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THE INTERNATIONAL TRIZ
OFFICIAL ASSOCIATION

THE 1st INTERNATIONAL CONFERENCE

ITC 2023

August 30 - September 2, 2023

CONFERENCE PROCEEDINGS

Editor: *Valeri Souchkov*

ITC 2023

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The collection of papers «*Proceedings of the 1st MATRIZ Official International TRIZ Conference ITC-2023*».

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 TRIZ lovers!

After four years of online events, the first International TRIZ Conference ITC-2023 by MATRIZ Official and Graz University of Technology has been held in the beautiful city of Graz, Austria. The conference was organized in a hybrid mode. Therefore, those participants who were not able to come physically, enjoyed the conference sessions online.

MATRIZ Official was established only a year ago (September, 2022) as a non-profit organization operating worldwide and legally registered in Brussels, Belgium as the International TRIZ Official Association (MATRIZ Official), asbl. The main tasks of our association include further development of TRIZ as a theory and its proliferation worldwide; providing a world-class five-level certification for TRIZ practitioners; development of creative and critical thinking skills for people in every age category, regardless of their field of activity. The International TRIZ Conference ITC-2023 proves that we are performing our tasks successfully!

A conference program started with three tutorials. Then, a unique event – “Solve It on the Spot Session” was conducted. During this session, participants collaborated under the guidance of TRIZ Master to address technological and inventive problems. Within three days, four outstanding keynote presentations were delivered with a great success. All details of tutorials, problem solving session and keynotes are available on the website of MATRIZ Official.

Of course, there were multiple sessions for paper presentations. A verity of topics discussed in the papers and a good number of case studies confirm a high interest to TRIZ development and application worldwide. These conference proceedings are published under ISBN and ISSN of Graz University of Technology.

I am very grateful to the Organizing Committee of ITC-2023, all speakers and participants. You have made this conference happened!

Enjoy reading these proceedings, learning and applying TRIZ.

A handwritten signature in black ink that reads "Oleg Feygenson". The signature is written in a cursive style with a large, stylized initial 'O'.

Oleg Feygenson, Ph.D., TRIZ Master
President, MATRIZ Official

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The International TRIZ Conference ITC-2023

A MATRIZ OFFICIAL MEMBER INTRODUCES ITSELF: EUROPEAN TRIZ CAMPUS E.V.

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Abstract

The members of the European TRIZ Campus (ETC) have been learning from and working together with many honorable members of MATRIZ Official for many years and feel very connected to the official International TRIZ Association.

To further spread the TRIZ methodology and TRIZ teaching in the European area in the past 12 months the ETC has put a lot of thought in how making TRIZ accessible to a broader audience and getting more professionals in touch with the methodology was one of the focal points.

To this end, we at the ETC have

- developed new formats such as the "Trainer Day" to support trainers on their way into practice.
- we have drawn up detailed quality guidelines for the teaching of the TRIZ methodology, which are intended to provide orientation for the design of training classes and documentation.
- we strive for exchange with representatives of "neighbouring" methods such as Six sigma, Lean, DFMA and Design Thinking to indicate synergies and added value among methods and approaches of different kinds.
- we are testing formats for community building, in order to connect users of all places more strongly with the TRIZ methodology through communication and information offers. If TRIZ users feel alone in their organizations, the exchange outside their organization helps them to keep up with the TRIZ methodology. Moreover, the ETC strives to increase the ability to communicate the benefits of TRIZ-usage inside organizations.
- we discuss, how to reach teachers and students of all age, to make them the unique way of inventive thinking accessible.

In our paper we want to give other MATRIZ Official members insights and share our experiences and best practices with our fellow MO members.

Keywords: European TRIZ Campus e.V., TRIZ-Trainer, TRIZ-Community

1. Who is the European TRIZ Campus e.V.?

In 2006 the first TRIZ Level 3 course took place in Graz, Austria, run by Sergei Ikovenko. Among the participants, the desire grew to continue learning the TRIZ methodology and to take it into the world.

So after the German TRIZ Centre and the Austrian TRIZ Centre, which was already a member of the former MATRIZ Society, had reduced their activities over time, a few TRIZniks from Germany and Austria got together and founded the TRIZ Campus e.V. in 2008.

The new association took over the membership number of the Austrian association and set itself the goal of further spreading the TRIZ methodology in German-speaking countries. The desired accreditation of new TRIZ trainers in Germany and Austria also required membership in a national TRIZ organization (non-profit organization) so that it could issue the necessary recommendation letters. The creators of TRIZ Campus e.V. also organized events and publicity for the TRIZ method in Germany and Austria, such as the TRIZ Conference 2008 in Heilbronn, 2010 in Wolfsburg as well as smaller events that individual members of TRIZ Campus e.V. realised privately in cooperation with the association.

In 2022, the board of the TRIZ Campus wanted to strengthen the life of the association because interest in the TRIZ methodology seemed to be declining in Germany and Austria. So the board asked the members of the association to discuss and collect ideas about which association concept would be promising for the future.

The results of these exchange rounds were, for example:

- the offers should be low-threshold and understandable for people without TRIZ training.
- more exchange opportunities for TRIZ trainers should be offered.
- there should be more discussion on how common management systems in companies could benefit from the TRIZ methodology.
- and more.

Based on these suggestions, the board developed the previous association into the European TRIZ Campus e.V. and decided on a new orientation based on the following objectives.

Our objective

The association sees itself as an association of users and interested parties of the TRIZ methodology in Europe. The official languages are German and English.

The purpose of the association is the promotion, dissemination and further development of the TRIZ innovation methodology in Europe. To this end it aims above all to:

1.1.1 Develop uniform quality criteria at a high level regarding the international state of the art for the training and application of the TRIZ methodology for all age levels.

1.1.2 Disclose interfaces to other methods such as Six Sigma, QFD, DFMA, Design Thinking, Lean, etc., develop synergies of the method combinations and publish or communicate them.

1.1.3 Take up future topics of education and training for the promotion and development of future skills, for the support of sustainability goals (environmental awareness, climate, water,

innovation, health, education, etc.) as well as digital transformation in further education concepts, training and training documents and develop working aids for this,

1.1.4 Establish and maintain a network of regional and international contacts for TRIZ education and application,

1.1.5 Coordinate and conduct further training events and seminars on TRIZ,

1.1.6 Cultivate cooperation with domestic and foreign organizations dealing with innovation-promoting methods.

1.1.7 Conduct specialist congresses, events and meetings.

2. Our mode of operation

In consultation with MATRIZ Official, the European TRIZ Campus has set itself the task of testing new formats and approaches for disseminating the TRIZ methodology and sharing the experience gained with the MATRIZ Official organization.

Since all the active people here are volunteers, we chose the accreditation process and the implementation of the trainer workshop as our first action.

A typical feature of the cooperation in the European TRIZ Campus is the participation-oriented collaboration: in the case of important open questions, all members are called upon to participate in the development of ideas and solutions. In this way, the Executive Board and the entire association benefit from the knowledge of the many, even if the coordination processes are sometimes somewhat more extensive as a result.

