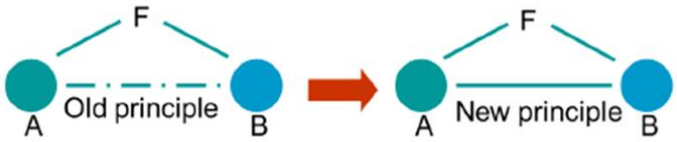


Figure 4. Inventive Standards solution 3-3 Diagram (Valeri Souchkov. 2015)

Generate idea: Make students group discuss cases and report them

### 3.3.4 Inventive Standards solution 3-4

A control over an effect of the interaction between two objects A and B can be improved by transforming one of the objects into an independently controllable object. (Valeri Souchkov. 2015)

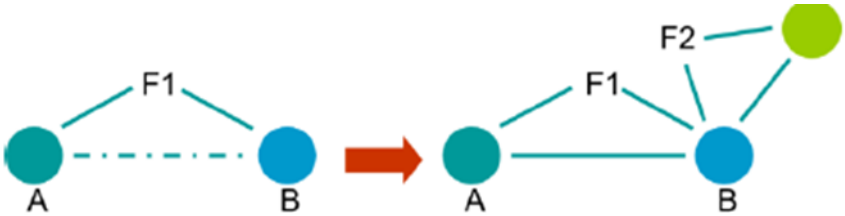


Figure 5. Inventive Standards solution 3-4 Diagram (Valeri Souchkov. 2015)

Generate idea : Military training instructors are invited to the classroom to assist teachers to control students

## 3.4 Ideas obtained with the Inventive Standards

Table 4 Ideas Collecting table

| Inventive Standard | Ideas |
|---|---|
| 3-1 | Demo real innovation products to attract students |
| 3-2 | Give gifts to students for learning well |
| 3-3 | Make students group discuss cases and report them |

| | |
|---|---|
| 3-4 | Military training instructors are invited to the classroom |

## 3.5 Comparing and Evaluation

### 3.5.1 Multi-Criteria Decision Matrix

Table 5 Ideas Multi-Criteria Decision Matrix table

| | **Ideas** | **Easy** | **Students Happy** | **Cheap** | **effective** | **Total score** | **Rank** |
|---|---|---|---|---|---|---|---|
| | Weight-> | 5 | 4 | 6 | 7 | | |
| 1 | Demo real innovation products to attract students | 0 | 1 | -1 | 1 | 5 | 2 |
| 2 | Give gifts to students for learning well | 0 | 1 | -1 | 0 | -2 | 3 |
| 3 | Students groups discuss cases and report them | 1 | 0 | 1 | 0 | 11 | 1 |
| 4 | Military training instructors are invited to the classroom | -1 | -1 | 0 | 1 | -2 | 3 |

Score (Performance of an idea) = SUM (Criterion x * Weight x) per idea
Weight of each criterion is better to set from 1 to 10

### 3.5.2 Estimating Time to Implement

Table 6 Estimating Time to Implement Ideas

| **IDEA** | **Time to market** |
|---|---|
| Demo real innovation products to attract students | 5 month |
| Give gifts to students for learning well | 2 month |
| Students group discuss cases and report them | 1 month |
| Military training instructors are invited to the classroom | 3 month |

### 3.5.3 Ideas Landscape

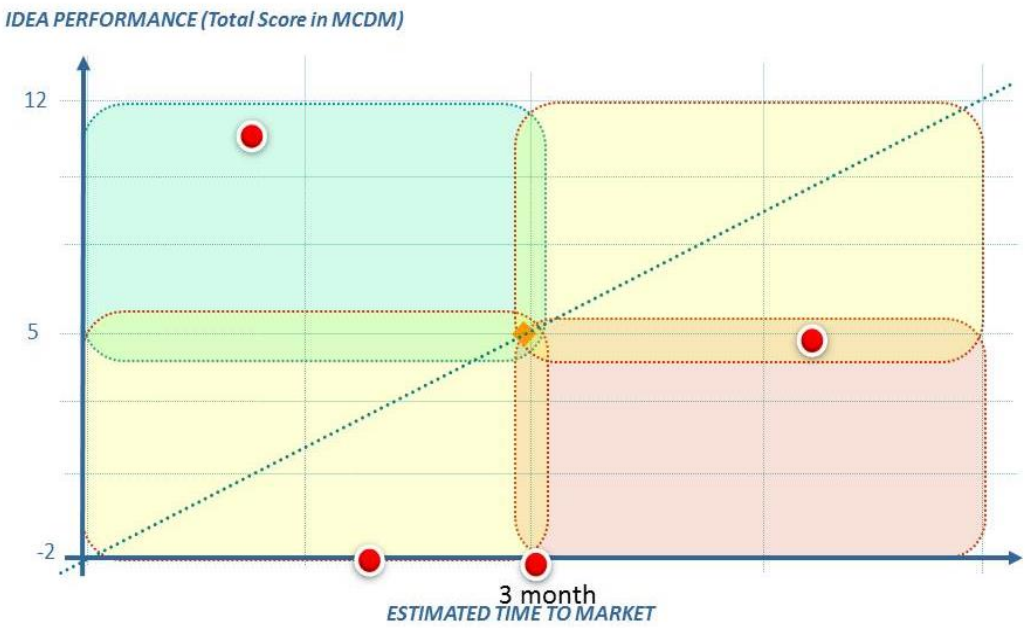


Figure 6. Ideas Landscape Diagram

### 3.5.4 Selected idea

The best idea is Students groups discuss cases and report them.

## 4 Results and Discussion

TRIZ was used in this paper to deal with the problem about Teacher's poor control in class. Trough the use of Functional Analysis and Binary Problems Ranking, Teacher's poor-control became the most Important Problem in this paper case. Then, Inventive Standards for Business and Management Applications Group 3 (Improving poorly controllable effect of an interaction) generated four ideas. After Multi-Criteria Decision Matrix and Estimating Time to Implement to Comparing and Evaluation, the best idea is "Make students group discuss cases and report them".

## References

1. International TRIZ Association website, www.matriz.ru
2. Valeri, Souchkov, "Systematic Innovation with TRIZ for Business and Management, ADVANCED COURSE Training & Certification", *MATRIZ level 2*, 20151128-1206, Taiwan
3. Valeri Souchkov. "TRIZ and xTRIZ Techniques Business and Management Applications, Basic and Advanced Courses References Book", 1998-2015 *ICG Training & Consulting*, Enschede, The Netherlands

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# THE ISSUES OF TRANSITION TO THE SUPERSYSTEM

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## Abstract

Examples of deviations from the subtrend "Integration of Homogeneous Systems" are analyzed in the present paper. Four typical situations in which such a deviation occurs have been identified. Recommendations for the analysis of such cases are given be the author.

Application of recommendations will help to improve the accuracy of forecasts based on the Trends of Engineering System Evolution.

Keywords: *Trend of Transition to the Supersystem, Integration of Homogeneous Systems, TRIZ*

## 1 Problem statement

Trends of Engineering System Evolution represent an effective tool for forecasting and improving engineering systems. The Trend of Transition to the Supersystem is one of the strongest and mostly often applied tool because it provides a great number of mechanisms. Let's remind the formulation of this trend [1]:

"A regularity of engineering system evolution consisting in the fact that in the course of evolution, as an engineering system (ES) internal resources get exhausted, an ES integrates with other systems and continues its evolution in the supersystem. According to this mechanism, the systems are integrated in the following order:

- Homogeneous systems (homogeneous - means the same);
- Systems with shifted characteristics (systems that differ from one another in terms of any parameter);
- Alternative systems (systems that are structured and designed differently and that have mutually opposed pairs of advantages and disadvantages);
- Alternative systems, one of which is inert (an inert system is practically incapable of performing the required main function, but it is free from a disadvantage inherent to the active system in this pair of systems)".

One of the implementation mechanisms is the following subtrend: "A regularity of engineering systems evolution consisting in the fact that in the course of evolution the number of systems integrating together increases steadily". This subtrend has many practical embodiments and manifests itself in the huge number of ES surrounding us. Among these are multi-core

processors, assemblies of several LEDs in LED lamps, heating system radiators assembled from several identical sections, multi-cylinder internal combustion engines and many other ES.

At the same time, in some cases we can observe a "step back" from this subtrend. An ES progresses for some time moving towards an increase in the number of integrated systems, and then their number starts decreasing. Let us consider a typical example of such situation:

Nieuport 17

Vickers FB.27 Vimy

Sikorsky Ilya Muromets S-22

At early stages of aviation evolution (approximately in 1910-1920) insufficient engine power was one of the main factors holding back the development of high cargo-carrying capacity aircraft. Designers quickly switched from a single-engine designs to two-, and later to four-engine design options.

Tupolev ANT-22

Dornier Do X

In the 1930s, experiments with an increase in the number of engines were continued. Exotic multi-engine aircraft designs (Tupolev ANT-22 - six engines - 830 hp each, Dornier Do X - twelve engines - 640 hp each). Such a large number of engines created a lot of problems. That's why with the advent of more powerful engines in the early 1940s, the number of engines was decreased to four for the majority of heavy aircraft (Boeing B-29 Superfortress had four engines - 2 200 hp each, Handley Page Halifax – four engines - 1 615 hp each).

Boeing B-29 Superfortress

Handley Page Halifax

From here we will omit several interesting models that appeared in the 1950s in the course of transition from piston engines to jet ones. For those who are interested in this issue, I would recommend to study the history of the six-engine piston-type Convair B-36 in greater detail. The hybrid B-36J model, which had four General Electric J47-GE-19 turbojet engines with a thrust of 2 720 kgf each, in addition to six high-power Pratt & Whitney R-4360-25 engines (28 cylinders, 3 500 hp), is of special interest in this respect. As a result, the B-36 bomber holds an unbeaten record - 10 engines of two fundamentally different types were installed on this aircraft. However, this interesting aircraft represents a funny casus. Boeing B-52 Stratofortress that

replaced B-36 bomber is still in use. B-52H (used even nowadays) have eight Pratt & Whitney TF33-P-103 turbojet engines. The first flight of this aircraft took place in 1952, which determined the level of technologies used. A stock of manufactured engines and spare parts was produced, which allowed to continue flights until present time (almost 70 years!). In the seventies, the engines used were considered to be outdated and requiring replacement. Later the first engine-replacement project was launched. However, this work has not been completed due to economic or other reasons.

By the beginning of the 70s, heavy aircraft for long-range flights had acquired a stable four-engine configuration. Examples of this configuration include Boeing 747 (first flight in 1971) and Ilyushin Il-86 (first flight in 1976).

Boeing 747

Ilyushin Il-86

The development of gas turbine engines led to a further increase in engine power. At some point it was found out that two engines were quite enough to produce the required thrust. The history of the development of the four-engine Airbus A340 (first flight in 1991) and the two-engine Airbus A330 (first flight in 1992) is quite interesting. The fuselages, wings and on-board equipment are identical in A340 and A330, they differ only in terms of type and number of engines[1]. As for the world's largest twin-engine aircraft Boeing 777 (the first flight in 1994), from the beginning it was designed as a twin-engine version only.

Airbus A340

Airbus A330

At present all newest and most promising aircraft for long-distance flights are designed in a two-engine version only. Among these are Boeing 787 Dreamliner (the first flight in 2009), promising Russian-Chinese CR929 (the first flight is expected in 2022) and recently shown Airbus Zero-Emission Concept (expected to be commissioned by 2035).

1 One of the reasons for the appearance of two versions of actually one and the same aircraft consists in safety requirements for transoceanic flights. Details can be obtained via search request – “rule for 60. 120 and 180 minutes”)

Boeing 787 Dreamliner

CR929 (Comac C929)

Airbus Zero-Emission Concept

Let us summarize the above-presented information. We can see that in the period from about 1910 to 1940, aircraft for long-distance flights have been developing in full compliance with the subtrend - the number of engines used increased, sometimes going far beyond reasonable values. Fragile equilibrium was characteristic for the period between 1950 and 1970 (this equilibrium was mainly associated with a transition from piston engines to turbojet ones). Later this equilibrium was replaced by a trend towards a reduction in the number of engines used. The reasons for this transformation are quite understandable:

- Development of piston engines, which allowed increasing the power of a single engine from 50-100 hp to 5 000 hp.[2]
- Further growth of turbojet engine power
- Extremely high level of reliability achieved for present-day engines.

Now let's ask a question - how often does such a situation occur in the course of engineering system evolution? What reasons (with the exception of growth of a single ES parameters) can lead to a "step back"? Can we forecast such a "step back"?

## 2 Typical reasons for the "step back"

The search for and analysis of examples of engineering system evolution enabled to identify several typical situations. The results of this analysis are presented below.

### 2.1 Evolution of integrated ES in terms of Main Function parameters

The aviation development history presented above represents an example of the first typical situation. This is a situation where the number of integrated systems is growing because at the current level of development we have insufficient parameters of the Main Function (MF) performed by the engineering system. For an aircraft, engine power represents this parameter. Careful consideration enables to see an interesting specific feature. At first the focus was made on specific power. The plane manufactured by Wright brothers made its first flight in 1903; it had a gasoline engine only 14 hp in power. The engine weight was around 80 kg, which today looks extremely low. However, for its time their plane was a unique high-tech product. It suffice to say that the creator of the Charlie Taylor engine used a cast aluminum housing!

In terms of standards of 1903, the power of this engine was very low. At that time, internal combustion engines 100-120 hp in power were produced. However, the weight of these powerful engines was too high, which did not enable to employ them for the aircraft. Therefore, it was rather specific power that was the critical parameter enabling an aircraft to take off. Later the efforts focused on increasing the absolute power (although the specific power also continued

2 Lycoming XR-7755, which was created specifically for Convair B-36. Unique nine-beam four-block star, 36 cylinders, working volume - 127 liters. It was developed and tested, but was not accepted for serial production bacause turbojet engines replaced piston ones.

increasing). At the same time, the technological limit of evolution (in terms of "absolute power" parameter) was reached by piston engines by about 1950.

Let's consider another example. Look at three pictures below:

Menshikov's Palace (Saint Petersburg) is shown on the left picture. The building was built in 1714 and its glazing is quite characteristic for that time. It was assembled out of small glass blocks. The limitation of glass blocks in size was preconditioned by specific features of the glass manufacturing technology used in the 18th century. Modern glazing, not limited by the size of glass blocks, is shown on the right. This is a typical example of a "step back" caused by overcoming technological limitations.

A change in the number of steam generators in WWER power reactors represents another example. It would be more correct to talk about the number of loops of the main reactor circuit, since a reactor loop includes a heat exchanger (steam generator), circulation pump and valves. Nevertheless, the number of steam generators is often used for the sake of brevity. Steam generator is a heat exchanger employed for the production of water steam with a pressure above atmospheric one due to the heat from the primary heat carrier supplied from the nuclear reactor. Table 1 shows how the number of steam generators changed with an increase in the thermal output of the reactor from 760 to 3 000 MW. Six steam generators were used for the first (smallest) reactor. The growth of power required an increase in the number of steam generators (up to 8), which is quite consistent with the sub-trend under discussion. However, subsequently one can see a "step back" - a drop in the number of steam generators to six, and then even to four.

Table 1. Main parameters of WWER reactors (USSR)

| | WWER-210 | WWER-365 | WWER-440 | WWER-1000 |
|---|---|---|---|---|
| Thermal/electrical output, MW | 760/210 | 1320/365 | 1375/440 | 3000/1000 |
| Pressure in the reactor vessel, MPa | 10.0 | 10.5 | 12.5 | 16.0 |
| Water temperature at reactor output, C | 273 | 280 | 301 | 322 |
| Steam pressure upstream of turbine, MPa | 2.9 | 2.9 | 4.4 | 6.0 |
| Number of loops of the main reactor circuit (number of steam generators) | 6 | 8 | 6 | 4 |

Source https://leg.co.ua/arhiv/generaciya/aes-s-vver-9.html

Since there are no physical limitations on the power of a single heat exchanger, a reduction in the number of used steam generators is connected with accumulation of experience in the design and operation of such systems, as well as with noticeable increase in heat carrier parameters (temperature and pressure).

The next example refers to the history of Soviet armored personnel carriers evolution. If a decision is made to analyze consistent evolution of BTR-60, BTR-70 and BTR-80 models, the attention of the analyzer will be attracted to a change in the power plant. All the above-named models are all-wheel drive and four-axle armored personnel carriers characterized by power plant installed in the rear part. After its appearance in 1960, BTR-60 became the first serially-produced armored personnel carrier to use a four-axle scheme with independent suspension of large-diameter wheels. Armored wheel-based cars that were based on commercial or specially designed cars were used in other countries. However, despite all their advantages, BTR-60 is characterized by a unique feature - it is equipped with two (!) engines. And this was done for a very simple reason - the designers simply did not have an engine of required power... Moreover, BTR-70 (which appeared in 1971) had the same problems with the engine. And, as a consequence, BTR-70 inherited the same exotic power plant and all problems associated with it. And only on BTR-80 model (1986) designers installed an engine with the required parameters because such an engine was at their disposal by that time. Thus, the designers "stepped back" to the classical single-engine version.