This approach follows the development trend in the organizational cultures of many companies in the German-speaking world to move from purely top-down decision-making and action to a participation-oriented way of working.

3. Quality Guidelines

A very important first step for the ETC was the creation of quality guidelines for the certification of course participants in TRIZ. In the beginning, the guidelines of the MATRIZ Official for the levels 1 to 3 were followed very closely. This enables the ETC to also accept participants who have attended a course according to the guidelines of the international TRIZ Association MATRIZ Official. The quality guidelines should therefore use the MATRIZ Official guidelines as a basis but describe them more precisely and offer more freedom for the introduction of new TRIZ topics.

To be able to describe more precisely to what extent a method should be taught and how deep the understanding of the method should be at the respective level, the following classification was developed:

Class	Meaning
A	<u>Knowledge and purpose</u> : method/tool has been briefly introduced and trainees know what the method/tool is used for
B	<u>Simple applications and purpose</u> : method/tool has been explained and trainees can apply the method/tool to simple problems (out-of-the-box examples, training examples)

C	<u>Complex and/or complicated applications and purpose:</u> Method/tool has been taught in detail using an example. Trainees know the method/tool very well and can apply it/it to complicated and complex problems (own project)
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For each method, it was specified which scope is expected in which level. Also, in the quality guidelines for each method, we briefly described what is understood by the method and according to which textbooks the method can be taught. We named both English and German references for each method. We have made an effort to include books of all TRIZ masters known to us in this source list. This should make it easier for the trainer to obtain the appropriate books and references and to build up his training according to them.

In the individual method descriptions, the ETC often allows for more recent developments. For example, in the 40 inventive principles, reference is made to the more recent MATRIZ 2003 and 2010, or to the work of Valeri Souchkov in the functional analyses.

We believe that we have made an important contribution to our trainers with these quality guidelines, which describe the training levels more precisely and at the same time allow more freedom in the design.

3.1 Accreditation

At the beginning, the ETC also thought of accreditation as it is common in the international TRIZ Association MATRIZ Official. The trainer accredits himself for a certain level of training. Then the thought came up that we don't have to stay with a rigid system here. How would it be if trainers could choose for which of their favorite TRIZ content they want to get accreditation?

This concept would allow participants to take part in trainings offered by different trainers and get a Level 1 certificate as long as all topics required for a Level 1 are covered.

Shorter trainings and specific trainings would be possible. This holds the chance to diversify the offer from TRIZ teachers and to make it more colorful. This is the direction in which the ETC is currently working. The status is still strongly oriented towards the level structure of the MATRIZ Official, but this will probably be softened in the next few years.

3.1 Accreditation guidelines

To ease the entry into TRIZ and the certification of course participants, the ETC has significantly reduced the prerequisites and costs for a trainer. For example, it is almost impossible for professors who hold only one TRIZ course at the university within a year to be certified according to the guidelines of the international TRIZ Association, because the expense of accreditation is disproportionate to the benefit.

We also see a difference between the suitability as a teacher and the own practical knowledge level in TRIZ. Therefore, at the ETC, a trainer must have learned the entire classical TRIZ knowledge up to level 3, to be able to better understand cross connections between the methods, but it is not necessary to always be two levels above the level to be certified.

A trainer must be a member of the ETC and confirms with a declaration of honor that he accepts the quality guidelines and behaves according to them. Also, he should bring a proof of his teaching experience. This can either already be provided by his profession (teacher, professor) or be proven separately with a sample lecture. The board decides whether this is necessary.

3.2 Trainer Accreditation

One of the central elements of the trainer accreditation process according to the new ETC guidelines is the submission of an exemplary test by the trainer candidates including the suggested solutions for the respective TRIZ level.

These exemplary tests are then reviewed by some ETC members to ensure conformity with the quality requirements. The main topics of the review process are the topics:

- Is the submitted test suitable for testing the respective TRIZ level?
- Is the curriculum of the respective level covered?
- Is the test an obvious copy of an existing test, which is not allowed?
- Is the candidate's own contribution recognizable?
- Are the suggested answers correct?

Each test question is categorized by the ETC members in terms of their taxonomy (1. Knowing facts - pure memorization; 2. Understanding - justifying with own words; 3. Applying - implementing the content of the course with practical examples) and according to the level of complexity (1. Easy question; 2. Moderate question; 3. Difficult question). Lastly the members decide whether the question must be discussed with the candidate or if the question can be added to the ETC catalog of accreditation questions.

The feedback of the ETC members is submitted to the candidate and will then be discussed in an accreditation meeting.

All of the questions are then stored in a ETC database and are marked with CC0 (Public Domain Dedication) for further use of the questions by the ETC members.

3.3 Trainer Accreditation Experiences

The uniform feedback after the first trainer accreditations according to the ETC guidelines was very positive. Although the process is somewhat time-consuming and involves a few people, it was considered very valuable by all involved.

It allowed questions to be discussed and any misunderstandings to be eliminated. It was also possible to incorporate suggestions and tips from the experienced trainers into the test questions, and on the other hand, new, interesting questions could be introduced by the new candidates. The community concept, in which everyone learns from everyone else, seems to be promoted in this way. The train-the-trainer concept thus seems to have been a complete success.

3.4 Trainer Workshop (Trainer Day)

Trainers who wish to become accredited with the European TRIZ-Campus or who wish to renew their accreditation are required to attend the Trainer Workshop at regular intervals. The exact requirements are described in the accreditation guideline.

Furthermore is the aim of the trainer workshop to get to know colleagues, learn from each other and thereby enrich one's own way of working.

In the trainer workshop, trainers present:

- Didactic or methodological examples
- Their own training concept with documents, examples, procedure, exemplary chapter, ...
- "How can others benefit from my knowledge?"

- "What happened to me?" - Successes and "fuck-ups"

and get feedback from the participants.

3.5 Trainer workshop program

Here we present the agenda of the first trainer workshop as an example:

18.00-18.15 Welcome round, current programme of the workshop, explanation of the feedback rule.

18.15-18.45 1st trainer presentation: Jochen Wessner, Functional analysis - learning poster and introductory example, feedback via mentimeter, followed by oral exchange

18.45-19.15 2nd trainer presentation: Jürgen Moosburger, A Systematic Ideation Approach at ams Osram, feedback via mentimeter, followed by oral exchange

19.15-19.45 3rd trainer presentation: Joachim Runck, TRIZ course revitalisation by means of KAHOOT quiz, feedback via mentimeter, followed by oral exchange

19.45-20.15 hrs 4th trainer presentation: Andreas Späth, TRIZ methodologies as tools for strategic analysis - experiences from a course, feedback via mentimeter, followed by oral exchange

The moderated meeting took place online.

3.6 Trainer workshop experiences

The first trainer workshop went very well. The schedule was well adhered to and the written feedback was collected for the presenters via Mentimeter. Both the presentations and feedback will be made available to all members.

The feedback from our participants was all very positive. They welcomed the "exciting perspectives and contributions", the "mix was great" due to the "different topics" of the speakers and they were all happy to learn and benefit from each other's experiences. So we will continue the Trainer Workshop with this concept in November.

During the final round, the wish was expressed that a regular meeting without an agenda would be a great opportunity, for example, to clarify questions about moderation and to discuss more about procedures in trainings and workshops. Therefore, a first ETC regulars' table will take place in the next few weeks.

4. TRIZ and other methods in the context of innovation management

4.1 Combination of TRIZ with other tools

One of the goals we have set is to combine TRIZ with other valuable tools for driving innovation. TRIZ has its absolute power in solving problems in the technical area, business wise or partwise in the analysis of a value propositions. The understanding of customer thinking is a weak point in the methodology. Tools like Design Thinking, Scrum for execution or Business Canvas for Business and Value propositions on a higher-level business are very helpful. The idea is to seek out for interfaces between TRIZ and other tool applications in order to have the best overall fitting systematic approach for the task given in daily research and professional life.

For example, with Design Thinking we can find out how people are using a product, how are they operating it, how are they feeling with it. TRIZ can then help finding root causes, identifying problems, and solving them. Backwards after implementation of a solution the effect / improvement can then be tested with Design Thinking as observation of different usage behavior by a customer.

With the implementation of solutions created with TRIZ usually a process for high quality requirements come along. Here tools like SixSigma are very helpful. While applying SixSigma you often meet challenges, contradictions and problems with then again can be solve with TRIZ.

Future challenges will be to solve problems occurring from sustainable product / process designs or from resilience analysis of companies. Here as well TRIZ can play an important problem-solving role. It is very often the case that not all the TRIZ tools are needed, but only parts of them, the ones that are correlating with the challenge. Nevertheless, identifying these intersections is key.

We intend to identify the definition of these intersections for data exchange and for tool merging to combine TRIZ with other tools, where it makes really sense as a valuable add on for the total topic of optimal innovation creation.

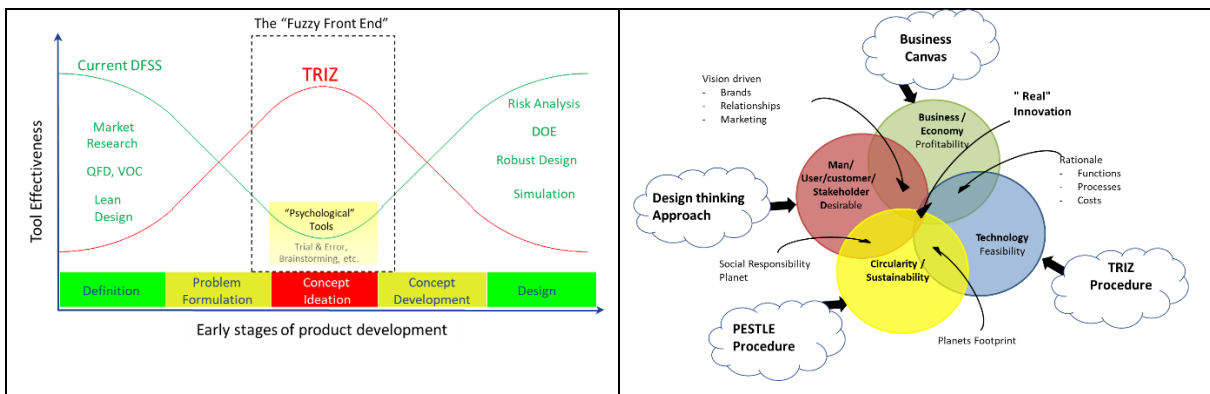


Fig. 1. “Early stages of product development” (GEGR, Munich) and “Options of method combinations”

4.2 Example of a combination of methods

4.2.2 The process of ideation

Sometimes it is simple - TRIZ helps to find the right questions.

Ideas often need a kind of inspiration – this inspiration could be given as a goal oriented question or an example of a working system. But nevertheless, it needs to be asked.

The different tools of TRIZ leads the developer and their teams to exactly do that.

However, it is important to apply the right tools at the right time to reach the development target effectively on the one hand and to save valuable time of the participants on the other hand. Contradictions also exist within the development process.

So, sometimes it is important to involve a moderator which is not involved in the development process but leads the team through the process.

Moderation skills as given i.e. VAVE seems to be more and more important.

4.2.2.1 The process of ideation towards the IDEAL

Ideal means Benefit divided by Expenses (Costs) + Problems.

$$I = \frac{B}{E(+P)}$$

As an additional further tool TRIZ could be enlarged with tools like DFMA/EVI which leads to a first idea of possible expenses without going into detail calculation. This perspective could lead either to additional questions (and new ideas) or describing new requirements for partners and suppliers. This path is purposeful because creating ideas without thinking of the denominator in the fraction is only half the job.

5. Conclusions

Reviving the European TRIZ campus has taken some effort. But in the meantime we are pleased with the success of the map. We have the impression that in this way we can succeed in inspiring even more people for the TRIZ method and ensure a high standard in TRIZ training.

Acknowledgements

We thank all TRIZ Masters, MATRIZ Official and the previous MATRIZ organization for the great support, the opportunity to learn and develop the methodology.

References

1. European TRIZ Campus e.V. Bylaws (www.triz-campus.eu)
2. European TRIZ Campus e.V. Accreditation Guidelines, 2022 (www.triz-campus.eu)

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The International TRIZ Conference ITC-2023

TRIZ AND PRACTICAL ARTIFICIAL INTELLIGENCE

Boris Zlotin and Alla Zusman

Ideation International Inc

Abstract

Today's environment could be characterized by the following recently emerging factors: the rising complexity of our world, Practical Artificial Intelligence, and growing demand for intelligent products.

Attempts to create Artificial Intelligence (AI) systems began with the creation of the first computers in two directions:

Algorithmic programs (Turing machines) modeling explicit (rational, logical) thinking using verbal descriptions and methods of logic and mathematics.

Artificial neural networks (ANN) modeling tacit (non-verbal, subconscious, intuitive) component, including creativity.

Unfortunately, despite a certain level of success, today's ANNs still have plenty of weaknesses because of non-obvious errors in their basic design and methods of their training, which lead to insufficient intelligence of these networks, the inability to additional learning in the process of use and the huge cost of development and training.

In this paper, we present a new approach allowing for creation of a powerful and affordable Practical Artificial Intelligence (PAI) that could be achieved via integrating the new artificial neural network with removed original errors and "rational AI." We trace the evolution of rational thinking tools, from language and writing to computers, and especially the Theory of Inventive Problem Solving (TRIZ), as the breakthrough in the rationalization of human subconscious activity representing the continuous efforts to convert tacit knowledge and skills of naturally inventive individuals into explicit rules and procedures via identifying reliable patterns of invention and evolution. This hybrid AI could effectively model the work of the mind, especially in the search for new, non-standard creative solutions.