Is there anything common in the examples given above? After integration of several ES into a polysystem, evolution of these ES does not stop. MF parameters are improved (increased), and at a certain point in time the number of integrated ES becomes excessive. That's how a "step back" from the subtrend takes place, and the number of system to be integrated goes down.

## 2.2 Removal of supersystem limitations

The second typical situation is related with the presence of supersystem limitations. The bearing capacity of a road is limited; therefore, the load on one axle of a vehicle is also limited. As a result, we see that the evolution of heavy trucks occurs as follows:

The trend of load capacity growth by increasing the number of integrated ES (axle) is obvious and clear. However, if the supersystem limitation is removed, we would see a completely different situation.

The picture on the left shows two dump trucks. The left dump truck is BELAZ 75710 - one of the largest mine dump trucks in the world possessing the carrying capacity of 450 tons. The right dump truck is BELAZ 75581 - one of the smallest models of this truck manufacturer offering the carrying capacity of 90 tons "only". Both dump trucks are characterized by simplest two-axle design. A polysystem with a larger number of axles is not needed at all because roads in quarries are intended for much higher loads.

Another example (described above) dealing with the number of aircraft engines. Let me remind that the "step back" from the four-engine configuration to the two-engine one was limited for a certain period by safety requirements for transoceanic flights, i.e. there was a typical supersystem restriction. This restriction was removed not immediately, but in several stages (transition from the 60 minutes rule to the 120 minutes rule and then to the 180 minutes rule). Nevertheless, at present this supersystem restriction has been removed.

Thus, a "step back" from a subtrend can be caused by a change in supersystem restrictions (of course, if previously the subtrend action was associated with the presence of this supersystem restriction).

## 2.3 Trimming of integrated ES

The third typical situation is a "step back" due to trimming of polysystem components. Let's take a look at the drawing below and recollect the history of sound reproduction system evolution:

The transition from monophonic to stereophonic sound reproduction systems was a revolutionary step. It was a breakthrough both from the standpoint of quality (listeners obtain a reliable spatial sound pattern, at least two-dimensional) and from the marketing standpoint (now buyers pay not for one "amplifier+acoustic system channel", but for two channels!). Now imagine the delight of marketing professionals after the advent of spatial sound systems of the 5.1 format (it offers quite a reliable three-dimensional sound pattern)! Now clients can buy not two channels, but as many as six channels! The 7.1 format was even more attractive for marketing professionals, but their enthusiasm did not last too long. In 2005, the market was astonished by a new product - the Yamaha YSP-1 soundbar. The engineers succeeded in "assembling" all channels (with the exception of low-frequency one) in a compact housing, and a spatial sound pattern was formed due to time and phase shifts between the radiators. The minimalist design of monophonic past came back - one radiating unit and subwoofer (optional).

It is reasonable to consider such a radical change in the design as a deep trimming that has transformed the polysystem into a one-component system. Yes, in fact, the number of reproduction channels has even increased in this case, but this complexity has descended one system level lower. For users, the system has become one-component.

Transition from multi-barrel hand weapons to revolver systems represents another example of "step back". The history of multi-barrel weapons is very interesting. We will make a passing mention of this subject and compare the family of multi-barrel pistols known under the collective name "Mariette Pepperbox"[3] (the picture below shows an 18-barrel pistol with a rotating barrel block) and a classic Colt revolver).

Both pistols belong to about the middle of the 19th century and have a primer ignition system. However, the revolver has a single barrel, and the only part that rotates is a drum with charges. This is an obvious "step back" obtained via trimming of a multi-barrel hand-held weapon (the first samples of multi-barrel weapons date back to the middle of the 15th century). In the course of technology evolution revolvers quickly replaced multi-barrel pistols (mating a drum with barrel end represents a difficult designing and technological problem).

## 2.4 Dynamization of integrated ES

And, finally, the last typical situation is a "step back" due to dynamization of the Main Function parameters. The simplest example here is the transition from using a set of lenses with a different focal length to zoom lenses. This example has a significant difference from the ones previously described - it refers rather to the situation of "Integration of Systems with Shifted Characteristics". Nevertheless, the example is very close to the subject matter under discussion.

In conclusion, let us discuss in what way a lyre differs from a harp? It would seem that both musical instruments represent a simple combination of independent strings, each of which is tuned to a certain note. This is true for the lyre (shown in the figure below). But a harp represents a more complex system. I believe many people have paid attention to pedals of a concert harp. What are they intended for?

Since a harp is characterized by a wide audio (sound) range (five octaves) and there is not enough space for strings of the complete chromatic scale, a harp has those strings that are intended for touching sounds of diatonic scale. Only two scales can be played with the harp without using pedals – namely, C-major and A-minor (only natural harmonics). In the past the strings had to be pressed with fingers at the neck to produce chromatic elevation. Later

3 Majority of the "Mariette weapons" were patented by Guillaume Mariette de Cheratte, who of 1840 to 1888 deposited 22 Belgian patents

musicians started using hooks driven by their hand to cause this kind of pressing. Such harps turned out to be extremely inconvenient for musicians. The disadvantage was eliminated by means of a mechanism in pedals. Pedals were introduced in 1697 by Jakob Hochbrucker. In 1811 they were upgraded to the "double action" pedal system patented by Sebastien Erard. This mechanism is used at present time.

Thus, a concert harp represents a partially trimmed system, which enables to have a wide range with acceptable size.

## 3 Conclusions

Let's summarize the aforesaid. At this point in time, the author succeeded in identifying four typical situations, in which a “step back” (that is, a reduction in the number of components/systems integrated into a polysystem) takes place. These are as follows:

- Evolution of integrated ES in terms of MF parameters
- Removal of supersystem restrictions
- Trimming of integrated ES
- Dynamization of integrated ES

Hence, the following recommendations can be given:

- In the course of analysis, a researcher should, first of all, determine what actually leads to the integration ES into a polysystem – the inability of an ES to provide a required value of MF parameters or supersystem restrictions
- If the reason lies in supersystem restrictions, the researcher should consider the probability of restriction changes in the future
- If the reason lies in the inability of ES the vehicle to provide a required value of MF parameters, - the researcher should analyze the limits of these parameters development and make a forecast
- If the transition to a polysystem is undesirable within the frames of the problem being dealt with, the researcher should consider a possibility of “step back” via trimming or dynamization.

In conclusion, it should be pointed out that possibly there are other typical situations that the author failed to identify. Any additions and suggestions to the present paper will be considered by the author with gratitude.

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## References

1. S.Litvin, A.Lyubomirskiy Trends of Engineering Systems Evolution. Guide. 2003

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# TRIZ REVERSE – SPECIFICATION AND APPLICATION OF A 7 STEP-BY-STEP APPROACH FOR SYSTEMATIC KNOWLEDGE AND TECHNOLOGY TRANSFER

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Paper Category:

- Development of Methods and Tools: Presentation of new methods and tools or novel contributions to the improvement of existing TRIZ methods and tools for practical use.

## Abstract

A reverse inventing method for knowledge and technology transfer called TRIZ Reverse has been recently further developed by the HTW Dresden. The following paper presents this new methodology approach, which is based on the theory of inventive problem solving TRIZ. A comprehensive case study, e.g. patent analysis with the aim of alternative industry application identification, is conducted to specify and operationalize the single process steps involved. On this basis, the authors express their recommendations towards the desired and possible evolvement of TRIZ Reverse as a tool for innovation acceleration as well as their aims with regards to the exploitation of the selected patent.

Keywords: *TRIZ, TRIZ Reverse, Reverse Inventing, Reverse Engineering, Knowledge and Technology Transfer, Systematic Invention and Innovation, 7-Step-Approach, Patent Analysis*

## 1 Introduction

In the year 2019, Germany was one of the countries with the highest number of patent applications with a total of 178,184 filings [1]. Looking at this number it would be easy to assume that German inventors are successfully transferring their protected innovative theoretical knowledge and ideas into promising, market fitting products and services. Unfortunately, this assumption does not mirror the current situation. The German Patent and Trade Mark Office estimates that "in fact only three to five percent of the patents applied for lead to economic benefits income and thus meet the expectations of the applicants" [2].

On the one hand, this is a serious issue, since it reveals that the resources invested into the development and protection of intellectual property do not provide a certainty for the realization of viable products or services. On the other hand, the status quo offers a huge profit gen-eration improvement opportunity for inventors, innovation managers and technology transfer experts. In this regard, the Institute of German Economy (IW) estimates that “the German economy is sitting on unrealized assets of at least eight billion euros” [3]. The development of a systematic technology transfer method as a tool for the amplification of potentially expected Return on Investment (ROI), e.g. in R&D activities, is therefore highly desirable.

In this paper, we will briefly describe the fundamentals of the TIRZ Reverse approach. Based on a review of existing methods and algorithms in this field, in our study we developed a 7-Step procedure for a structured TRIZ Reverse process. This process has been developed alongside a concrete case study concerning a patent issued by HTW Dresden in 2019.

## 2 From TRIZ to TRIZ Reverse

### 2.1 Theoretical Basis

The aim of the Theory of Inventive Problem Solving (TRIZ) is to systematize the creative idea generation process, largely exclude chance, and to shorten the time resource required to come up with inventions [2]. Meanwhile the TRIZ method has been known in the western hemisphere for more than 30 years. It is being continuously developed and refined by various research facilities and institutes, i.e. TRIZ-fest. The research focuses primarily on the transfer to non-technical areas like service and support, as well as the connection with other methods in product development, such as QFD and FMEA [4]. The expansion of TRIZ to include new areas of knowledge, such as biology and psychology, is also being examined [5].

Additionally, the use of TRIZ for the identification of application areas for existing technical "solutions" has hardly been considered so far. A TRIZ Reverse method, which methodically supports the finding of application areas for already existing technical "solutions", would therefore be indeed desirable. It would not only facilitate the (knowledge) transfer into practice for universities and research institutions, albeit also significantly accelerate this process. From a scientific point of view, the specific question arises as to whether TRIZ's problem-solving process is generally reversible. According to the motto "solution seeks problem", new potential applications, i.e. problem areas, should be identified based on a known technical solution.

Current research results indicate that this possibility exists in principle, and that (generic) exploitation principles can be extracted. This primarily relates to the use and/ or sale of patents. Authors in current literature often speak of “reverse inventing” or “reverse engineering” when it comes to opening up new markets and/ or target groups for existing products or (technical) solutions [6]. While conventional market research instruments mainly rely on direct questioning and observation of potential customers, reverse inventing methods prefer to use abstraction. The strengths of the company or the products/ services are translated into abstract descriptions. The vocabulary used in the patent literature serves as a reference or frame of reference.

### 2.2 General Approaches

There are several suggested procedures in the literature for using TRIZ Reverse. More than 10 years ago, Darrell Mann [7] proposed a “principles-based patent search”. It contains step-by-step instructions to link search terms from patent databases with the inventive principles from Genrich Altshuller’s contradiction matrix. The greatest challenge faced, is the semantics used

in the reference documents, since in today's patent specifications - not infrequently for legal reasons - different terms are used in comparison to Altshuller's time.

To overcome this dilemma, Mann et al. (2006) developed a keyword catalog for all 40 inventive principles. Once the relevant inventive principles for a given technical solution are assigned, the key words can be used to search specifically in relevant patent databases. It is relatively easy to identify "patent clusters" or "areas of technology", in which a relatively large number of patents exist that are related to the innovation principle sought. The International Patent Classification (IPC) codes (or classes) with which the technical contents of patents have been uniformly classified into 8 main groups worldwide since 1971 are the basis for clustering [8], [9].

During the past decade, several proposals of the TRIZ Reverse methodology were introduced. Depending on the objective and focus of the investigation, the algorithms are comprised of four to eight steps that the user must pass through in order to find suitable new areas of application [6], [10], [11], [12]. A main distinguishing feature is the use of the contradiction matrix. In essence, this concerns the question of whether the 40 inventive principles including or excluding the 39 technical parameters are to be used for reverse inventing. From a methodological point of view, the use of the technical parameters should be aimed for, since in this way the examination scope for the patent search is restricted more effectively.

### 2.3 Common Barriers

Since the literature meanwhile contains several proposals for potential TRIZ Reverse methodological approaches, it is questionable, why the use of this approach has not yet become "mainstream" in most organizations, universities and research institutes.

One possible answer is that important figures in companies (c-suite members) are simply not aware of the various TRIZ Reverse methods for knowledge and technology transfer, and do not therefore not insist on the application when it comes to innovation processes. Another reason might be that the numerous potential benefits arising out of the incorporation of such a reverse invention method, e.g. portfolio expansion, ROI and/ or resilience increase in general, are not understood or not trusted yet due to the lack of experience and expertise.

In this regard, the question arises if the development of more comprehensive software tools to support the users might be what is still missing when it comes to supporting them in the process of the identification of suitable additional fields of application. Compared to the classic TRIZ, the presently available selection of professional software solutions using a TRIZ Reverse is significantly smaller. PIFURRA is one example, and the result of a PATE project funded by the DFG to improve and accelerate technology transfer in connection with the use of "adaptive surfaces for high-temperature applications" [13]. The software supports the automated assignment of relevant (scientific) publications to corresponding search requests.

## 3 TRIZ Reverse Procedure

### 3.1 6-Step Procedure by Glaser and Miecznik (Status quo)

One of the currently most elaborated on TRIZ Reverse methods, was proposed by Glaser and Miecznik in 2009. It was developed as a part of a collaborative case study with the German electronics company Wittenstein SE. The aim was to identify additional business opportunities for "a system for the controlled prolongation of limbs by means of a dynamic intermodular nail for implantation into the bone marrow of limbs, typically legs" in order to increase the revenue generated and boost the market growth potential [6]. The researchers have defined their version of the TRIZ Reverse inventive process in six steps as demonstrated in Figure 1.

One year later, Bianchi et al. [11] have developed a TRIZ Reverse methodology based on the work of Glaser and Miecznik. The aim of the research team was to support small- and medium-sized enterprises (SMEs) in finding alternative technology applications (ATA) in a more efficient way. Their process starts with a definition of the technology's requirements followed by a TRIZ-based analysis of the very same. Afterwards abstract problems are selected and ATAs identified. The last step of Bianchi et al.'s method is the creation of a strategic positioning matrix for the selected results.

In 2020, the researchers of the current paper have developed an advanced algorithm as part of a case study on the research of potential alternative use cases for a patent of a collagen based composite material, invented by the Faculty of Ecology at HTW Dresden.

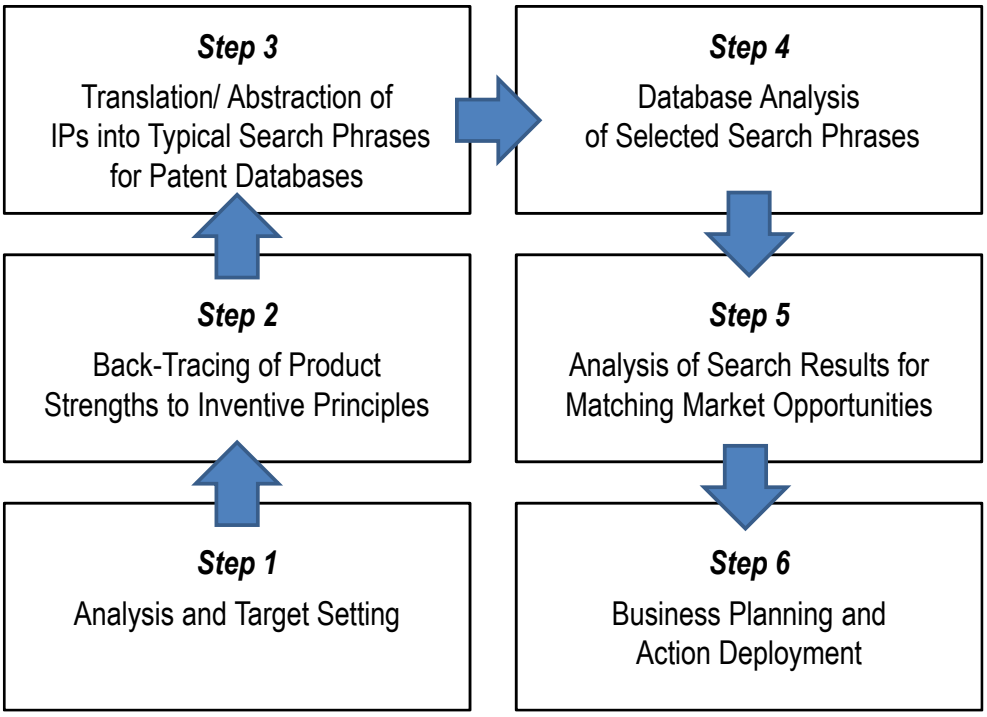


Fig. 1. TRIZ Reverse methodology approach in six steps by Glaser and Miecznik [6]

## 3.2 Advanced 7- Step Procedure by HTW Dresden

*Step 1: Selection of a suitable invention (patent)*

The initial step of the methodology is to conduct a research on appropriate patents. The researchers suggest using personal or professional contacts (network) with the objective to inform oneself on relevant inventions. Another option to gather information is to contact universities, companies or even private persons, who are involved in the area of intellectual property creation or management.