An essential step in the creation of TRIZ-based rational AI was the development of a set of software tools for organizing and supporting creative processes by Ideation International Inc., specifically the design of the first AI-enabled Ideation Problem Formulator® and a new type of artificial neural network, PANN, developed with the help of TRIZ by Progress, Inc. Today, we envision an upcoming new, significant leap in the development of PAI based on integrating these tools with AI chatbots to generate creative solutions and reduce the uncertainty of our world.

To illustrate the practical applications of this approach, we provide examples of how the advanced Ideation Problem Formulator® system, with Refined Directions, can be used as a front-end to AI chatbots to generate creative solutions. We also highlight selected software modules from Progress, Inc. that can be utilized for inventing new intelligent products with the possibility of image recognition, comparison, clustering, classification, search, formation of associative links, approximation, prediction, and other analytical operations.

Keywords: TRIZ, AI, ANN, PANN, SuperPrompt, ISQ, SAQ, Problem Formulator, Ideation Process, TRIZSOFT

1. Introduction

The human thinking process includes two essential components:

- Rational consciousness based on speech and logic, including the ability to reason, calculate, use algorithms of actions, etc.
- Intuition based on subconsciousness, the ability to understand a situation without words and logical reasoning, make decisions with insufficient information, engage in creativity, etc.

The following two venues could characterize the history of human civilization:

- The creation of various methods and instruments contributing to improving the thinking process – language, writing, formal logic, math, scientific methods, counting devices, and finally, computers.
- Transforming elements of subconscious thinking (intuition, tacit knowledge) into verbally described methods, processes, and algorithms (explicit knowledge).

Attempts to create Artificial Intelligence (AI) systems began with the creation of the first computers in two directions:

- Algorithmic programs (Turing machines) modeling explicit (rational, logical) thinking using verbal descriptions and methods of logic and mathematics.
- Artificial neural networks (ANN) modeling tacit (non-verbal, subconscious, intuitive) component, including creativity.

While the evolution of Turing machines has been successfully proceeding, ANN hasn't been so lucky, mainly because of the approach, based on the attempt to reproduce the intuitive activities of the human brain without sufficient knowledge of its complex and, in many aspects, unknown nature. In 1943 American scientists McCulloch and Pitts created a model of intuitive perception ("MP machine") based on limited knowledge available in biology at that time. Based on this model, in 1958, Rosenblatt built the first ANN named "perceptron," which became the first tool to support intuitive thinking and the precursor of all modern neural networks.

Unfortunately, despite the first successful attempt at building ANN, the limitations of the original model and non-obvious errors in their basic design and methods of their training led to insufficient intelligence of these networks, their inability to additional learning in the process of use, and the massive cost of development and training. As a result, the evolution of ANN was slow and distorted for an extended period.

In the last dozen years, with the efforts of hundreds of thousands of engineers and scientists worldwide and enormous costs, ANN reappeared as a fast-evolving technology. However, they remain an "elite product, " costly in development and use, unreliable, and potentially dangerous.

At the same time, substantial progress in modeling intuitive creative activities was made in the mid-1990s by Genrich Altshuller, the creator of the Theory of Inventive Problem Solving (TRIZ) [1].

The main reason for his success was a brand-new approach to creativity, suggesting that instead of copying the human way of thinking, reconstructing the creative output using refined human innovation experience documented in patents and other sources of technical information

resulted in identifying patterns of invention and technological evolution. In fact, he started building an artificial, more streamlined (and economical) way to transform the initial situation with the problem into the desired solution. The picture below (Fig. 1) shows a complicated and uncertain natural way of searching for inventive solutions haphazardly and a much more organized, though still difficult, and only sometimes successful way of inventing based on TRIZ.

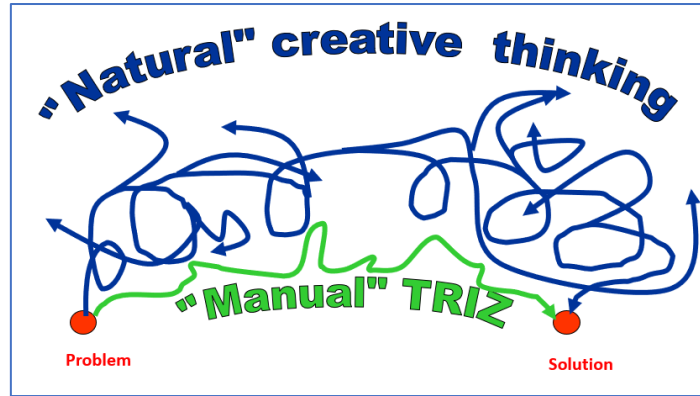


Fig.1. Ways of natural and TRIZ-based thinking

For decades, ANN and TRIZ have been evolving in their separate ways, until the last decades when the authors got involved in developing a new type of ANN – Progress Artificial Neural Network (PANN) based on the new approach and new model of an artificial neuron. The recent emergence of AI Chatbots has made clear the following:

- In addition to allowing to clarify the immediate possible future TRIZ evolution to re-assess its past in the light of AI explosion.
- Mutually beneficial relationship between TRIZ and ANN.

Given the above, we could characterize TRIZ as a contemporary working Practical Artificial Intelligence (PAI) tool. In the given paper, we will address how ANN benefited from TRIZ and vice versa.

2. What is Practical Artificial Intelligence?

Unlike Artificial General Intelligence (AGI) which is supposed to rule the world and thus is becoming a subject of all fears, PAI is a collection of methods and devices invented by people to support and empower the human way of thinking.

PAI is:

- Artificial, because it has been developed by humans, starting dozens of thousands of years ago with the emergence of human speech. Its evolution has brought logic, mathematics, education methods, science, arts, and informational technologies.
- Practical, because it allowed humanity to dramatically improve everyday life, providing comfortable housing, sustainable food, transportation, prolonged life span, etc.

Given the above, TRIZ could be considered an important component of PAI development. While AGI is still a mystery, possibly unattainable, and quite possibly dangerous, PAI can flourish, especially with the help of TRIZ.

3. TRIZ for ANN

Throughout human civilization, PAI has supported natural human intelligence with means for information accumulation, transfer, storage, simple transformation, and more. With the advent of computers, PAI began penetrating the thinking processes. However, while Turing machines were quite successful, ANN were lagging.

As mentioned above, one of the main reasons for the long delay in the appearance of PAI was a wrong model of a biological neuron. The second, and probably more impactful, was the wrong approach involving an attempt to reproduce a human way of thinking. The enormous complexity of the human brain with many still unknown mechanisms is predominantly responsible for huge costs and the mysterious nature of how most of the known ANN work.

This serious impediment became quite apparent when the traditional approach to ANN was analyzed from the TRIZ point of view, specifically from the Patterns of technological evolution [2].