*Step 2: Patent analysis and identification of relevant inventive principles*

After an appropriate intellectual property has been selected, the next step is to analyze the full patent text and identify the most relevant inventive principles. The person in charge should search for key words which indicate technical solutions according to the 39 parameters of the TRIZ contradiction matrix. First of all, the technical solutions must be found which are improved by the invention, e.g. the new solution increases the speed of production. Afterwards,

such technical solutions must be spotted which indicate that at least one parameter is limited with regards to unwanted change, e.g. the invention might limit the use of energy resources.

The identified technical parameters have to be inserted into the inventive principle identification and prioritization matrix (IPIP matrix) – a tool based on the classic TRIZ contradiction matrix built for the acceleration of the inventive principle discovery procedure. It includes a focused contradiction matrix field, which delivers results for inventive principles for technical parameter contradictions, a field for calculation of the appearance of inventive principle's numbers, and a summary column delivering the sum of all the appearances of an inventive principle by taking all contradiction pairs into consideration.

*Step 3: Key word selection and search code creation*

In this step the identified inventive principles have to be "translated" into the vocabulary used in the common language in patent texts. For this purpose the key word approach for assigning terms to the single inventive principles as proposed by Mann [7] is applied. Moreover the researchers have decided that it is necessary to introduce key words from the patent text itself into the search code used for the database research. The most frequently used terms in any text can be quickly identified by copying the desired text and pasting it into a word density analyzation tool.

In this context, the application of a systematic approach for code creation is suggested, which shall be tested in the upcoming step. This system should prevent the incorporation of trial and error practices, and increases the efficiency of the whole process. Overall, the code consists first and foremost of key words from the patent text with the highest frequency of use as well as such terms which are related to the 40 inventive principles of TRIZ and the operators applied at the relevant database (e.g. AND, OR etc.). With the search code template created in Excel $16 \cdot 12 = 192$ different search code variations can be created.

*Step 4: Database research (search code testing)*

The aim of step 4 is to identify the best matching patent hit lists by systematically testing the search codes created in step 3 in a patent database, e.g. dpma.de. The authors suggest to look for hit lists containing between 100 and 500 (+/-10) patents. A similar recommendation is provided by Glaser and Miecznik [6] and Günther [14].

To find such hit lists, it is best to maintain a systematic approach with the code testing, so that a better overview can be obtained. If the time is limited, then the introduction of the "AND" instead of the "OR" operator in the search codes used might be necessary in multiple places. After at least one hit list with an appropriate number of patents has been identified, the analyst may proceed to the next step.

*Step 5: Semi-automated patent list analysis*

For the efficient analysis of the identified hit list, an automated IPC code identification matrix – including a systematic color code scheme to facilitate the readability of the results – has been created with the support of Excel. To take full advantage of the automation system, the authors of the current paper suggest following these four steps:

1. Download the patent list (with 100 to 500, +/-10 results) in an Excel spreadsheet from DPMA platform by using the expert search mode.
2. The file will likely be in ".xls" format. Make sure to save the Excel file once again under the more up-to-date format ".xlsx".
3. Copy and paste the semi-automated patent list analysis template starting exactly in the specified cell in the new file to ensure functions and links.
4. Visualization tools are included in the Excel file to display the preliminary results of the analysis, e.g. bar chart. A reselection of the area is necessary.

*Step 6: Manual patent list analysis (3 stages)*

The manual in-depth analysis shall continue with a review of the preliminary results from step 5. A focused analysis is further performed on one (or as many as desired) selected IPC codes of second level hierarchy (e.g. H01). In this context, the IPC codes of second hierarchy level with the most occurrences are selected, and from there on the IPC codes of third level hierarchy (e.g. H01L) with preferably five or more patents included identified by color coding. All relevant patent clusters (in full line, i.e. with all the information provided by the patent database) have to be copied and pasted into a new Excel sheet for the purpose of organization. After aligning the data and shifting several columns, the titles of the columns in the final Excel spreadsheet are as follows: Release date, IPC main class, IPC minor/index classes, Common Patent Classi-fication (CPC), Reclassified IPC (MCD), Test substance, IPC, Inventor, Applicant/ Owner, Product, Process, Country, Entity, Industry, Contact, Title, Patent Plot, Summary, 1. Page, Complete Document, Sequence listing URL, and Searchable text URL.

Not all necessary information is provided by the patent research database, i.e. Country, Entity, Industry, Contact and Patent Plot. Therefore, the final task in step 6 is to gather these facts or data via Internet research or other tools for information gathering. For the column Patent Plot, selected parts from the first paragraphs of the full patent text description may be used. Another part to carefully review in the search for potentially appropriate text passages is the patent claims section.

*Step 7: Discussion of possible cooperation and patent exploitation opportunities*

The final step of the advanced TRIZ Reverse method is the presentation of the results to the client, which includes the discussion of any further steps of the technology transfer process. The authors suggest starting the presentation by revealing the most outstanding findings, which could be for example huge patent clusters in specific or unexpected areas. In conclusion, it should be noted that the decision for future executive steps in terms of cooperation or product development should not be made without careful consideration of the current market status or a market trend analysis [11].

# 4 Application of the HTW Dresden Procedure

## 4.1 Case Study Introduction

For the purpose of the development of the TRIZ Reverse methodology and the identification of alternative application fields of an already protected technology, a HTW Dresden owned patent [15] in the area of medicine (IPC main class: A61L 27/44) has been selected. The full title of the patent is "Biocompatible molded part and process for the production of a collagen-based

layer material“. A simplified illustration of the process (patent code DE102017123891) can be seen in Figure 2.

A short fragment of the patent text shall provide a brief understanding of the new technology: “A method for providing a collagen-based layer material (3), comprising the following steps: - providing at least one swellable collagen material (1), - contacting the swellable collagen material (1) with an aqueous solution so that the swellable collagen material (1) can swell, arranging the swollen collagen material (1) in layers so that a layer arrangement (2) with at least two layers (1.1 to 1.5) lying on top of one another at least in some areas is formed, and air-drying the layer arrangement (2) at a temperature below 50 ° C, whereby the superficially adjacent layers (1.1 to 1.5) are crosslinked with one another.” [15].

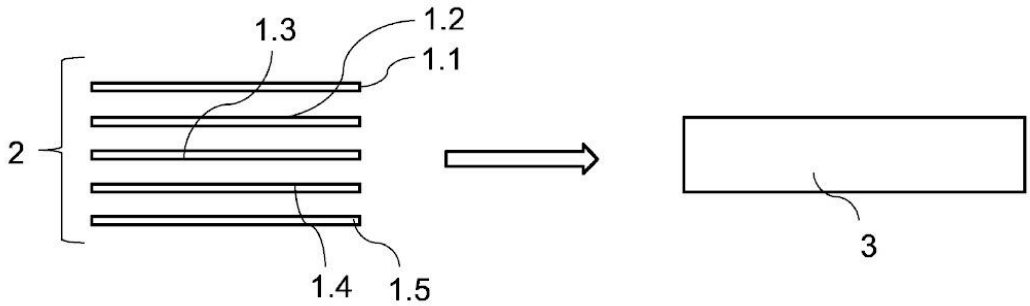


Fig. 2. Patent DE102017123891 (invention 1) [15]

## 4.2 Step-by-Step Approach

In this chapter the analysis of the previously introduced patent is presented according to the 7-Step TRIZ Reverse procedure developed by the HTW Dresden (see chapter 3.2).

*Step 1: Selection of a suitable invention (patent)*

The patent selected for the analysis was discovered within the scientific network community of the university, hence through cross-faculty networking endeavors including members of the Faculty of Ecology and the Faculty of Business Administration. The initial input was provided by the vice president´s office for knowledge and technology transfer.

*Step 2: Patent analysis and identification of relevant inventive principles*

After reading the full patent text and pointing out, as well as inserting the relevant key words in the IPIP matrix, the top three inventive principles – (35) Parameter changes (13 points), (1) Segmentation (10 points) and (40) Composite materials (7 points) – have been identified. A screenshot of the applied Excel spreadsheet is depicted in Figure 3.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | PA (KBSM) collagen-based layer material | (1) Weight of a moving object | | | | (7) Volume of a moving object | | | | (13) Stability of an object | | | | |
| 2 | Undesired change: | | | | | | | | | | | | | |
| 3 | (11) Pressure or tension | 10 | 36 | 37 | 40 | 6 | 35 | 36 | 37 | 2 | 35 | 40 | | |
| 4 | (12) Shape | 10 | 14 | 35 | 40 | 1 | 15 | 29 | 4 | 22 | 1 | 18 | 4 | |
| 5 | (13) Stability of an object | 1 | 35 | 19 | 39 | 28 | 10 | 1 | 39 | | | | | |
| 6 | (15) Durability of a moving object | 5 | 34 | 31 | 35 | 6 | 35 | 4 | | 13 | 27 | 10 | 35 | |
| 7 | (17) Temperature | 6 | 29 | 4 | 38 | 34 | 39 | 10 | 18 | 35 | 1 | 32 | | |
| 8 | (27) Reliability | 1 | 3 | 11 | 27 | 14 | 1 | 40 | 11 | | | | | |
| 9 | (31) Negative side effects of the object | 22 | 35 | 31 | 39 | 17 | 2 | 40 | 1 | 35 | 40 | 27 | 39 | |
| 10 | (32) Ease of manufacture | 27 | 28 | 1 | 36 | 29 | 1 | 40 | | 35 | 39 | | | |
| 11 | (33) Ease of use | 35 | 3 | 2 | 24 | 15 | 13 | 30 | 12 | 32 | 35 | 30 | | |
| 12 | | | | | | | | | | | | | | |
| 13 | Innovation principles (IPs) | | | | | | | | | | | | | |
| 14 | 1. Segmentation | 3 | | | | 5 | | | | 2 | | | | 10 |
| 15 | 2. Separation | 1 | | | | 1 | | | | 1 | | | | 3 |
| 16 | 3. Local quality | 2 | | | | 0 | | | | 0 | | | | 2 |
| 17 | 4. Asymmetry | 1 | | | | 2 | | | | 1 | | | | 4 |

Fig. 3. Inventive principle identification and prioritization matrix (IPIP matrix)

*Step 3: Key word selection and search code creation*

In this part of the process, the authors have created a huge variety of suitable search codes for a further testing session on the patent database DPMA. The task has been performed by using key words related to the previously determined relevant inventive principles as suggested by Mann [7] as well as an open-source word density analysis tool [16] in order to discover the five most frequently used terms in the patent text. In this case the most frequently used terms were: “Schichtanordnung”, “Schichten”, “Schichtmaterial”, “Verfahren” and “Kollagenmaterial”.

*Step 4: Database research (search code testing)*

Subsequent to performing the elaborate testing process with the formerly created search codes, the decision had been made to proceed with analyzing the code, which has contributed to the localization of the hit list with the highest acceptable number of patents.

The following search code supported the identification of the relevant outcome and led to 511 hits: BI=(Schichtanordnung UND Schichten ODER Sichtmaterial ODER Verfahren UND Kollagenmaterial) UND BI=(Eigenschaft? UND Druck? ODER Temperatur? UND Dichte?) UND BI= (segmentieren ODER zerlegen ODER teilen) UND BI= (Verbund? ODER Verbindung?). The standardized search code is: S6.7 (1001)-101-00-0.

*Step 5: Semi-automated patent list analysis*

After downloading and inserting the relevant hit list into the semi-automated patent list analysis tool - starting from line 520 in the Excel file - the most prominent IPC sectors (also IPC main classes or industries) were immediately revealed to be B, G and H. Furthermore, some other smaller potentially relevant patent clusters were localized in sectors A and C. The bar chart in Figure 4 shows the search results of the case study “biocompatible material”.

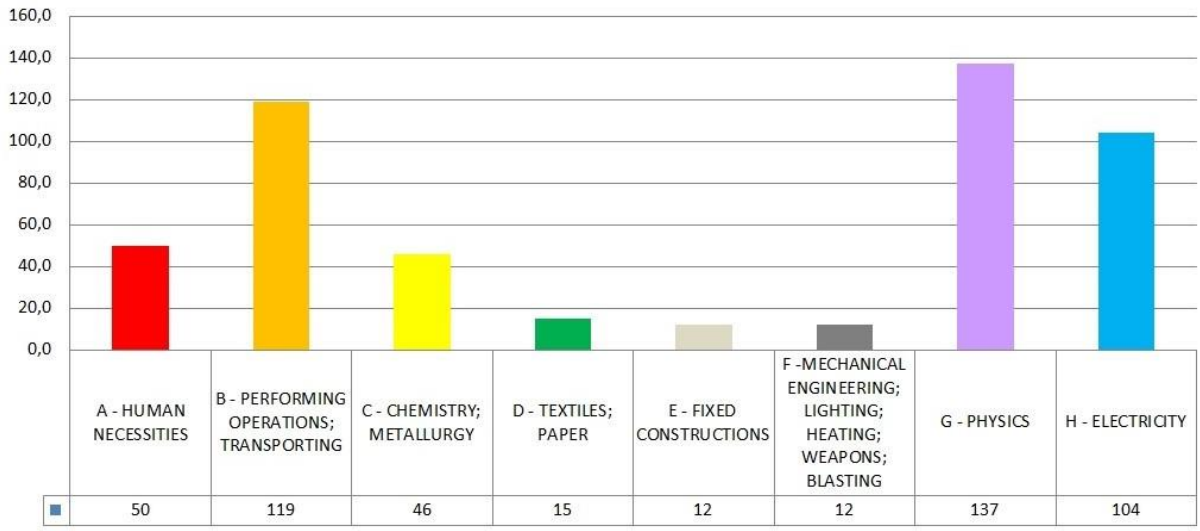


Fig. 4. Semi-automated analysis tool – hit list results from search code S6.7 (1001)-101-00-0

*Step 6: Manual patent list analysis (3 stages)*

In the fifth patent analysis step of the procedure, the most relevant IPC main classes were revealed by using the incorporated count function of the semi-automated analysis in Excel.

The current sixth step included a manual analysis in three stages focusing on the sectors A, B, C, E, G and H, which contained the most patent clusters (with more than five patents of one IPC class) in the selected hit list. The in-depth analysis revealed the largest patent clusters in the semiconductor industry (IPC class H01L). Further large patent agglomerations were recognized in the areas of photosensitive materials (G03C), electrography (G03G), layered products (B32B), printing (B41M), implantable filters (A61F), separation (B01D), containers for storage (B65D) and processes or means (H01M).

The relevant patent clusters identified – applying the previously defined color code for the respective sectors – can be seen in Figure 5.

| IPC? | # | |
|---|---|---|
| H01L | 64 | SEMICONDUCTOR DEVICES; ELECTRIC SOLID STATE DEVICES NOT OTHERWISE PROVIDED FOR |
| G03C | 40 | PHOTOSENSITIVE MATERIALS FOR PHOTOGRAPHIC PURPOSES; PHOTOGRAPHIC PROCESSES, e.g. CINE, X-RAY |
| G03G | 33 | ELECTROGRAPHY; ELECTROPHOTOGRAPHY; MAGNETOGRAPHY |
| B32B | 23 | LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB |
| B41M | 19 | PRINTING, DUPLICATING, MARKING, OR COPYING PROCESSES; COLOUR PRINTING |
| A61F | 15 | FILTERS IMPLANTABLE INTO BLOOD VESSELS; PROSTHESES |
| B01D | 13 | SEPARATION (separating solids from solids by wet methods B03B, B03D, by pneumatic jigs or tables B03B) |
| B65D | 12 | CONTAINERS FOR STORAGE OR TRANSPORT OF ARTICLES OR MATERIALS, e.g. BAGS, BARRELS, BOTTLES, BOXES, CANS |
| H01M | 12 | PROCESSES OR MEANS, e.g. BATTERIES, FOR THE DIRECT CONVERSION OF CHEMICAL ENERGY INTO ELECTRICAL ENERGY |
| A61K | 9 | PREPARATIONS FOR MEDICAL, DENTAL, OR TOILET PURPOSES |
| C08G | 9 | MACROMOLECULAR COMPOUNDS OBTAINED OTHER THAN BY REACTIONS ONLY INVOLVING CARBON-TO-CARBON BONDS |
| A61B | 8 | DIAGNOSIS; SURGERY; IDENTIFICATION (analysing biological material G01N, e.g. G01N 33/48) |
| B42D | 8 | BOOKS; BOOK COVERS; LOOSE LEAVES; PRINTED MATTER CHARACTERISED BY IDENTIFICATION OR SECURITY FEATURES |
| E04B | 8 | GENERAL BUILDING CONSTRUCTIONS; WALLS, e.g. PARTITIONS; ROOFS; FLOORS; CEILINGS; INSULATION |

Fig. 5. IPC class in-depth analysis - results from search code S6.7 (1001)-101-00-0

*Step 7: Discussion of possible cooperation and patent exploitation opportunities*

The team is currently analyzing market entry and expansion opportunities based on the outcomes of the patent analysis. Cooperation options with industry partners in the area of packaging (part of sector B) are in the stage of negotiation. The future executive steps need to be carefully considered. For the time being, the objective is either to set up a licensing plan i.e. aim for a cooperative business contract or to actively support a successful spin-off based on the protected technology.