3.1. PAI and Patterns of technological evolution

One of the Patterns of technological evolution, “Reducing human involvement in technological systems,” provides rules for successful automation, computerization, and, finally, making the systems autonomous. Importantly, it warns against typical mistakes people make during this process – first, trying to automate (computerize) the human way of performing. Unfortunately, these attempts are rarely successful, like the first locomotive with legs or the first sewing machine with arms. The reason for these failures is the enormous complexity of even the simplest living organisms, preventing us from sufficiently understanding the underlined mechanisms of their operation and consequently successfully reproducing them. The answer to these problems was the invention of a new way to produce the same results more suitable for automation (computerization), which required a better understanding of the original process.

3.2. Bionics and “technionics“

In the early 1960s, the science of bionics (biomimetics) appeared, proposing to study the features of the structure and vital activity of living organisms to use them to create technical devices. Unfortunately, the huge expectations have never come through. Biological mechanisms are very complex and multifunctional, and an engineer trying to apply a “biological invention” faces a task similar to the one of a blacksmith of the 16th century, who would suddenly get a spacecraft “for plunder” and figure out how to use some parts to improve a cart.

While working on a methodology for solving scientific problems [3], we jokingly came up with a science we called “technionics,” which is the reverse of bionics. Its essence is the transfer of understandable ideas from technology and applied sciences to biology, sociology, psychology, pedagogy, medicine, art, etc. Once it was defined as such, numerous excellent examples of its applications have been discovered. This was no coincidence. The technology aims to get the maximum benefit at the lowest cost, targeting higher Ideality (defined as benefits versus cost ratio, one of the central premises of TRIZ). The intellect and talent of engineers and scientists, engineering science and practice, plus TRIZ contribution for the last 60 years, make it possible to find optimal solutions to various problems.

Over time, “technionics” has become an essential tool in our biological and social evolution research. But the main benefit it provided in our research on AI and ANN. A continuous cyclical process arose when the solution of inventive problems in the field of AI made it possible to

understand better what biologists wrote about perception, thinking, and intellectual processes, often making it possible to get answers biologists could not find. And a new understanding of biological problems helped invent a more straightforward and transparent ANN and AI ...

3.3. Progress Artificial Neural Network (PANN)

The study of ANN using the TRIZ methodology for solving scientific problems made it possible to identify and correct the earlier mentioned errors of McCulloch, Pitts, and Rosenblatt, considering more recent biological knowledge. As a result, Progress Artificial Neural Network (PANN) was built and protected (current count) by 16 patents [4]. Unlike classical artificial neural networks, PANN is a completely “transparent,” easily predictable system that can be used and trained by anyone (not necessarily a programmer or engineer). Let's compare the basic ideas classical ANN and PANN are built on (see below).

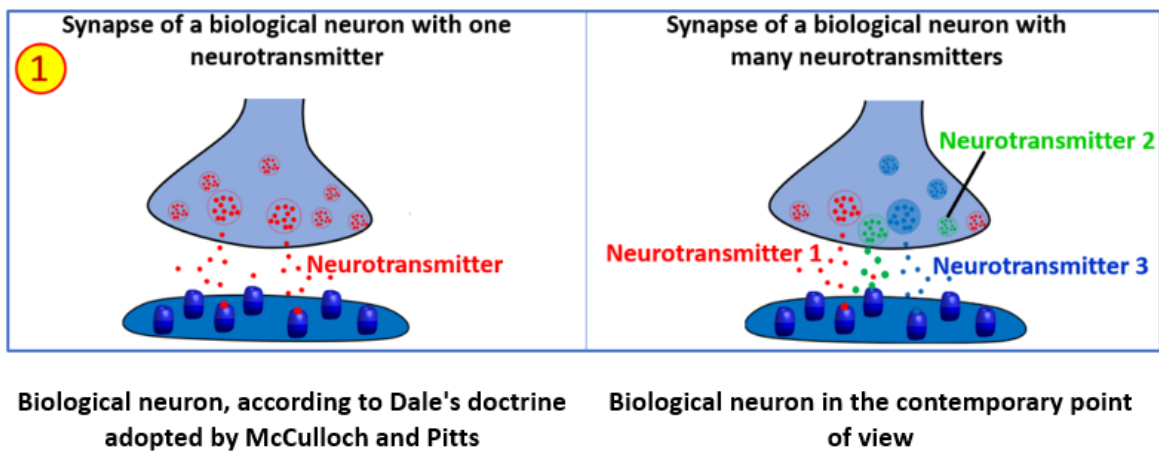
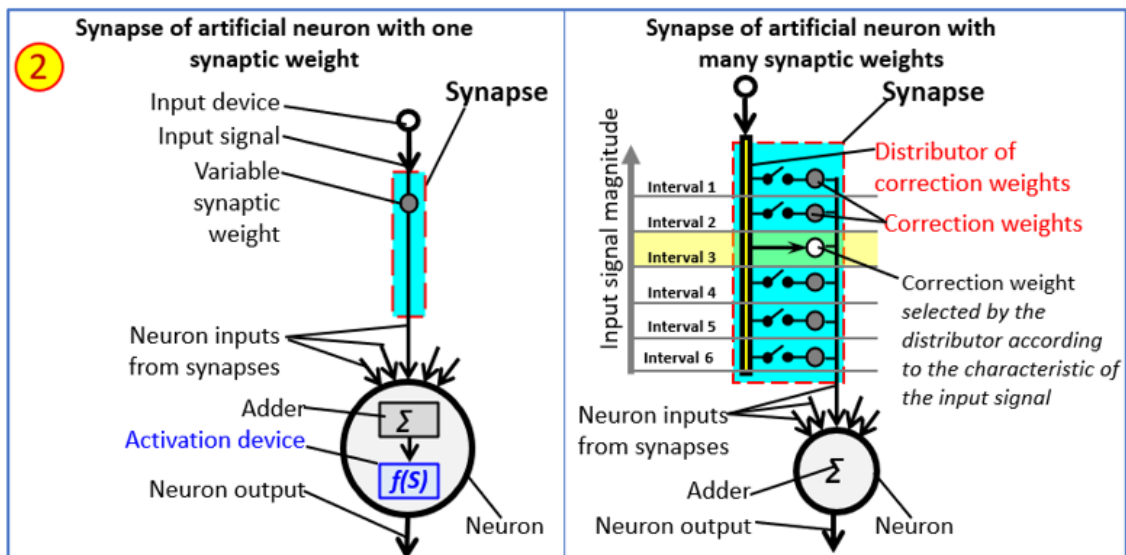