### 4.3 Results and Findings

The case study performed using the new TRIZ Reverse method for systematic invention, as well as knowledge and technology transfer, has revealed a multitude of unexpected alternative areas of potential business ventures. Most of all the researchers were surprised by the occurrence of huge patent clusters – hence development opportunities - in the industries of semiconductors (H01L), construction (E04B) and container/storage/transport (B65D). Even though the identified results are promising, the authors' opinion is that there is still work ahead of the team until first tangible evidence can be provided in terms of successful product development and large-scale entry of at least one desired target market. When it comes to the process itself, the group has achieved a remarkable increase in the degree of automatization of the analysis procedure of relevant patent texts. Nevertheless, the research team aims to further increase the efficiency, data recognition and handling accuracy of the tools utilized.

Given the recent results and findings of the patent analysis performed, the research group has made the decision to actively pursue diverse options of accelerating the process of product development and market entry. Meanwhile, a very important cooperation partner has been found as a promoter for the validation funding for the exploitation of the currently selected patent. The team is looking forward to working together with this industry partner and to contributing to a successful transfer of knowledge and technology. Additionally, public funding by the Federal State of Saxony was granted to accelerate the transfer of project results.

## 5 Conclusions

The authors have recognized that the newly developed TRIZ Reverse method offers a lot of possibilities to facilitate the knowledge and technology transfer process. However, a variety of improvement suggestions are proposed by the researchers.

First of all, the technical parameter identification process in the second step could be accelerated by the incorporation of comprehensive text analysis software, programmed to target specific terms. Secondly, the function of the IPIP matrix needs to be further automatized in terms of gathering the inventive principle data immediately from an online or offline source. Thirdly, this tool could be further developed to generate the connected key words necessary for the subsequent search code generation. Moreover, the search code template used could be analyzed with the help of empirical research with the aim to identify if there are logic gate combinations, which are generally applicable for finding fitting patent hit lists.

Furthermore, the authors' overall future aim is to contribute to the establishment of a wide user base for this newly developed methodology. A semi-automated patent list analysis – actually performed by Excel – could be potentially evolved to a state of full-automation. In order for this to gradually happen, the team is currently discussing diverse options for the holistic improvement of the methodology and its toolkit – in particular the enhancement of the user friendliness of all elements incorporated in a professional software tool.

Reflecting on how these improvements could be implemented, the cooperation with programming experts in the field of artificial intelligence (AI) at the HTW Dresden, or at other partner universities and/or organizations, has been identified as a viable option. The jointly developed method and its tools would enable the increase of not only the speed of text analysis, but also (potentially) enable an accurate data harvesting process. This in turn would facilitate the interpretation of the results generated.

## References


1. WIPO, "World Intellectual Property Indicators 2020," 2020. [Online]. Available: https://www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2020.pdf.
2. B. Klein, TRIZ/TIPS - Methodik des erfinderischen Problemlösens (3. Auf.), Berlin, München, Boston: De Gruyter Oldenbourg, 2014.
3. K. Lange, "Patent-Problem In Deutschland erdacht - im Ausland gemacht," 9 April 2007. [Online]. Available: https://www.spiegel.de/wirtschaft/patent-problem-in-deutschland-erdacht-im-ausland-gemacht-a-475407.html.
4. G. Streckfuß, S. Günther and A. Töpfer, "QFD, DOE und TRIZ als wirkungsvolle Methoden-Kombination Rahmen von Design for Six Sigma," in Lean Six Sigma: Wirkungsvolle Kombination von Lean Management, Six Sigma, und Design for Six Sigma, 2008, pp. 159-204.
5. M. G. Moehrle, "What is TRIZ? From Conceptual Basics to a Framework for Research, in: Creativity and Innovation Management 14(1)," February 2005. [Online]. Available: https://www.researchgate.net/publication/228254493_What_is_TRIZ_From_Conceptual_Basics_to_a_Framework_for_Research.
6. M. Glaser and B. Miecznik, "TRIZ for Reverse Inventing in Market Research: A Case Study from WITTENSTEIN AG, Identifying New Areas of Application of a Core Technology," 2009. [Online]. Available: https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1467-8691.2009.00516.x.
7. D. Mann, "Systematic Innovation e-zine, Issue 55," October 2006. [Online]. Available: http://systematic-innovation.com/assets/iss-56-nov-06.pdf.
8. WIPO, "International Patent Classification (IPC)," [Online]. Available: https://www.wipo.int/classifications/ipc/en/. [Accessed 01 04 2021].
9. "International Patent Classification," [Online]. Available: https://en.wikipedia.org/wiki/International_Patent_Classification. [Accessed 01 04 2021].
10. A. Ngassa, R. Brachelet and P. Truchot, "How to turn an invention into an innovation? An approach based on a reverse use of Triz," 13-15 May 2003. [Online]. Available: http://www.guillaumegronier.com/cv_documents/_CDRom_CONFERE/communications/35.Ngassa.pdf.
11. M. Bianchi, S. Campodall'Orto, F. Frattini and P. Vercesi, "Enabling Open Innovation in Small- and Medium-Sized Enterprises: How to Find Alternative Applications for Your Technologies," September 2010. [Online]. Available: https://www.researchgate.net/publication/227833408_Enabling_Open_Innovation_in_Small-_and_Medium-Sized_Enterprises_How_to_Find_Alternative_Applications_for_Your_Technologies.
12. J. Harlim and I. Belski, "On the effectiveness of TRIZ tools for problem finding," December 2015. [Online]. Available: https://www.researchgate.net/publication/289130883_On_the_Effectiveness_of_TRIZ_Tools_for_Problem_Finding.

13. A. Pechmann, M. Schoof and K. Tampe-Mai, "PIFURRA – Pull Information From Unknown/ Unfamiliar Research Results Automatically, pp. 189-203," in Praxishandbuch Technologietransfer, Düsseldorf , 2013.
14. S. Günther, "Erfinderisches Problemlösen und seine Umkehrung," WISU - Das Wirtschaftsstudium, pp. 308-315,348, March 2019.
15. K. Harre, T. Pietsch, D. Firzlaff and E. Tobiasch.Deutschland/Sachsen Patent DE 10 2017 123 891 B4, 2019.
16. Gillmeister Software, "WORTHÄUFIGKEIT ZÄHLEN Keyworddichte eines Textes ermitteln," 2021. [Online]. Available: https://www.gillmeister-software.de/online-tools/text/keywortdichte-berechnen-fuer-seo.aspx.

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# TRIZ REVERSE: A SYSTEMATIC REVIEW AND COMPARISON WITH EXISTING KNOWLEDGE AND TECHNOLOGY TRANSFER TOOLS

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## Abstract

The reverse version of TRIZ known as TRIZ Reverse is used in technology and knowledge transfer processes to identify appropriate industries and market segments for deploying new technology. This paper aims to make a comparison of TRIZ Reverse with other tools in technology and knowledge transfer through basic qualitative comparison criteria and a clustering model, with which all tools were contrasted, resulting in a classification according to their similarities and divergences. The output offers a rich understanding of the nature and application of TRIZ Reverse and the other instruments, taking into account the purpose, requirements and conditions of the specific transfer process.

Keywords: *TRIZ, TRIZ Reverse, Technology Transfer, Technology Transfer Tools.*

## 1 Introduction

Several disciplines have included the use of the TRIZ Reverse technique in the assessment of new products and their feasibility of implementation. For instance, Ngassa et al. [1] obtained relevant information related to diverse applications for a shape memory alloy developed in a French research laboratory. Glaser and Miecznik [2] evaluated a company's flagship product running market research on a cost-effectiveness basis, where the favourable results led to the identification of specific market segments for the product.

In turn, Brokmöller, et al. [3] implemented TRIZ Reverse to evaluate the feasibility of manufacturing components using tailored forming technologies. They found the specific contradiction-duet to discover a variety of uses for tailored forms as well as which features of the regularly used components had to be modified. Furthermore, Kloock-Schreiber et al. [4] visualized

the areas in which Product Service Systems could be utilized, managing to identify the Inventive Principles (IP) contained in the technology and discovering the contradictions it solves.

It would be necessary to have a larger variety of tools besides TRIZ Reverse to replace it as the operator of the transfer if necessary, or to fill the gaps it may have in achieving a successful Technology Transfer Process (TTP). Therefore, it is imperative to find other tools that enable the dissemination of technology and compare them with TRIZ, in order to discover the existing alternatives and obtain accurate information about their specific attributes. These necessities became the source of research for this study.

## 2 Literature Review

### 2.1 Searching Approach and Methodology

A qualitative analysis was taken as reference, based on the descriptive-comparative method. The descriptive method aims to provide information regarding the characteristics of an entity or phenomenon. This description can be either quantitative or qualitative [5].

The research process was carried out in the following stages:

1) Information collection: scientific documents were collected from both electronic and physical resources. The digital resources were extracted from the academic information bases Emerald, Jstor, Oxford journals, Proquest, Researchgate, Sage books, Sage journals, Sage premier, Science direct, Scielo, Springer palgrave books, Springer link journals, Taylor and Francis journals, Wiley online library and from websites specialized in the subject under study, using keywords and key phrases such as Knowledge Transfer, Technology Transfer (TT), Technology Transfer Methods, Technology Transfer Tools, Technology Transfer Instruments, among others.
2) Selection of the documentary material, obtained through the reading of abstracts and conclusions to define their relevance to fulfil the research purpose.
3) Literature analysis and design of the conceptual framework for the study.
4) Construction of the research approach and methodology for information analysis.
5) Definition of variables and criteria, supported in the general characteristics found for each TT tool in the literature review.
6) Analysis of the information using a systematic comparison methodology by means of a contrast matrix, taking the variables and criteria in point 5) as the elements to be compared.
7) An additional cluster analysis using statistical software was performed to have another practical-comparative perspective with the aim of finding a classification of tools according to their features.

According to the scientific literature included in the analysis, the overlapping of terms such as method, instrument, tool, approach and channel was noticeable. To carry out the comparison exercise, ‘Tools’ were considered as complex elements that operationalize the Technology Transfer (TT) by their execution, i. e. these elements that trigger the process linking technology resources to business objectives [6].

### 2.2 Technology Transfer Tools: Overview

The literature review revealed elements with the characteristics of the definition of 'tool' mentioned above. From a chronological perspective the elements selected to compare with the corresponding author are shown in Figure 1.

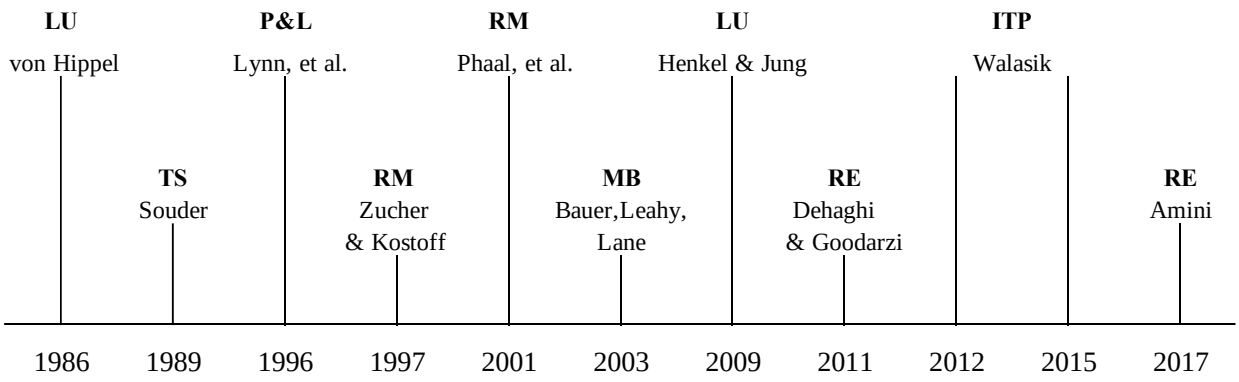


Fig. 1. Tools included in the study – Chronological perspective

1) *Lead User* (LU) is built on the assumption that there is a defined industry or sector where related lead users can be identified. They are invited to co-create product concepts based on their needs [7]. LU embraces four major activities: identifying the trend, identifying lead users, analysing lead user data and projecting lead user data into the general market of interest [8]. An alternative version of the LU is the Technology-Push User Concept (T-PLUC) outlined by Henkel and Jung [7], in which the difference is that T-PLUC starts with a given technology instead of a market trend.
2) *Total System* (TS) seeks to increase technology-push success rates by removing the main transfer barriers through the active involvement of the inventor along with the technical and commercial team. The inclusion of the technology creator promotes interdisciplinary interaction and turns unfamiliar technology into familiar technology. In doing so, basic and complex usages as well as different potential markets can be identified. It recognizes that some combination with pull strategies strengthens the method, e.g., prototype tests with consumers or free demonstrations [9].
3) *Probe & Learn Method* (P&L) is based on the idea that there is a product embodying a new technology and that there is one or more markets to serve with its application. This is a technique in which the inventor tests early versions of the product in its potential markets with a cyclical learning and testing process consisting of three general stages: probing, learning and iteration. In each stage, the technology is shaped and improved according to the acquired information [10].
4) *Roadmaps* (RM) are utilized in TTP for handling a large amount of information required to find a path for implementing innovation. Being a Graphical Modelling System (GMS), RM graphically portrays relationships between R&D and potential applications. With the use of this tool, researchers can see the big picture of the context and find new functions and uses, having a complete mapping of resources and information flow. Since this relationship can be made through several pathways, a roadmap also functions as a tool for decision-making to find the best alternative [6], [11].
5) *Market Brokering* (MB) has been widely explored by federal laboratories and other research and promotion centres of innovation. It begins with the existence of advanced technology or advanced stage prototype that seeks an application in the market under the assumption that this novelty will add value to existing product lines in the marketplace [12]. Even though many technological developments meet specific needs with new features and functions, the manufacturers often do not have detailed market information (e.g., market size, market segmentation and penetration, etc.) or do not know how to obtain it [13]. This tool removes these marketing barriers by capturing the technology target through a flow of key information that enables a well-informed licensing decision [14].

6) *Reverse Engineering* (RE) has been considered a useful mechanism in the TTP mainly in developing countries to access the technical knowledge comprised in machines or any advanced technology in its final development stage. The technical information is extracted by breaking down the product into its parts, for example, if the information about its planning and design is not available. With this knowledge, it will be possible to use the technology, maintain it, copy it or build a new one with similar characteristics and new specifications [15], [16].
7) *Information Technology Platforms* (ITP) serves as a tool for marketing activities execution at research organizations that seek to strengthen relations between the R&D sector and companies, allowing for optimal implementation of research results [17]. The functional activities supported by the technology transfer platforms are: disseminating scientific research results, horizontal activities (promotion, promotional products preparation supervision, product distribution), marketing activities, support in the process of International TT, brokering, building consortia, carrying out related projects, managing electronic tools supporting cooperation and evaluate innovative products [18].

# 3 TRIZ Reverse

## 3.1 Philosophy and Approach

TRIZ Reverse is based on the idea "solution seeks problem". Therefore, new potential problem areas are to be identified to deploy the innovation, starting from a complete understanding of the technical solution. Current research outputs show that this is possible and that the principles that allow the exploitation can be extracted from the use and/or sale of patents [19]. In 2020, the exploitation of patents in commercial terms was 36% in the European Union and only 10% of these were deemed insufficient for commercialization [20]. The figures suggest the great opportunity to convert knowledge into marketable technology that contributes to the progress and economic growth.

The scientific foundation of TRIZ Reverse is rooted in the concept ‘reverse inventing’, which refers to the process through which the strengths of a company or research agent are initially tracked and found and transferred to an abstract form. Finally, the market is analysed by seeking the possible beneficiaries of the offer [2]. TRIZ Reverse requires a reduced solution that reveals the IPs and contradictions that relate to the technology; however, hundreds of concepts can be found [1], [4]. To solve this problem Mann [21] created a search word catalogue for patent database analysis. There are several suggestions for the application of TRIZ Reverse. Depending on the aim of the investigation, the algorithms comprise 4 to 8 steps to find suitable new areas of application [2], [22].

## 3.2 Six-step Procedure

The procedure for finding potential users of the intellectual property contained in the patents is implicit in the study carried out by Glaser and Miecznik [2], in which TRIZ Reverse was employed to find market opportunities for the core capabilities of a specific company. The process stages followed by the authors were:

1) Analysis and target setting.
2) Back-tracing of product strengths to IP.
3) Translation/abstraction of IPs into typical search phrases for patent databases.
4) Database analysis of selected search phrases.
5) Analysis of search results matching market opportunities.
6) Business planning and action deployment.

The scholars stated that it is essential to establish the core competences of the company, commonly reflected in successful products or the results of competitive analyses. With the aid of this clear information, it is possible to identify the research targets that will enable the technology to become a significant player in a previously unattended market. In the next stage, a back-tracing of technology core-features to IPs takes place. The author proposes the use of 'product DNA theory' to find the key elements that lead an IP to be found; nevertheless, other abstraction methods can be employed.