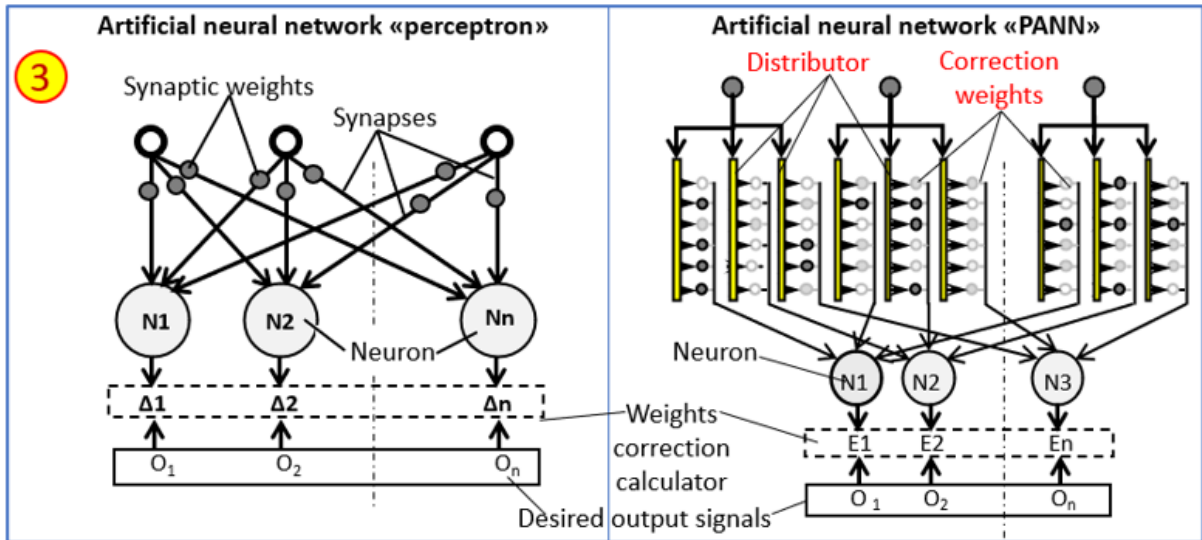
Fig.2. Biological neuron model



Artificial neuron perceptron
 The signal from the input passes through an electrical variable resistor, which acts as a synaptic weight. Changing this resistance simulates synapse training.

Artificial neuron PANN
 The signal from the input passes through the distributor, which, depending on the magnitude of the signal, selects one of the electrical variable resistors that play the role of corrective weights. Changing this resistance simulates synapse training.

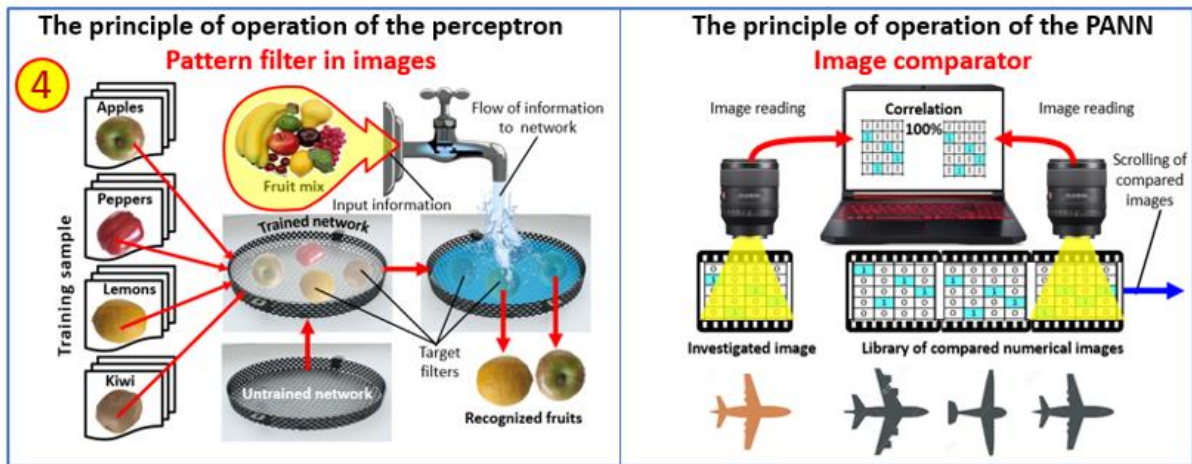
Fig. 3. Artificial neuron model



Typical perceptron circuit
 In training, change in each synaptic weight affects all other weights. Therefore, training is carried out using the gradient descent method, which involves conducting many (tens of thousands for problems of the middle class) training epochs, each of which includes solving large systems of multiple equations with multitudes of unknowns. This requires high-end computers, leading to a long duration, high energy consumption, and cost of network training. The training process is entirely non-transparent, challenging to manage, and often ineffective. The trained network does not allow additional training after the training cycle is completed.

Typical PANN scheme
 In training, change in each corrective weight has little to no effect on all other weights. Therefore, the training is carried out without gradient descent, at once, for the entire value of the error, using very simple calculations. In most cases, one training epoch is sufficient. Therefore, training can take place on computers of the middle and lower classes (up to laptops and phones); it is swift, efficient, and completely transparent. The trained network can constantly learn, combining learning with operation in real-time.

Fig.4. Typical structure



A simple model of the functioning perceptron
 The perceptron works like a "sieve of knowledge" built from the knowledge gained during training. This is essentially a mathematical filter that extracts some patterns from a set of training images and forms structures similar to training images in its architecture.
 When other images (knowledge) pass through, it selects those similar to its architecture.

A simple PANN operation model
 PANN is not a sieve of knowledge; it's a comparator that compares the image (knowledge) given to it with any number of other images and determines the degree of similarity (correlation coefficients) of the image in question with other images selected for comparison, the number of which can be unlimited.
 By manipulating the parameters of the comparator, it is possible to provide high recognition accuracy and automatic classification and clustering of images.

Fig.5. Simple operational model

4. TRIZ and AI Chatbots

4.1. TRIZSoft®, Innovation Situation Questionnaire® and Problem Formulator®

In the late 1950s, Altshuller prognostically named his creation Algorithm for Inventive Problem Solving (ARIZ), intended for manual application. During the next three decades, the initially rather lax algorithm went through multiple improvements, mainly in the direction of strengthening and detailing the rules to increase the efficiency and consistency of results obtained by different users.

Eventually, the time has arrived to build the next parallel artificial way for the problem-solving and creativity to increase its efficiency further to guarantee innovation success (Fig. 6)



Fig.6. New artificial way of inventing by utilizing TRIZSOFT®

By the late 1980s, personal computers became available for the TRIZ groups, encouraging the development of the first TRIZ software (Minsk, Belorussia, project Invention Machine, and Kishinev, Moldova, project Innovation WorkBench®). Since 1992, when Kishinev TRIZ School transformed into the US company Ideation International Inc, Ideation has come with over a dozen professional and simplified software packages¹.

Ideation software development followed the abovementioned rule from the beginning: a new technology suitable for this purpose should be developed first for successful computerization. This technology included the following new tools:

- Analytical:
 - Problem Formulator ® (PF)
 - Innovation Situation Questionnaire ® (ISQ)
 - Situation Assessment Questionnaire (SAQ)
- Knowledge-based:
 - System of Operators (over 400) for solving technological problems
 - Set of Operators (over 100) for solving business, management, logistics problems, etc.
 - Set of Patterns of technological evolution

For the leading platform for the development of TRIZ software, Expert Systems (ES) were selected based on their availability at that time. However, there were differences in the human-machine interface. For example, while a typical ES would suggest a final recommendation(s) based on the user's input, with our software, the user is the one producing the final results based on the ES recommendations. Oddly enough, this change in the principle of operation made it possible to move the development from heavyweight programming languages such as Prolog, Lisp, and CLIPS to the most straightforward use of hypertext languages.