Once found, IPs can be translated into common search phrases to perform a database search (intellectual property databases). A number between fifty and five hundred hits per query is considered optimal, taking into account up to the third hierarchical level of the international patent classification code (IPC) for each case. The set of patents found constitutes the field of exploration to find market opportunities. After refinement utilizing conventional strategic business management tools, the business plan and strategy are developed and implemented [2].

# 4 Comparison Tools

## 4.1 Criteria-based Evaluation

Conceptual macro-areas or dimensions were defined to characterize the tools. Some of them were established by Weijo [23] as the influencing factors for choosing a TT strategy. However, customized dimensions inherent to the object of research were constructed by extracting, analysing and grouping key information from the literature. These are the dimensions considered for the comparison:

- *Dimension 1 – Purpose:* refers to the core aim of the tool. It answers the questions: What is the purpose of the tool? What need does the tool fulfil?
- *Dimension 2 – Market approach character:* corresponds to the market-approach style and answers the question: Does the tool actively seek out market opportunities? Therefore, the possible values are, *passive* if the tool makes information accessible to individuals looking for technological solutions, or *active* if it promotes technology in the market [23].
- *Dimension 3 – Stage of research and development:* refers to the development point needed to initiate the TT, which answers the question: At which stages of development is it possible to use the tool? The possible values are *early* if premature stages of technology before prototyping are necessary, *middle* if a prototype is needed, *late* if a consolidated technology is required as input and, *any* if the tool does not require a specific stage of development.
- *Dimension 4 – Structure of the distribution channel:* related to the driver with which the tool operates and answers the question: Is the tool market-driven or technology-driven? Therefore, the values are *pull* if it works from an identified need in the marketplace toward the necessary technology to solve it, *push* if it works from an innovative technology toward the identification of a need and marketplace, or *mixed* if it has pull and push mixed characteristics
- *Dimension 5 – Process shape:* deals with the process type identified in the tool implementation and answers the question: Does the application of the tool fulfil its purpose with a single-use or are more cycles required? In this case, the values are *linear* if only one usage is required to achieve the goal, *cyclic* if more than one use is needed, and *mixed* if the process has both linear and cyclic characteristics.

- *Dimension 6 – Market focus:* related to the market-targeting goal and answers the question: Does the tool focus on a specific market? For this dimension, the values are: *focused* if the tool is directed towards a specific market, or *diverse* if multiple markets are the target.
- *Dimension 7 – Agents' interaction:* refers to the participation of own agents or third parties in the application and answers the question: Does the tool require (or makes necessary) the intervention of several actors in its implementation? The possible values are, *interactive* if it includes a variety of agents, or *unilateral* if it includes just a few or no agents.
- *Dimension 8 – Focus on communication:* related to the existence of formal ways and channels of communication, which answers the questions: Does the tool require (or makes necessary) two-way information transfer? Does it promote a formal means of making communication constant? Therefore, the values are: *formal* if the tool requires or promotes formal ways and communication channels, *informal* if formal ways and communication channels are absent and, *mixed* if formal and informal ways of communication are present.
- *Dimension 9 – Knowledge requirements:* refers to the technical skills required for the tool operation and answers the question: Is specialized knowledge required to apply the tool? The values are *specific knowledge* if specialized skills are required in the performing and *intuitive* if just common or intrinsic knowledge is necessary to use the tool.
- *Dimension 10 – Optimization of resources orientation:* corresponds to how the resource-use is addressed and answers the questions: Does the tool take into account the appropriate use of resources? Is it based on cost reduction? Therefore, the values are *resources optimizer* if the tool is efficiency-oriented and *resource dispenser* if not.

For an accurate visualization of results, a comparison matrix was constructed. The columns represent the tools and the rows represent the dimensions. Their intersection takes a particular value according to the definitions of each dimension. The similarities with TRIZ Reverse are highlighted in green and the differences remain unmarked (Figure 2). For the dimension 'purpose', although there are specificities according to each tool, since all of them seek industries, market segments and users for technologies, a total complete similarity is assumed.

| No. | Tool / Dimension | TRIZ-R | LU | TS | P&L | RM | MB | RE | ITP |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Purpose | | | | | | | | |
| 2 | Market approach character | Active | Active | Active | Active | Active | Active | Passive | Passive |
| 3 | Stage of research and development | Late | Any | Middle | Middle | Any | Middle | Late | Any |
| 4 | Structure of the distribution channel | Push | Pull | Mixed | Push | Mixed | Mixed | Push | Mixed |
| 5 | Process shape | Mixed | Linear | Cyclic | Cyclic | Linear | Cyclic | Linear | Cyclic |
| 6 | Market focus | Diverse | Focused | Diverse | Diverse | Diverse | Focused | Diverse | Diverse |
| 7 | Agents interaction | Unilateral | Interactive | Interactive | Interactive | Interactive | Interactive | Interactive | Interactive |
| 8 | Focus on communication | Informal | Formal | Formal | Informal | Mixed | Formal | Formal | Formal |
| 9 | Knowledge requirements | Specific knowledge | Intuitive | Intuitive | Specific knowledge | Specific knowledge | Specific knowledge | Specific knowledge | Intuitive |
| 10 | Optimization of resources orientation | Resources optimizer | Resources optimizer | Resources optimizer | Resource dispenser | Resources optimizer | Resources optimizer | Resource dispenser | Resources optimizer |

Fig. 2. Comparison Matrix (Contrast)

By performing a comparative-absolute analysis4 (solid colour) is obtained that the most similar tool to TRIZ Reverse is P&L with 6/10 coincidences, while the most different are ITP and LU with only 3/10 equal values each. The absolute qualitative comparison scenario concerning TRIZ Reverse from greatest to least similarity is as follows: P&L (6/10 – 60%) → RM and RE (5/10 – 50%) → MB and TS (4/10 – 40%) → ITP and LU (3/10 – 30%). However, in the comparative-relative analysis5 (gradient colour) the scenario changes; RM is the most similar tool with 9/10 coincidences and LU is the one with the greatest difference with only 5/10 similarities. The relative qualitative comparison scenario with TRIZ Reverse from greatest to least similarity is as follows: RM (9/10 – 90%) → P&L (7/10 – 70%) → MB, ITP, TS and RE (6/10 – 60%) → LU (5/10 – 50%).

Performing the same contrasting exercise taking dimensions as the subjects to contrast, the comparative-absolute analysis shows that besides ‘purpose', 'market approach character', 'market focus' and 'optimization of resources-orientation' are the most homogeneous among the

[4] The Comparative-absolute analysis refers to strict compliance with the value of the dimension, i.e., the value of tool x is considered to be absolute-equal to the value of TRIZ Reverse because they are exactly the same. To claim that a tool is equal in the 'market approach character' dimension to TRIZ Reverse it is necessary that both have the 'active' value. This rule also applies in the dimensional analysis.

[5] The Comparative-relative analysis takes into account the fact that for some dimensions the observed case can take several values. In this case, the similarity is assumed if a tool reflects all the values and TRIZ Reverse only one of them or vice versa. For example, for the 'stage of research and development' dimension, a case is considered similar to TRIZ Reverse if it takes the value ‘late’ or 'any', as it includes the value 'late' shown by TRIZ Reverse. This rule also applies in the analysis of dimensions.

cases, since the value assumed by TRIZ Reverse in these dimensions is shared by 5/7 tools. 'Process shape' and 'agents interaction' are totally heterogeneous with TRIZ Reverse, since none of the cases share the same value.

The absolute comparative analysis by dimensions from greatest to least similarity is: 'market approach character', 'market focus' and 'optimization of resources-orientation' (5/7 cases – 71,4%) → 'knowledge requirements' (4/7 cases – 57,1%) → 'structure of the distribution channel' (2/7 cases – 28,6%) → 'stage of research and development' and 'focus on communication' (1/7 cases – 14,3%) → 'process shape' and 'agents interaction' (zero cases).

On the other hand, the dimensional comparative-relative analysis shows a different performance; 'process shape' is the fully homogeneous dimension with 7/7 coincidences, while 'agents interaction' continues as the only dimension with zero-similarity; the result of the relative dimensional analysis, from more to less similarity, is: 'process shape' (7/7 – 100%) → 'structure of the distribution channel' (6/7 – 85,7%) → 'market approach character', 'market focus' and 'optimization of resources-orientation' (5/7 – 71.4%) → 'stage of research and development' and 'knowledge requirements' (4/7 – 57,1%) → 'focus on communication' (2/7 – 28,6%) → 'agents interaction' (zero cases).

## 4.2 Statistical-based Evaluation

As previously mentioned, a clustering analysis was conducted using SPSS. Although the number of cases and attributes is small, the quality of the model is 'fair' obtaining two defined clusters. This means that the outcome is representative and suitable to continue with the analysis. According to the internal analysis carried out by SPSS, the first cluster contains three cases, TRIZ Reverse, P&L as well as RE and the second cluster contains the remaining five cases, MB, ITP, RM, LU and TS. SPSS takes as a basis the variable or 'predictor' that differentiates the most among all cases to perform the comparison. For this specific study, SPSS ranked 'structure of the distribution channel' as the most important variable to classify each case. Figure 3 shows the order of how the other dimensions were included as criteria for separation, i.e., the ranking of similarity related to dimensions according to the clustering-model, where 'structure of the distribution channel' is most heterogeneous within the cases.

According to the output data the following two clusters can be assumed:

- The first cluster contains the tools TRIZ Reverse, P&L and RE. Based on their characteristics, they can be summarized as 'diverse-market and push-oriented advanced tools'. Their use can be considered as effective if push market orientation and focus on various market opportunities in various segments, industries and users are required. However, it must be taken into account that specialized knowledge is essential for their successful implementation. These tools are not appropriate for promoting technology in the early stages of development and their specific use should be reviewed if a cost reduction objective is aimed.

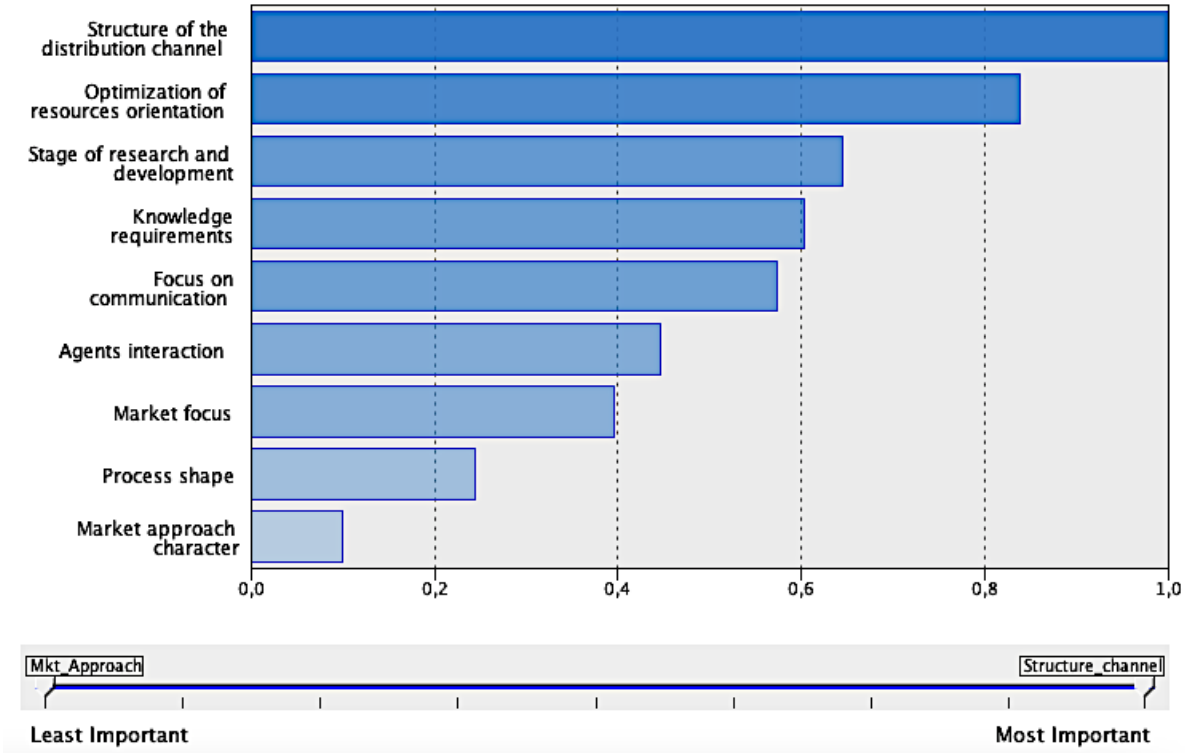


Fig. 3. Predictor importance ranking for clustering analysis

- The second cluster contains the remaining tools MB, ITP, RM, LU and TS. They can be summarized as 'collaborative-active push and pull driven tools'. The use of these tools is assumed to be effective in an active, push-and-pull oriented TT with a complete orientation towards optimizing costs, including permanent interaction between agents through formal communication channels, which is the aim at any stage of technology development.

## 5 Conclusions

Both the systematic analysis carried out through dimensional comparison and the clustering carried out in SPSS show the existence of similar and dissimilar tools concerning TRIZ Reverse, but neither can be found to have identical characteristics. These two analyses show that the starting point in their process determines the result in terms of differences and similarities:

1) The systematic-comparison analysis based on the 1-to-1 contrast of each dimension between TRIZ Reverse and the other TT tools, results in a similarity ranking that despite having a defined frame of reference has no analysis context beyond simple contrast. The results obtained with this method are also useful to establish what elements differentiate the subject-reference (TRIZ Reverse) from other tools and how this relationship of semblance or distinction is expressed.
2) With the cluster-based analysis it is possible to obtain dissimilar groups. Although this method is also based on dimensional-contrast, the comparison is carried out among all the TT tools, taking as a guiding principle the most heterogeneous dimension to establish the relationship between them. Since each dimension has specific importance in the differentiation and that all cases are compared between them iteratively, the outcome scenario probably minimizes the bias of the systematic comparison obtained from the contrast matrix.

Considering the above information, it is feasible to infer that although the differences between the findings in the results from the two types of analysis are evident, it is not possible to affirm

that they are mutually exclusive, since their method of differentiation is distinctive. Hence, both provide valuable information regarding the characteristics and use of TRIZ Reverse and the other TT tools. This data can serve as key information for decision-making regarding the use of one or another TT tool according to the objective and specific conditions in a particular TTP.

Through the methodology used and the instruments employed to carry out the analysis, it was possible to make such contrast, reaching relevant findings from a theoretical and practical point of view. In the theoretical field, the methodological structure implemented can serve as a conceptual reference framework for the characterization and assessment for a TT tool, since a relevant number of dimensions were defined to collect relevant data from all the cases included in the study, which can be used in other research activities.

When it comes to the practical relevance, the results obtained suggest a selective implementation of TRIZ Reverse or one of the other tools according to the specific conditions and requirements in a TTP contained in the dimensions designed as part of this study, for example, the state of development of the technology to be transferred, the use of resources in the TTP, required knowledge to perform the process, among other considerations.

## References


1. Ngassa, A., Bachelet, R. & Truchot, P., 2003. How to Turn an Invention into an Innovation? An Approach Based on a Reverse Use of Triz. Nancy, France, s.n., pp. 265-272.
2. Glaser, M. & Miecznik, B., 2009. TRIZ for Reverse Inventing in Market Research: A Case Study from WITTENSTEIN AG, Identifying New Areas of Application of a Core Technology. Creativity and Innovation Management, 18(2), pp. 90-100.
3. Brockmöller, T., Mozgova, I. & Lachmayer, R., 2017. An Approach to Analyze the potential of Tailored Forming by TRIZ Reverse. Vancouver, Canada, s.n., pp. 445-452.
4. Kloock-Schreiber, D. et al., 2020. TRIZ-reverse for PSS Potential Determination. Novi Sad, Serbia, s.n.
5. Sekaran, U., 2003. Research Methods for Business. New York: John Wiley & Sons, Inc.
6. Phaal, R., Farrukh, C. & Probert, D., 2001. Technology Roadmapping: Linking Technology Resources to Business Objectives. Centre for Technology Management, University of Cambridge.
7. Henkel, J. & Jung, S., 2009. The Technology-Push Lead User Concept: A New Tool for Application Identification. [Online] Available at: https://www.researchgate.net/publication/228820209_The_Technology_Push_Lead_User_Concept_A_New_Tool_for_Application_Identification [Accessed 21 December 2020].
8. von Hippel, E., 1986. Lead Users: An Important Source of Novel Product Concepts. Management Science, 32(7), pp. 791-805.
9. Souder, W. E., 1989. Improving Productivity Through Technology Push. Research Technology Management, 32(2), pp. 19-24.
10. Lynn, G., Morone, J. & Paulson, A., 1996. Marketing and Discontinuous Innovation: The Probe and Learn Process. California Management Review, 38(3), pp. 8-37.
11. Zucher, R. & Kostoff, R. N., 1997. Modelling Technology Roadmaps. Journal of Technology Transfer, 22(3), pp. 73-80.
12. Lane, J. P., 2003. The State of the Science in Technology Transfer: Implications for the Field of Assistive Technology. Journal of Technology Transfer, Volume 28, pp. 333-354.

13. Bauer, S. M., 2003. Demand Pull Technology Transfer Applied to the Field of Assistive Technology. The Journal of Technology Transfer, Volume 28, pp. 285-303.
14. Leahy, J. A., 2003. Paths to Market for Supply Push Technology Transfer. The Journal of Technology Transfer, Volume 28, pp. 305-317.
15. Dehaghi, M. R. & Goodarzi, M., 2011. Reverse Engineering: A Way of Technology Transfer in Developing Countries like Iran. International Journal of e-Education, e-Business, e-Management and e-Learning, 1(5), pp. 347-353.
16. Amini, G. H. R., 2017. Process of Technology Transfer and Reverse Engineering. International Journal of Engineering Trends and Technology (IJETT), 45(2), pp. 76-79.
17. Walasik, M., 2012. Model Technology Platform for Cooperation of Research Centres with the Business Sector. Marketing of Scientific and Research Organization. Institute for Sustainable Technologies – National Research Institute in Radom, 6(227), pp. 55-66.
18. Walasik, M., 2015. Role of a Technology Transfer Platform in Commercialization of Research Results. Marketing of Scientific and Research Organizations, 17(3), pp. 103-119.
19. S. Günther, "Erfinderisches Problemlösen und seine Umkehrung," WISU - Das Wirtschaftsstudium, pp. 308-315,348, March 2019.
20. European Patent Office, 2020. Valorisation of Scientific Results. Patent Commercialisation Scoreboard: European Universities and Public Research Organisations. [Online] Available at: http://documents.epo.org/projects/babylon/eponet.nsf/0/f90b78b96b1043b5c1258626006cce35/$FILE/Valorisation_of_scientific_results_en.pdf [Accessed 12 December 2020].
21. D. Mann, "Systematic Innovation e-zine, Issue 55," October 2006. [Online]. Available: http://systematic-innovation.com/assets/iss-56-nov-06.pdf.
22. Harlim, J. & Belski, I., 2015. On the Effectiveness of TRIZ Tools for Problem Finding. World Conference: TRIZ FUTURE, TF 2011-2014. Procedia Engineering, Volume 131, pp. 892-898.
23. Weijo, R. O., 1987. Strategies for Promoting Technology Transfer to the Private Sector. The Journal of Technology Transfer, Volume 11, pp. 43-65.

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# What TRIZ tools where used in the pre-TRIZ age? - a study of an aircraft engineering project

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**Paper Classification:**

Case study

## Abstract

Altshuller started his studies on TRIZ in 1946 but the term TRIZ itself was mentioned in 1970 for the first time. Today many engineers in the world use the TRIZ method for their work and especially for problem solving. But what did engineers do in the pre-TRIZ age? Did they use TRIZ tools and maybe even other techniques not incorporated in TRIZ? We will study this on the example of the construction process of the flying boat *BV-222*. Although this development dates to the 30s of the last century, techniques corresponding to *inventive principles* and problem statements with antagonistic aspects were used in addition to searching and solving the key problem. Furthermore, other modern engineering techniques similar to *Failure Mode and Effects Analysis (FMEA)* or *Design For Manufacturing and Assembly (DFMA)* appear to be used at least implicitly.

Keywords: pre-TRIZ age, inventive principles, flying boat

## 1 Introduction

Altshuller performed his first studies related to TRIZ in 1946 to 1949. After a break he published together R.Shapiro's the article "About Technical Creativity" in 1956.[1] These studies were intensified over the following years based on the analysis of patents leading to the todays known *ARIZ* methodology, the *40 inventive principles*, the concept of *engineering contradictions (EC)* and *physical contradiction (PC), function oriented search (FOS)* and further TRIZ tools and methods. Today these TRIZ tools are helping engineers all over the world to analyse and solve problems during construction and development of machines or related products.[2,3,4] Worth to mention, one recommendation within the *FOS* is to look for related systems in technological frontrunner fields like aircraft-technologies.[2] But, how did engineers work in the

pre-TRIZ age? Especially when developing such kind of high-technological products like airplanes. Did they use approaches comparable to modern TRIZ methodology? What other modern methods can be anticipated and derived from their way of working?

In general, there are plenty of final construction results of machines, airplanes and related that are preserved until present, but well documented descriptions on the technological problems during constructions and especially on the analysis of the contradicting requirements and the approaches how they were solved are rather scarce. Yet, a review of an invention process from a TRIZ point of view is fuelled by this analysis, thinking and work towards the solution. Furthermore, this work with its focus on novel solutions with proven market values can be seen as an early example for the modern TRIZ approach.[5]

The development reports from Richard Vogt for the *Blohm & Voss* BV-222 offer a rare impression of inventive processes in the pre-TRIZ era and the option to study their analytical and inventive approach even after more than 80 years.[6,7] The large-scale airplane BV-222 was developed from 1937 for the intercontinental passenger transport over 7000 km weighing 50 tons, see figure 1. Obviously, the BV-222 was a frontrunner system with multi-aspect requirements requiring solutions for many problems. Besides its high degree of innovation and thus need for inventive work, the BV-222-project also is a rewarding object of study, because Richard Vogt reported the project in a way that does not only include solutions but also comprises the way of solution generation and discussions of alternative solutions enabling a comparison with modern TRIZ methods.

## 2 State-of-the-art at construction time 1937

To even-handedly evaluate a historic invention process, it is vital to be familiar with the technical and application situation in that time. In September 1937 typically the intercontinental passenger travel was conducted by ship, while only postal services were organized with small water-based planes since the 1920s. Large-scale air passenger transport crossing the Atlantic Ocean was possible as well by using airships, but the Hindenburg catastrophe earlier in May 1937 at Lakehurst (NJ) brought that concept to a sudden stop. The abrupt ending of the airship era thus imposed the need for large long-distance planes and parts of the requirements for BV-222 can be understood from the need for replacement for airship travel. Apart from airships the technical situation in 1937 was shaped by three different concepts, land-based planes, planes with floats and flying boats. Aerodynamic aspects are key for all airplanes focusing on the wings, but also the hull and all rudders are very important, for an introduction in aerodynamics see literature.[8,9,10]

Land-based airplanes of the 1930s like Ju52 or DC3 had capacities of 20-30 passengers, partly an aerodynamic hull but still using tail wheel limiting the airplane size and no intercontinental distance capability. Furthermore, the lack of land-based airports around the world diminished the options for intermediate refueling on long-distance flights, whereas water-based planes allowed for landing and refueling on every lake or ocean.[10]

In the 1930s, water-based airplanes of the 8-10 ton class like the Dornier Wal or later the Ha-139 were used successfully for the regular intercontinental post service carrying ca 500 kg of post and optional 1-2 passengers.[11] The Ha-139 is shown in figure 2. First concepts to scale flying boats aiming for intercontinental passenger traffic like the Do-X were tested with limited success, see figure 1. The Do-X concept looks still like a “boat with wings”, underpinning the difficulties in merging the requirements given by the aerodynamic and water-based boundary conditions for safe take-off, landing and swimming on the water including high waves.[12] Thus, the concept for the “boat with wings” enables the required swimming capabilities by placement

of the engines on top of the wing, as far apart from the water line to avoid water plashes and damage to engines. But this was on cost of the aerodynamic properties, air resistance and weight.

The alternative concept are planes with floats, like the Ha-139 in figure 2. The use of floats instead of the flying boat concept like Do-X or Dornier Wal enables a partial separation of the requirements. The aerodynamic aspects with the overall airplane shape can be optimized and water constrains only handled by the floats placed far apart from the airplane. As a consequence the engines are installed in the wings improving the aerodynamic performances and weight.

Due to the good experiences with the *Blohm & Voss* Ha-139 for the intercontinental mail service the *Deutsche Lufthansa* gave *Blohm & Voss* in September 1937 the order for 3 passenger intercontinental airplanes in the 50 ton class for distances of 7000 km. This was a significant increase in distance and size leading to several challenges and problems. At this point the work of the team from Richard Vogt starts with analysis and problem solving as described in his report.[6,7]

The inventive process described here was performed a decade to twenty years before the development of TRIZ. But as parts of the TRIZ methods were developed from analysis of previous invention processes, the development of the BV-222 might potentially be considered an ancestor of a modern TRIZ-driven development process. Thus, this work should review the original report[6,7] of the BV-222 development in light of TRIZ methods or if the BV-222-development was performed by different lines of thinking.

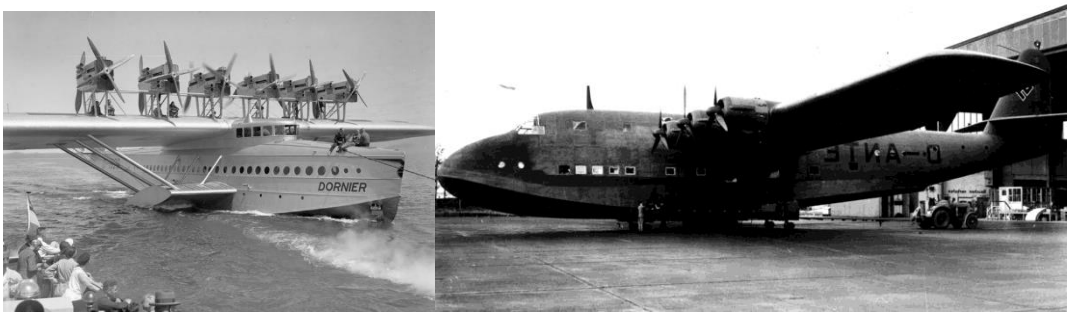


Fig. 1. Flying boat Do-X (lhs)[12] and BV-222 airplane (rhs)[7] on a wheel-based service-wagon. The hull shape of the flying boat Do-X looks almost like a “ship with wings” and the position of the wings and engines is placed far apart. In contrast, the BV-222 looks more like an airplane not a ship

Fig. 2. Sketch of (BV) Ha-139 (lhs), landed on water (middle) and positioned on a catapult on the service ship (rhs)[11]. After start in North-Africa with 500 kg of post typically 1-2 adventure like stops in the Atlantic close by service ships were required with preferred catapult re-start. This was state-of-the-art for intercontinental airplane traffic. This gap in distance and passenger count was addressed by the BV-222

# 3 Analysis & Results

## 3.1 Type of airplane

The first questions to answer is either to use a land-based or water-based airplane. Land-based airplanes have the disadvantage of a lack of airports in general and especially the lack of service points for refueling in the Atlantic or Pacific. This refuelling becomes possible with airplanes that can land on the water, which is technically achieved either by a flying boat or an airplane using floats to swim. Here the report mentions that the customer Lufthansa decided to order the new airplane from *Blohm & Voss*, due to the successful use of their float airplane Ha-139 in the intercontinental post traffic. Surprisingly, Lufthansa defined a flying boat and not a float airplane.[7]

This decision is not further discussed in the historical documents. But we can assume, that this order was done after first discussion between the team from *Blohm & Voss* and *Lufthansa*. Taking a closer look on this decision and anticipating the potential ways of thinking towards this decision using todays TRIZ description for illustration purpose. Float airplanes like the Ha-139 use two floats to swim on the water and to keep water splashes apart from the engines during takeoff and landing, see figure 2. The construction of the plane itself is quite similar to a land-based airplane. The disadvantage of this approach is, that for increasing dimensions and weight of the cargo and airplane, also the dimensions of the floats need to be increased linearly adding further weight. In addition, the floats increase the air resistance, thus limiting velocity and implying increased fuel consumption reducing the maximum distance. For illustration, today this contradicting requirements would be formulated as an EC in the following: if the floats increase in size, than the plane can be enlarged and carry the higher payload, but this leads to higher fuel consumption and lower distance.

A solution at that time was to use the hull of the airplane as the main part of the float, which from a modern TRIZ perspective could be called the implementation of inventive principle 25 self-service and as local resource the hull of the airplane itself as float. The main floats beneath the hull can be trimmed, improving the air resistance and fuel consumption. A secondary problem, the issue with the water plashes hitting the engines was handled by the hull as well. Today in TRIZ formalism, the solution would be described as using the principle 3 local quality, by moving the wings to the top of the hull and principle 4 asymmetry, by modifying the hull from a circular to an 8-shape type, which increases the distance of the engines from the water line reducing the impact of water plashes. This hypothetical argumentation and invention path was maybe the guideline for *Blohm & Voss* and *Lufthansa* to move from a float plane, like Ha-139, to a flying boat, like BV-222. Thus, the decision to go for a flying boat instead of a float plane can be called an intuitive ideal implementation of TRIZ principles without knowing the TRIZ formalism.

## 3.2 Engines to power the airplane

The customer requirements for the weight of cargo together with a distance range of 7000 km results in the overall weight leading to the question of powering the airplane, thus the engines and propellers. In addition, the customer had safety concerns like that the flying boat should still be able to fly in a controlled manner even in case of an engine fail after take-off. Instead of going for 4 engines they decided to implement 6 identical and exchangeable engines, thus a segmentation approach easing service logistics.[7] This segmentation is further done by having not a central fuel or central lubricant tank but each engine has its own tanks with short supply lines, thus the segmentation is consequently done for all engine parts.

The ability to refuel e.g. in the Atlantic from a ship makes it reasonable to use the same fuel as ships are using and not some high-octane based fuels preferred for land-based airplanes. Consequently, the use of diesel as fuel comes from the use of available resources from a ship in the Atlantic, corresponding today to the principle 25 selfservice and local ressources.

The airstream of the moving airplane is guided around the engines for cooling – principle 25 self-service - and in addition, this heated air is collected and ejected at an outlet duct below the wings,[7] which will participate to the buoyancy – relating to principle 6 universality, multi-use.

## 3.3 Water compatibility – size of the hull

They considered the width of the hull, thus the boat, to be defined in dimensional steps related to the number of seats next to each other or placing beds. For a fixed number of passengers and a wide hull, the hull can be shorter and the payload-to-hull weight ratio is improved but water and air resistance increase dramatically. Large flying boats at that time had a length to width ratio of 6. Furthermore, due to aviation reasons the hull needs to have a minimum length, so that the width of the hull is an optimization process rather than an inventive step. Here, they came to the solution to use a higher length-to-width ratio of 12, which was a remarkable step at that time.[6] The inner dimension of the hull structure are shown in figure 3 illustrating the use of rectangular shapes and similar parts simplifying assembly. Figure 3 of the BV-222 gives an impression of the length-to-width ratio.

## 3.4 Water compatibility – shape of the hull, start and landing

Having defined the width and length of the hull, the shape needs to be defined as well. Here beside the aviation aspects especially the compatibility for water take-off and landing is of special interest. The shape of the hull defines the direction of water plashes, which should not reach the engines, propellers and landing gears. The measures described above are supported by the shape of the lower hull, which was evaluated and optimised by experiments.[6,7] Beside the water plashes also the swimming behaviour was investigated leading to conclusion for the payload distribution and maximum load. However, here the report does not mention details for problem solving but describes this as plenty of tests using flying boat models swimming and landing in a water canal. Nonetheless, focusing purely on the lower part of the hull for optimization follows the principle 3 local quality or 15 the dynamization. Other flying boat designs of that time ensured the water compatibility in a less TRIZ-typical way e.g. by complex additional wings at the hull as done for the Boeing Clipper.[10]

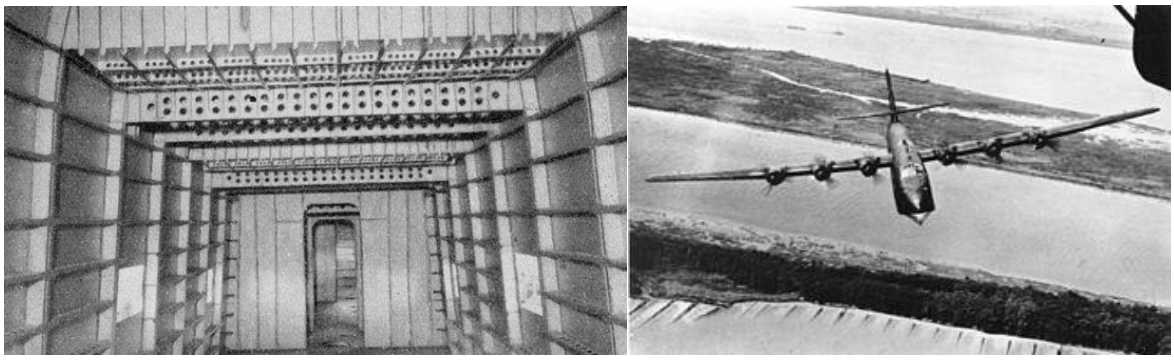

Fig. 4. Picture of the inner hull-structure showing the dimensions and the use of a rectangular inner shape with similar parts (lhs). The overall shape of the flying boat with its length-to-width of 12 compared to other flying boats with ca 6 illustrated during flight (rhs)

## 3.5 Aerodynamic aspects

A large scale model was tested in a wind channel with running propellers to determine the sizes of rudders like vertical tail, the position of the engines and the buoyancy during takeoff and landing. The positioning of the 6 engines was described like an optimization, whereas the rudders and vertical tail required engineering.[7] The problem was described that during normal flight for small pushing angles the required forces by the pilot should be low, such that the pilot had a good feedback with respect to the airplane behavior. In case of failure of one or more engines, by contrast, larger pushing angles thus larger forces from the pilot are required to control the airplane. To respect these two contradicting requirements of small and large pushing angles, they decided to segment the rudder for these two cases, thus using intuitively principle 1 segmentation.