¹ See at www.ideationtriz.com.

TRIZ software became the next critical step in building PAI. An analytical tool Problem Formulator (PF) module became the main feature of the TRIZSOFT® family. From its inception in 1992, it had several “smart” features, including:

- Automatic recognition (highlighting) contradictions.
- Automatic capturing (from the diagram) factors and cause-effect relationships between them to generate meaningful sentences - Directions for Innovation.
- Automatic conversion of a visual diagram into a comprehensive set of possible Directions for Innovation.

PF was built to visualize the typical human thinking process and verbalize its results, specifically when addressing tough challenges. Today we know that all thinking processes in living organisms are realized via natural neural networks, making the Problem Formulator system a prototype for an AI-enabled TRIZ-based tool.

Another viable possibility for PAI is using Ideation knowledge-based tools as well-organized and illustrated knowledge libraries.

Today, considering the AI Chatbots explosion, we have found new value in two other TRIZSOFT analytical tools: ISQ and its simplified version SAQ.

4.2. Ideation Brainstorming software (IBS) v. 4.x

IBS is an AI-enabled general-purpose tool designed to facilitate the process of generating out-of-the-box solutions to the most pressing challenges/situations arising in product improvement and development, business and management, organizational and social development, and more.

The software implements the systematic step-by-step user-friendly Ideation process helping individuals and teams analyze the challenge/situation at hand and develop a set of possible directions for solutions (innovation):

This tool is based on Ideation TRIZ (I-TRIZ) Methodology [5] and is recommended for individuals and teams involved in problem-solving, innovation, complexity management, etc.

The ideation Process for IBS includes three stages:

- Completing Situation Assessment Questionnaire (SAQ) (a set of specifically selected questions optimizing the search for creative solutions).
- Generating Directions for Solutions and Brainstorming.
- Concept Development.

4.3 AI Chatbots

According to Wikipedia, AI chatbots are artificial intelligence (AI) systems capable of maintaining a conversation with a user in natural language and simulating how a human would behave as a conversational partner. Such technologies often utilize aspects of deep learning and natural language processing. One of the first was ChatGPT, developed by OpenAI and released in November 2022. Chatbots are being built based upon broad foundational large language models that get fine-tuned to target specific tasks or applications (i.e., simulating human conversation, in the case of chatbots). Chatbots can also be designed or customized to target further even more specific situations and/or particular subject-matter domains. Recently, companies spanning various industries have begun using the latest generative artificial intelligence technologies to power more advanced developments in such areas.

The first experiments with ChatGPT-3 and 4 were both exciting and confusing. In practically any response from ChatGPT, some information was made-up and n false. Besides various biases, the quality of responses has shown a strong dependence on the quality of the answers, giving birth to numerous offers of prompts and SuperPrompts – specifically structured sets of standard phrases proven to contribute to higher-quality responses.

Given the above, we have constructed an exploratory case study using Ideation Brainstorming software as a SuperPrompt for using ChatGPT for problem-solving.

4.4. Exploratory Case Study. Using IBS v.4 as a SuperPrompt for AI Chatbots

4.4.1 The purpose and the method

The study intended to explore the effectiveness of using IBS software as a SuperPrompt (front-end) to AI Chatbots. The study consisted of two parts:

Part 1. Working with Ideation Brainstorming software (IBS) 4.x., including:

- Completion of the Situation Assessment Questionnaire (SAQ).
- Using the Problem Formulator to build the Diagram and generate Directions for Innovation (Solutions).

Part 2. Three sessions with ChatGPT-4, including uploading information produced with the help of IBS outputs, as follows:

- Session 1 – the original problem statement.
- Session 2 – completed Situation Assessment Questionnaire (SAQ).
- Session 3 – three selected Directions for Innovation (Solutions) with Refined Directions².

Obtained suggestions for each session with ChatGPT-4 have been divided into the following groups:

- General (obvious)
- Useful or somewhat useful
- Interesting or creative.

4.4.2 Summary of the results

The summary³ of the results is shown below.

² *Refined Directions are more specific recommendations within Directions for Innovation (Solutions) generated by the Problem Formulator. See more in [6].*

³ *See edited ChatGPT suggestions in the full report here: <https://docs.google.com/presentation/d/1q7msyD4aodzMMBdUfh3S0rCsO8mv-hVT/edit?usp=sharing&oid=102498674467750091976&rtpof=true&sd=true>*

Table 1. Summary of the recommendations provided by Chat-GPT-4 for IBS

Session #	Session Description	Number of ChatGPT recommendations			
		Total	General (obvious)	Somewhat useful	Interesting (creative)
1	Original problem situation	4	1	3	0
2	Completed SAQ	7	2	5	0
3	3 selected Directions (from 14 available)	7	0	6	1

1. The number and especially the quality of the ChatGPT-4 recommendations steadily increased with the continuous use of software outcomes.
2. Just 3 of the 14 directions almost doubled the number of total ideas (7/4) compared to the original problem statement.
3. The interesting (creative) recommendation provided by the ChatGPT-4 during Session 3 (using the Direction for Innovation generated by Problem Formulator with Refined Directions) was close to a 100% solution developed earlier by the TRIZ professional team.

5. AI Chatbots as a new platform for TRIZ dissemination

During almost 80 years since TRIZ inception, it had its ups and downs, including:

- Low visibility for the first 40 years, practically no recognition from the Soviet government or academic world.
- Rising popularity in the former USSR in the early 1980s due to some support from government agencies involved in implementing the Value Engineering technique that have been convinced of the utility of using TRIZ for its creative stage. Another reason was the emergence of commercial activities after Perestroika.
- Quite a demise of TRIZ utilization after the crash of the USSR in the early 1990s, causing immigration of many leading TRIZ professionals to the West.
- Rising popularity of TRIZ in the USA as “The Next Big Thing” after many popular quality techniques lost their bizazz and numerous consultants were looking for a new field to earn their bread.
- Despite some successes with Fortune 500 companies and limited TRIZ dissemination in Europe and Asia, TRIZ hasn’t become “The Next Big Thing” in the 21st century.

While considering TRIZ as a real breakthrough in making innovation and creativity teachable and thus attainable for the masses, our first commercial experience of implementation of TRIZ in its classical form has forced us to think of a better platform, like developing software to support TRIZ activities making it easier to learn and use.

The TRIZSOFT family developed by Ideation has proved to be appreciated by professional innovation consultants. However, the software platform they were built upon still required much work. Although with the software, a TRIZ beginner could learn the basics and start utilizing TRIZ after a 3-day workshop (versus 3-4 weeks of intensive learning and several years of practicing to become self-sufficient with classical TRIZ), the barrier to getting involved was still high. Plus, of course, various cultural, organizational, etc. issues which are out of consideration for this paper.