## 3.6 Wings

Since a flying boat comes into contact with sea water regularly steel was the main construction material for all important static parts. The wings had to deliver the buoyancy and to carry the engines. Thus, the wings require a static element supporting these high forces but not delivering too much weight by itself. Typically, static elements supporting high forces over long distances use massive steel elements like a double T-girder. Obviously, a double T-girder can support high forces over long distances, but its high weight would reduce the possible payload. Here the team from Richard Vogt designed the supportive element of the wings as a tubular spar (tube) with a hollow body, see Figure 4h. The tubular spar was separated into an inner part, carrying the engines and fabricated from electro-welded metal half shells, and the outer part for the wings beyond the outmost engines fabricated in an even more lightweight geometry.. [7] Their inventive approach using a hollow body as static element corresponds to inventive principle 31 use of porous material. For further weight reduction, the wall thickness of the tube was thinned at areas, where less forces are acting, e.g. at the side and the outer parts, nowadays classified as principle 3 local quality.

Furthermore the hollow body of the inner tubular spar had a diameter of 1m and was used as fuel tank, thus eliminating or at least reducing the amount of fuel tanks, thus saving additional weight,[7] corresponding to principle 25 self-service, use of local resources. To reduce the weight further the outer tubular spars design was altered from thick welded parts towards the use of thin metal sheets for the tube, [7] corresponding to the inventive principle 30 thin sheets and foils.

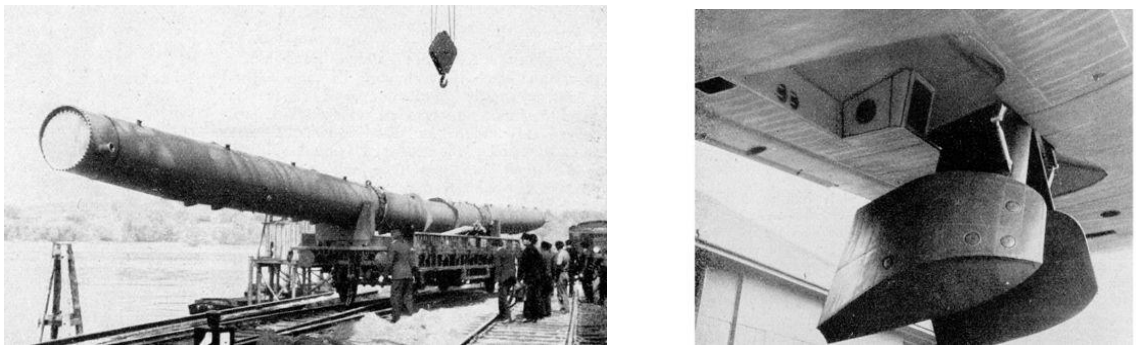

Fig. 4. Supporting structure of the wing using a tubular spar (tube), the picture shows the inner tubular spar manufactured from welded steel (lhs). One outboard wing float which is segmented and retractable for flight operation. The relevant surfaces are optimized either for water or flight operation (rhs)

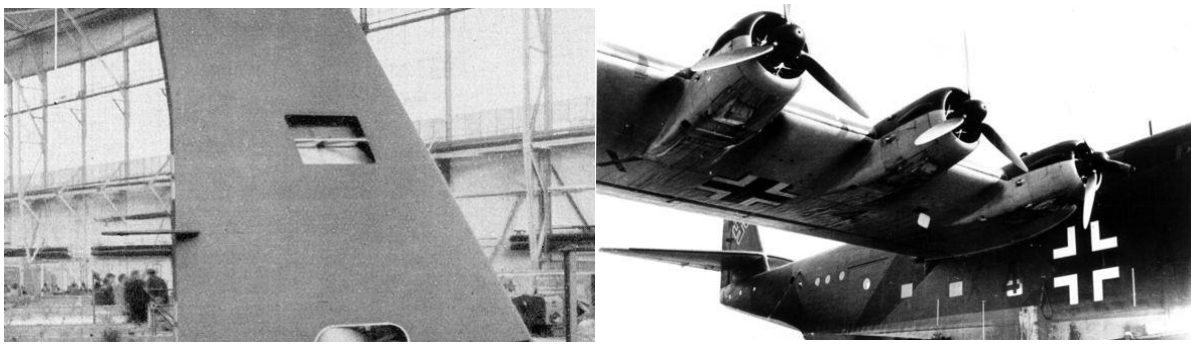

Fig. 5. Details of parts of the flight control rod for mechanical transfer of the pilots control commands to e.g. the vertical tail (lhs) and detail view of the wing with 3 engines and sufficient access for service (rhs)

Around this static tubular spar with integrated fuel tank the remaining wing is build based on rips and mouldings, which shape the sheet metal of the wing. This approach was done such that many of the rips and mouldings have the same dimension, easing the manufacturing and assembly. [7] This can be related to the use of the inventive principle 33 but also other techniques, as will be discussed later. The report mentions, that this approach enables certain scaling effects in the manufacturing despite the prototype amount of ordered airplanes.[7] The safety aspect with respect to engine failure was already discussed. Especially service of a failed engine during flight was beneficial, but access to the engines from the hull is only available via the top of the wing, which is not a good solution. But the special construction of the wings consisting of a tubular spar with a diameter of 1m and a lightweight surrounding structure offered space for a small path from the hull through the wings to the engines.[6,7] Using this empty volume for this purpose follows the principle 25 self-service, use of present resources.

This wing design combined many inventive ideas and calculations showed that this tubular spar construction could support the required maximum 50 ton weight but even 100 ton. Next to the main static aspect this wing design supports plenty of additional benefits. These are intuitively engineered but most of the engineering problem solutions correspond to TRIZ inventive principles.

## 3.7 Outboard floats on the wings

In case of landing or starting on water, the flying boat may swing due to wave motion. As a consequence the wings might touch the water surface leading to sudden deceleration during take-off or landing. To avoid this, outboard floats are installed at the outer wings. Here an antagonistic approach by Richard Vogt can be anticipated from the report[7] and we reformulate this here as a PC: Those outboard wing floats should be large in size, to prevent the wings from touching the water surface during take-off or landing and they should be small to feature a low air resistance during flight. This contradiction was resolved using retractable wing floats.[7] Due to the required buoyancy of the wing floats they must be large. Consequently, retracting them completely into the wing would not be feasible or require thicker wings. Thus, this contradiction was intuitively solved by segmentation, thus principle 1 as shown in the figure 4. To be more specific, in TRIZ language this corresponds to a combination of principle 1 segmentation with principle 7 nested doll for the retraction into the wing. This anticipated antagonistic situation they have analysed can today be formulated as a PC and solved by separation principles using TRIZ formalism. Here separation by time is used, leading to several innovative potential solu-

tions, including the applied one. Furthermore, the shape of the segmented wing floats was functionalized by different shapes either for the aviation (inner side) or the water traffic (outer side), corresponding to principle 3.

## 3.8 Control system

Due to the increased size and higher velocity of the airplane the forces on the rudder, e.g. elevator pitch, are increased significantly. But at the same time the pilot should fly the airplane with reasonable force to have good control with a similar feeling like known from flying smaller airplanes. This problem of antagonistic requirements was seen by Richard Vogt.[7] The typical approach at the time of construction was transducing the movements of the rudders by cables triggered by the pilot, but this principle was not scalable to larger airplanes As one solution Vogt proposed the replacement of mechanics by hydraulic or electric actuators corresponding to the inventive principle 28— replacement of mechanics— and 29—use of gases and fluids— or 24— intermediary by using additional energy sources and hydraulic or electric drives. Although such solution approach would solve the upper contradiction, it would not tackle the problem at its original source, the rudders. In addition, he pointed out that these solutions have the disadvantage of higher risk of failure and higher manufacturing cost, at that time at least.

Thus, they followed another approach, by proactive measures on the rudders especially the ailerons itself—following principle 11 beforehand cushioning. They decided to keep the aileron mechanic and to reduce the higher forces directly at their origin. Segmenting the ailerons into two parts, one with direct control to give the pilot the “feeling” he knows from small aircrafts, and the remaining with an additional Flettner rudder, which reduces the required forces significantly. With this solution the pilot can fly the large airplane with the required forces and the force increases known from smaller airplanes.[7]

The concept of the Flettner rudder was already known at that time and it is a combination of principles. Adding an additional small rudder at the tip of the main rudders, such that it moves in the opposite direction, corresponds to principle 9 prior anti-action. The airflow leads to a force on the main rudder but the Flettner rudder results in an opposite force due to the airflow leading to a significantly reduced net force for the main rudder, but still fulfilling the function to control the airplane. This corresponds to the principles 13 other way around, 25 self-service and 29 use of gases and fluids.[10]

For the long distance flight an automatic was incorporated to stabilize the airplane on a predefined height using the pitch elevator. Here initially the automatic should control the whole pitch elevator by small changes to stabilize the height. But they recognized that if the automatic would control the whole pitch elevator, small changes of the pitch could be done to stabilize the height correctly, but on the risk of uncontrolled maybe sudden large changes leading to a dive and an accident. Again, they worked out the antagonistic aspects of the problem and solved it in a proactive manner by separation of the pitch elevator into two parts, one smaller for the automatic mode and the remaining for direct control by the pilot. Furthermore, the pilot can switch off the automatic to gain control over the whole pitch elevator.[7] Their approach corresponds to using principle 11 and 1, as precaution measures for the automatic and segmenting the pitch elevator.

## 3.9 Flight control rod

At that time, the movement of the rudders was typically triggered by cables and thrust rods with many anchor and deflection points. Unfortunately, forces and complexity of such mechanics

increase for larger airplanes and the impact of deformation at the deflection points due to the applied forces imposes additional challenges by reducing the control of the rudders. Thus, if we increase the length of movement space for the cables, the required forces are reduced and airplane control is improved, but more space is required. They analyzed the key problem of the standard approach at that time and identified the low stiffness of the mechanical parts as root cause.[7] They solved this by shifting from light weight cable to thick rods and lateral movement to rotational movement by using rotating shafts leading to the positive effect that no deformation at the deflection and transition points diminishes the control actions. This corresponds to a combination of inventive principles, namely the shift from light weight cable to thick rods corresponds to principle 13 other way around. The replacement of lateral movement by rotational movement corresponds to principle 15 dynamization and 14 spheriodality.

Beyond the technical innovative steps they had also a focus on the assembly and implemented this approach by standardizing the parts reducing the assembly effort.[7]

# 4 Discussion

Based on our study techniques showing similarities to modern TRIZ methods were used. Furthermore, others approaches could be identified and will be discussed in the following:

## 4.1 TRIZ related

During the problem identification and solving process by the team from Richard Vogt many TRIZ related aspects could be identified leading to an innovative and reliable large air plane. For solving problems, they did deep analysis to find the key problem and solve the problem at its origin. Likewise, the control system was modified at the root-cause of higher forces e.g. aileron and not by adding e.g. a hydraulic system. Similarly, water plashes were diminished by modification and optimization of the hull shape and not by placing the engines onto of the wing like for the Do-X. Or, the shift from cable to rod for the flight control avoids the deflection leading to non-direct control. This kind of analysis contains the spirit of the *cause effect chain analysis CECA)* known from TRIZ going for solving the key problem, at its origin.

The way of approaching problems by formulating the contrary requirements reminds the reader of TRIZ-methods as well. Vogt's way of thinking can be highlighted e.g. for the outboard wing floats: In case of a large and heavy airplane these must be large to fulfill the job and prevent the wings to touch the water surface during e.g. take-off, but limiting the aerodynamic performance. He outlined that in 1937 the solution was to use fixed outboard wing floats and to tolerate this disadvantage. But he wanted to overcome this conflict and it can be anticipated from his descriptions, that he was having in mind an antagonistic description like "outboard wing floats must be large in size, to support the wings, but they should be small enabling a low air resistance during flight". This antagonistic description is almost similar to a PC in TRIZ. Today, such PC would be solved by separation and here separation in time is recommended. This directs towards the solution. When the outboard wing float is only present when the plan is close to or on the water and in the air it is not there anymore. Thus the outboard wing float can be e.g. retractable, as used by the *Blohm & Voss* team, or inflatable or similar solutions. Using TRIZ methods, the chosen solution of the team is in the path guided by TRIZ problem solving processes but this formalism would lead to even other innovative solutions, which might show even further benefits.

In contrast to the above mentioned TRIZ-like approaches of solutions, there are other examples that show, that the team did not use a formalism like TRIZ: One key problem for large and long

distance airplanes is, that the increased fuel capacity causes over-proportional extra weight. Thus, with every gallon of additional fuel the reach increases linearly, but the weight increases super linear, thus even more. This is a key issue Richard Vogt was aware off in the 30s and he mentioned that he found a solution for this "old" problem in the mid-50s by inventing the floating wing design. In case, he had formulated this problem as an EC this had enabled him to find his solution not in the 50s but already in the end of 30s and implementing this in the BV-222. Obviously, the way of working was not in the form and clearance as trained by TRIZ today. But from the described examples it can be anticipated that for some problems he was using antagonistic methods comparable to the contradiction concepts EC or PC as know from TRIZ.

Furthermore, the way of working enables the identification of inventive principles as listed in table 1. For design and construction the inventive principles 1 to 8 are frequently used, which is common for classical construction and design work.

The frequent use of principle 25 self-service is remarkable, using the available resources for solving problems. Examples are the use of the hull as floating element, but such that this floating element has the aerodynamics of an airplane. Using consequently the resources in the wings both for fuel storage and for improving the service functionality enhancing reliability. Thus, solving problems, with minimum changes of the aerodynamics of the airplane. Another example was the control problem of increasing forces for controlling the airplane via the rudders. He discussed this and in modern TRIZ EC this would be formulated as: "if the size and velocity of the airplane increases, than the forces on the rudders increase extraordinary as well, but the pilot should be able to fly the airplane with low force by himself". This contradiction was not solved by additional hydraulic or electric actuators leading to additional parts, but by making only minimal changes to the system using available, proven parts. Here the segmentation of the airleon and the use of additional rudders, called Flettner rudders enables easy flying of the airplane, almost as a small one, but handling the larger forces of a large, "high velocity" airplane. These self-service approaches come close to the *ideal final result (IFR)* concept as applied in ARIZ. But there are no indications that they used a formalism like ARIZ.

It is remarkable, how many approaches and solutions in the spirit of TRIZ methods can be found and anticipated in this construction process, even years or decades prior the world-wide rollout of the TRIZ methods in the 1970s. The approaches comparable to TRIZ methods like contradictions, inventive problems, CECA or maybe even ARIZ were regularly but more or less intuitively used and definitely not as a formalism as it is done today. At least, we could not find any hint for a fixed formalism. On the other hand, since the TRIZ methods are based on the study of patents, including patents from the time before 1946 and from the field of aviation, some similarities between the engineering approaches and TRIZ methodology could be expected.

Table 1

Inventive principles used in the construction approach listed for different components of the BV-222 (chapter numbering used)

| **Inventive principle** | **3.1 type of airplane** | **3.2 engines** | **3.3 size of hull** | **3.4 shape of hull** | **3.5 aerodynamic** | **3.6 wings** | **3.7 outboard float** | **3.8 control system** | **3.9 control rod** | **Sum** |
|---|---|---|---|---|---|---|---|---|---|---|
| **1 - segmentation** | | X | | | X | | X | 2X | | 4 |
| **3 – local quality** | X | | | X | | X | X | | | 3 |
| **4 - asymmetry** | X | | | | | | | | | 1 |
| **7 - nesting** | | | | | | | X | | | 1 |
| **9 – prior anti-action** | | | | | | | | X | | 1 |
| **11 – beforehand cushioning** | | | | | | X | | 2X | | 3 |
| **13 – other way around** | | | | | | | | X | X | 2 |
| **14 - spheroidality** | | | | | | | | | X | 1 |
| **15 – dynamization** | | | | X | | | | | X | 1 |
| **25- selfservice** | X | 2X | | | | 2X | | X | | 6 |
| **29 – use of gases and fluids** | | | | | | | | X | | 1 |
| **30 – thin films, flexible shells** | | | | | | X | | | | 1 |
| **31 – porous materials** | | | | | | X | | | | 1 |

Last but not least, what was the impact of this continuous problem solving on the construction results, the airplane itself? The airplane was not used for its design purpose, the intercontinental

passenger transport, but due to the outbreak of the war it was used for transporting goods and wounded flying over the Atlantic, Black sea, Mediterranean, Baltic Sea or Artic. That the BV-222 was an excellent maybe "the best flying boat in the world" was still mentioned in the mid 50s by experts e.g. from US Navy.[6] Many basic characteristics of this flying boats are still used today and modern planes like the ShinMaywa US-2 (Jp) feature more similarities with the BV-222 than the BV-222 had in common with its predecessors like the Do-X. These are e.g. the high-to-width ratio, position of the wings & engines and shape of the hull and maybe even the flight control rod approach. However, due to new materials and mature electronics many of the problems from 1937 can nowadays be solved differently. But still, the continuous problem solving lead to a reliable, long-distance airplane well ahead of its time.

## 4.2 Further observations

In a broader TRIZ perspective this example of flying boat development with its large amount of innovations can be seen as the phase 2 stage of a trend of engineering system evolution (TESE) for flying boats.[2]

Beside TRIZ-like solutions, many guidelines for the construction came from analysis of what can go wrong, fail and how to compensate this. Such kind of approach reminds of modern FMEA (Failure Mode and Effects Analysis). For example, how to compensate or recover an engine failure during flight? First of all segmentation increases the probability that one engines fails, but diminishes the risk of an airplane crash. This resilience is also improved by separated tanks for fuel and lubricant with short supply lines. Furthermore, the ability to service the engines during flight increases the resilience here by creating a path in the wings. Also, the shape of the vertical tail is designed to compensate non-symmetric propulsion. Using diesel as fuel is of advantage in case of landing in the Atlantic, since many ships at that time were running with diesel. A failure in the automatic height stabilisation could lead to a sudden dive, thus by segmentation this was covered. They avoided to use hydraulic or electric solutions for the movement of the rudders due to risk of failure by many new parts and unproven technology. As a consequence, they modified the mechanics in a way that it solved their problem. As a secondary effect, the amount of parts and skills for service is reduced by sticking to a mechanical solution. The report outlines the amount of pro-active failure analysis performed by the team, which reminds of modern FMEA. Obviously, the full FMEA formalism is not mentioned and likely not used, but the intention and spirit of FMEA can be derived from the report nonetheless.[6,7]

The guideline for reducing the amount and variety of parts and easing assembly and manufacturing can be found in many thoughts for the construction. Thus, not pure perfect technological ideas and solutions with high inventive potential are targeted but also simplification by using similar parts in the airplane is one of his key interests. His intention was to get scaling effects for manufacturing and especially assembly even for a prototype number of planes. This intention is mentioned explicitly in parts of the report. But the idea can also be derived from them skipping new types of energy transmission for the rudders, and the design of the wings with similar rips and parts. This holds also for the design approach of the control rod assembly. For the latter he explicitly emphasised the benefits in easing the assembly by using same parts.[7] In addition, the serviceability during flight but also for ground operation was his focus by adding large openings for service on engines.

These examples show that their design approach in 1937 was not only for looking on the function and finding good solutions to the problems, but combining this with aspects of assembly, manufacturing and serviceability. This establishes a link to modern techniques like DFMA (Design For Manufacturing and Assembly) and is well beyond "standard problem solving".

The construction project BV-222 lead to an airplane for which neither the reports nor other sources give an account of any "teething troubles". The innovative design resulted in a reliable airplane and the reported airplanes losses are related to war specific incidences and not to technical failures or handling issues during flight over open sea. Thus, these approaches in the spirit of an ancestor for FMEA and DFMA combined with problem analysis and solving showing similarities to modern TRIZ enabled a reliable and innovative flying boat.

## 5 Conclusions

Based on our study of the BV-222 development in 1937 approaches comparable to TRIZ methods like contradictions, inventive problems, CECA or maybe even ARIZ were regularly but more or less intuitively used and definitely not as a formalism as it is done today. The result was a flying boat which was ahead of its time. Using the TRIZ formalism of today could have resulted in even better solutions leading to an even more advanced flying boat or airplane.

Beyond these TRIZ methods also a failure analysis approach can be anticipated like FMEA and most remarkably their work was not only on finding good solutions to problems, but combining this with aspects of assembly, manufacturing and serviceability establishing a link to modern technique of DFMA (Design For Manufacturing and Assembly). The fact of no airplane losses due to none-war specific incidents and no reports on disadvantages of the design indicate that the use of all these techniques was beneficial for the development time and performance of such front runner project. The shown combination of TRIZ, FMEA and DFMA related methods might be beneficial even for projects started today which require further studies for verification.

In this pre-TRIZ age project TRIZ related approaches were more intuitively used but proved to be very successful. If this high accumulation of inventive techniques was purely related to the chief of engineering Richard Vogt or the *Blohm & Voss* teams or if such kind of high accumulation was also used by other engineers in the pre-TRIZ age deserves further study on other development projects of that era, but clearly goes beyond the scope of this work.

## References

1. Valeri Souchkov, A brief history of TRIZ, 2015; https://triz-journal.com/a-brief-history-of-triz/
2. MATRIZ level-3, training documents by Sergei Ikovenko, 2018
3. Sergei Ikovenko et al., State-of-the-Art TRIZ, Theory for Inventive Problem Solving, Novisimo, 2019 or MATRIZ level-2, training documents, Barbara Gronauer & Horst Nähler
4. Dietmar Zobel, Systematisches Erfinden, Expert Verlag, 2006
5. https://matriz.org/wp-content/uploads/2014/01/TRIZ-Assumptions-Revision-Eng.-012714-9SLAZ.pdf
6. Richard Vogt, Weltumspannende Memoiren eines Flugzeugkonstrukteurs, Luftfahrt-Verlag Walter Zuerl, 1978
7. https://www.flugrevue.de/klassiker/sechs-motoren-ueber-see-grossflugboot-blohm-voss-bv-222-wiking/
8. E.L.Houghton, P.W.Carpenter et al., Aerodynamics for Engineering Students, Butterworth-Heinemann, 2016
9. Hermann Schlichting, Erich A. Truckenbrodt, Aerodynamik des Flugzeuges, (Bd.I, Bd.II), Springer, 2001
10. https://de.wikipedia.org/wiki/Blohm_%26_Voss_BV_222

11. https://de.wikipedia.org/wiki/Blohm_%26_Voss_Ha_139
12. https://de.wikipedia.org/wiki/Dornier_Do_X

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# ABSTRACTS

# TRIZ-PEDAGOGY

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# Approaches to TRIZ Pedagogy in the Russian TRIZ Association (RA TRIZ)

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According to the ideas that have developed in the RA TRIZ, today there is an understanding of TRIZ in a narrow sense and in a broad sense. In a narrow sense, TRIZ is a theory. And, like any theory, it contains:

- conceptual basis,
- basic postulates,
- specific approaches to the objects under study, according to which objects are considered as developing systems with specified functions,
- objective patterns of this development,
- a set of object modeling methods that implement these approaches.

In a broad sense, TRIZ is a system of knowledge that includes the theory mentioned above, the practical part (various technologies based on this theory), the information base and TRIZ philosophy.

It is this system of knowledge that is the basis for TRIZ education in the Republic of Armenia. TRIZ education has two directions.

The first direction is the training of TRIZ users: technical specialists and humanitarian specialists. This training takes place in different programs.

The second direction is TRIZ-pedagogy. It includes the training of teachers and children.

In order that the training does not turn into profanity, since 2019, the certification of TRIZ teachers has been introduced in the RA TRIZ. Certification is based on the credit principle and involves obtaining credits for all aspects of the knowledge system based on TRIZ. The peculiarity of certification: differentiation by the educational level of trainees (schoolchildren, students, specialists), and by category (popularizer, trainee teacher, teacher, methodologist teacher, mentor teacher).

The certification procedure includes written assignments (3 attempts) and an oral interview. As a result, the teacher receives a RA TRIZ certificate and a certificate of state-issued professional development.

Teachers who have been trained in the RA TRIZ include 4 mandatory blocks in their programs for children: "Imagination", "Functions", "Systems", "Tasks". The first block is necessary for the development of controlled creative imagination, the second and third are devoted to the analysis of objects, the fourth to the solution of inventive tasks. Additional blocks, at the discretion of teachers, can be "The development of imaginative thinking of children", "The development of causal thinking", etc.

To help teachers in RA TRIZ, there is an educational and methodological complex on TRIZ pedagogy "On the steps of TRIZ", which consists of methodological materials on the main blocks of the program, methodological manuals with a detailed description of classes with children, workbooks for children, a number of sets of board games and other materials.

Testing and consolidation of knowledge of both children and teachers is carried out in the form of International competitions and the All-Russian TRIZ Olympiad. Preschool children, schoolchildren, students and teachers can take part in the competition. Works are accepted from any cities of Russia and abroad in Russian.

Another important feature of TRIZ pedagogy in RA TRIZ is an integrated approach to the development of children. TRIZ pedagogy is part of this approach, along with Eido pedagogy, which develops attention and memory, and Neuro pedagogy, which takes into account the neurophysiological characteristics of each student.

The listed approaches to TRIZ pedagogy, adopted in the RA TRIZ, contribute to the formation of a successful creative personality regardless of the age of the student.

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# Sensible creativity

Evgenia Guin

Creatime, Moscow, Russia

I teach the development of creative thinking, the ability to solve open problems and to think different. Parents are interested in this approach, but they are worried about the school. "Our children have to do a lot of typical exercises at school, they must follow the rules" – they say, "creativity will prevent children from being successful in school. In addition, it is important for us to give our children the knowledge, culture, not only the ability of open problem solving".

## 1. To add, not to replace

Let's say you learned to drive a car. Does that take away your ability to walk? "Of course no!"- any sane person would say, "why would it?!

This is the point.

Let's go further. Tell me, please, what is the best way to move around: walking or driving? "That's an absurd question!" - the reader will be indignant. "In one case it's better to walk, in another it's better to drive! There is no single answer. It's obvious."

I completely agree. The only thing I wonder is why it's not just as obvious when it comes to standard and non-standard thinking. Each way has its own niche and purpose. Learning one more way doesn't take you away from the others, it only expands your opportunities.

## 2. Gold standard

I am not urging you to consider every task or life situation as an open problem. Absolutely not! Standard solutions and templates greatly improve our lives, save resources and increase efficiency. In addition, mastery of standard approaches and solutions is one of the indicators of professionalism. I definitely wouldn't be happy to visit a doctor who would say on my symptoms "Wow, that's very interesting! I've never heard of that! Let's think about it!".

But in some cases, none of the standard ways works. In such cases there is a need of a super-professional - some kind of "M.D. House", who knows all the standard AND can solve a non-standard open problem, find a new approach. The point is that to be able to brilliantly and effectively solve a problem when life throws it at you, you have to be used to do it. We used to do what we have learned. For this reason, it is important to design non-standard situations artificially, to offer children open tasks for training. As a result, at the right moment their brain will not fail.

## 3. Productive communication

One of the results of using open problems in the educational process is an increasing of erudition. Children are exposed to a lot of facts, they think about it, they realize what they don't know yet, and they have a desire to learn it. So open problems contribute to the effective learning of culture facts and book knowledge. Open problems do not hamper the acquisition of knowledge.

## 4. Ready-made solutions

What should we do with already known solutions, with the standard way of doing something? Should we just tell it to the child or let him "invent it" by himself? It depends on the situation again. If the situation does not carry any serious risks, if you are not in a hurry and have time for self-trial and error, then you could let the child make conclusions by himself or herself.

For example, the child wants to hold the fork with the other side while eating. What should we do in this situation? Well, you can say, "you're holding the fork wrong," and insist on the right way to do it. Or you can give the child an opportunity to draw conclusions on their own and to see that the standard way is more effective (that's why we all use it). Perhaps, in the second case, the child will start to trust your recommendations more.

What to do in a particular situation is up to you, depending on the conditions and intended consequences.

But what if it is not an inventive situation, but an exploratory one? For example, your kid wonders why there are bubbles in the puddles when it rains. You can immediately load into his head a scientific answer to this question, or you can first offer to think and hypothesize. I think the second approach is more productive for developing thinking and a scientific mindset. In addition, understanding will be deeper and memorization will be more reliable.

## 5. An open problem not a problem

Does it happen that a standard task turns into a non-standard open problem?

Yes, especially when new constraints or conditions arise.

Here's a simple example from my own life.

My two-year-old son and I were at the Moscow Zoo. The zoo is very big, so we had planned to spend the whole day there. And I took some food in a container with me to feed Stepan at the lunch time. But I did not take a spoon. I knew that there are a lot of cafes in the zoo, so I could ask them for a spoon. I usually do that, during some of our "outings". But in reality it all turned out wrong. It turned out that there were no spoons in the cafes at Moscow Zoo. No spoons at all. They sell only the food that you can eat with your hands, so there are no spoons. What should I do?

Someone who is not used to see and solve problems in his/her life is likely to get upset, argue about the zoo, and go to a cafe outside of it - a child needs to be fed.

But a person who knows how to switch between "standard / non-standard" mode will say, "Oh, there is a problem, now I'll solve it".

In that situation, I looked around me, opened my handbag and began to analyze the "resources". I decided to use a thin hairbrush instead of a spoon, which I wrapped with a clean plastic bag. My son had a great meal! Of course, this is not the only way to solve this simple problem, I know about a dozen other good solutions (you can think of them yourself as a workout). Certainly, I wouldn't feed my son from a hairbrush in a normal situation.

Creativity also has to have sense, and it's good if it's sane.

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# TRIZ and thinking skills: can there be added value and where should we look for it?

Alexander Sokol,

TA Group, Latvia

The question of using TRIZ for the development of thinking skills is considered from two vantage points: a TRIZ professional and an education professional. While the former often assumes that TRIZ is valuable by default, it is an investment for the latter and they should be clear about the returns it may bring.

Current mainstream education discourse of "navigating the rapidly changing ecosystem to help the learner shape the future (OECD 2030 Framework) is very close to the driving contradiction of preparing for tomorrow one has no idea about (Khomenko), defined in the TRIZ education community at the end of 1990s. Thinking skills have been integrated in the intended curricula of many countries and jurisdictions around the world. It has been done both at the level of core competencies (e.g. in Australia or British Columbia) and specific subject curricula (e.g. Singapore maths curriculum).

Thinking skills are being brought into curricula without TRIZ. However, a number of problems remain unresolved:

- How can the thinking curriculum be described?
- How can thinking skills be assessed?
- How can one ensure integrated development of thinking and subject matter
- competences?
- How can interdisciplinary learning be organised?
- How can one build a dynamic inclusive curriculum?
- etc.

It is these problems where an investment in TRIZ can be useful for an education professional. The problems can be considered at different levels of the system. Addressing a problem of assessing thinking skills for a particular teacher is different from tackling it at the country level. Developing interdisciplinary learning solutions for a specific phase of education (e.g. primary school) differs from considering them for the education system as a whole. The added value of TRIZ is its use as an applied scientific theory (Khomenko). The theory that helps education professionals build tools (education technologies) for dealing with the problems.

Some examples of such technologies include the Thinking Approach to teaching and learning (http://www.thinking-approach.org/), assessment tools for thinking (http://www.ta-teachers.eu/) and problem-centred learning (https://otsm-triz.ru/home).

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# Using TRIZ for Designing Toys and Games with Pedagogy Students

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Methodology for the development of creative thinking skills focused on toy inventions has been proposed. It is intended for 9-year-old children, students and adults – pedagogy profesionals and engineers. In 2014, the methodology was presented in the book “Start Inventing”.

Useful TRIZ instruments:

1. 40 principles
2. Physical, geometrical, chemical effects
3. Trends of engineering systems’ evolution

The methodology uses only patented inventions from Russia, Germany, USA, France, Great Britain. To better understand components of TRIZ, visualization was used:

1. Practice examples – simple to understand invention diagrams (toys!)
2. Visual "Database of Patents" of toys was created

40 typical TRIZ principles for raising the inventive level of toys: starting from the analogue - patent for invention, we apply one of TRIZ principles and invent our own toy.

Developed schematics for principles for a workbook. *Predict the next invention along this line of development.* By using schemes where visually presented a line of toys we can observe the regularities of system evolution, transition to microlevel, using fields (MATChEM), by using vibrations in the toys.

Methodology for the development of inventive thinking was tested with graduate school students, with university students, with teachers. Stages of applying the methodology:

- Study of TRIZ principle
- Study of regularity of evolution
- Study of effect
- Process of new toy development
- First 3D model based on their idea
- Presentation of results.

A manual on the methodology with examples of students’ projects is available.

Working with the methodology allows students to engage to scientific research and prepare presentations at student conferences about own toy, create intellectual property, apply for patents, publish articles in magazines.

A number of products for application of methodology was developed:

1) Posters depicting TRIZprinciples in a large setting (toy exhibition).
2) A new book (manuscript) in 2021, supplemented with: step-by-step diagnostics, check lists for the development of an invention and writing the claims and description of an invention.
3) Online course: 17 webinars are available in Russian language. A complete course can be purchased with the knowledge test on https://otsm-triz.ru/landing_patent .
4) Computer game (demo) «Tumbler teaches how to invent».

At the moment we are looking for:

1. Translation and publishing of the book in English.
2. Development of the computer game based on the demo version.

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# Proceedings of the 16th MATRIZ TRIZ*fest*-2021 International Conference

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Editor: Valeri Souchkov

The collection of papers «**Proceedings of TRIZ*fest*-2021 International Conference**» is intended for TRIZ specialists and users: academics, engineers, inventors, innovation professionals, consultants, trainers, teachers.

The present book of Proceedings includes papers related to the research and development of TRIZ, best practices with TRIZ, cases of practical application of TRIZ, and issues related to TRIZ training and education.

All presented papers are double-blind peer-reviewed.

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