Analysis of the patterns of success of software-based products has produced, besides others, the following example.

We were introduced to our first electronic mail developed by AT&T by the end of 1992. It was not exactly user-friendly (based on the DOS operating system), but we had to learn it to communicate with American partners of our newly established Ideation International. Soon AT&T got competitors; however, it didn't make sense to switch as they used the same platform, and the improvements, if any, couldn't justify spending time learning them. The situation changed dramatically around 1995 when Microsoft released its first Windows product, and the new email service America Online was introduced. Practically in no time, it was spreading like fire. Its use became so simple that new customers exceeded the company's capacity.

As mentioned earlier, TRIZ software was built on the Expert Systems platform. For the last two decades, we have been waiting for a new platform to make TRIZ use easy. It was clear that it must be some widely available AI product. Our latest experience with ChatGPT, with all its deficiencies, confirmed that our expectations were correct. Based on this experience, we upgraded our Ideation Brainstorming software v.3 to version 4. to make it a possible front-end (SuperPrompts) to AI Chatbots and to use them together as a powerful brainstorming tool for general-purpose problem-solving.

As mentioned earlier, IBS 4.x is an analytical tool with an outcome in the form of automatically generated Directions for Innovation (Solutions). There are now three ways for the user to proceed:

1. Conduct traditional brainstorming with the project team.
2. Continue working with the Operators (Innovation knowledge bases in the professional Ideation software).
3. Upload the Directions in an AI Chatbot, get responses, and continue working with suggested recommendations.

While as a "partner," ChatGPT-4 is convenient and well-learned (although not really smart nor always correct), it has shown one additional and rather significant advantage: working with it is fun and much more exciting than trying to squeeze more ideas from the tired brain or clicking one screen after another in the software.

ChatGPT has also produced a good collection of materials that, in many ways, can replace or at least drastically reduce and simplify the search for information in projects, as it generates and maintains a wealth of associations. This will undoubtedly greatly help engineers educated in a narrow field (like most graduates of American universities). This can significantly raise the routine or semi-routine work level, making creativity less necessary. Again, this is consistent with the contemporary engineering culture in big corporations: "The best solution is the one you can buy on the market."

After experimenting with IBS 4.x, we are about to release the next version of the software to take more advantage of the new platform, including the possibility to easily upload and download the inputs and outputs to a chatbot of the user's choice. As the next step, we are planning web-based software.

6. Conclusions

1. Today, various AI Chatbots became available to help find solutions to complex challenges. However, the usefulness of a Chatbot response strongly depends on the quality of the questions.
2. The study aimed to explore the effectiveness of using Ideation Brainstorming Software (IBS 4.x) as a SuperPrompt (front-end) to AI Chatbots.
3. The study has shown that the number of useful and especially interesting (creative) solutions was steadily increasing from 3 in Session 1 (uploaded original problem) to 7 in Session 3 (uploaded Directions for Innovation with Refined Directions).
4. The ChatGPT-4 suggestion in Session 3 was very close to the best idea generated by TRIZ professional team.
5. The study results have confirmed that using IBS 4.x as a SuperPrompt (front-end) to AI Chatbots could be beneficial, especially as it could compensate for the known deficiencies of available Chatbots.
6. The results have also confirmed that the many members of the Ideation TRIZ software family TRIZSOFT® built on the platform of Expert Systems are reasonably compatible with AI Chatbots, which could become a critical event in the evolution of TRIZ becoming a new platform that can substantially increase TRIZ utilization worldwide.
7. Although AI chatbots so far are limited in delivering creative solutions, they compete with TRIZ experts to a certain extent. At the same time, the study showed the possibility of the emergence of something like a "Socratic dialogue" as part of a brainstorming session that clarifies the situation. That makes integration of Chatbots with TRIZ software a real necessity.
8. Another potential benefit to check could be using Chatbots for clustering ideas and concept development.
9. IBS software is available for a free 15-day trial (get it here : <http://oldsite.idea-triz.com/download/setups/ibs5-15/ibs5.html>) and subscription. Also, see a modified version of SAQ that could serve as a general-purpose SuperPrompt to AI chatbots for problem-solving (Appendix 1).
10. The next generations of the IBS are in the pipeline and will be available soon.

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The authors would like to extend their gratitude to:

Dr. Rada Granovskaya (1929-2022), a great friend and colleague – a world-renowned scientist and practitioner in psychology (psychology of creativity and innovation in particular) for explaining how our Problem Formulator technology reflects typical problem-solving thinking.

A global team of TRIZ-trained professionals that dedicated their time and efforts to find ways to use Ideation TRIZ to help organizations and individuals address various challenging situations and navigate the hardships and complexity caused by pandemics worldwide, especially the following members:

- Boudewijn Bertsch
- Bob King
- Dr. Sadegh (Ben) Babaii
- Dr. David Bonner

References

1. Altshuller G. “Creativity as an exact science”. Translated by Anthony Williams. Gordon and Breach Science Publishers. 1984.
2. Zlotin B. and Zusman A. “Directed Evolution: Philosophy, Theory and Practice”. Ideation International Inc., 2001.
3. Zlotin B. and Zusman A. “TRIZ Based Tools for Knowledge Creation”. *Proceedings of the annual TRIZ Conference of the Altshuller Institute for TRIZ Studies TRIZCON 2002*.
4. US patents: 11494653 B2, 2022; 10423694, 2019; 9619749, 2017; 9390373, 2016. Also patented in Japan (7041078, 2022; 6382354, 2018), Israel (247533, 2019), Taiwan (I655587, 2019). China (ZL201580012022.2, 2018), Mexico (MX357374B, 2018), Hong Kong (HK1227499, 2019), Singapore (11201608265X, 2019), Eurasia (035114, 2020), Korea (10-2166105, 2020), Europe (EP3114540, 2021), Canada (2941352, 2022).
5. Ideation Research Group. “TRIZ in Progress”. *Proceedings of the first annual TRIZ Conference of the Altshuller Institute for TRIZ Studies TRIZCON 1999*.
6. Zlotin B., Zusman A. and Hohnjec M. “TRIZ-based software as a front-end to AI Chatbots”. *Proceedings of the International TRIZ Conference ITC 2023: August 31, September 1-3, Graz, Austria*.

Appendix 1. Ideation Universal Problem-solving SuperPrompt (UPSS)

Name the system your situation relates to (product, process, technology, organization, etc.).

Describe:

1. Your challenge/situation, preferably in a single phrase.
2. The Primary Objective(s) of the situation resolution.
3. The system's components and structure. Be sure to indicate all essential elements and how they are connected.
4. What the system was designed for, and how it works.
5. Other systems that interact with your system.
6. The most challenging issue you are facing in pursuing your objective. If there is more than one, try to list them in order of importance.
7. The factors responsible for this challenge.
8. The consequences if the challenge is unresolved.
9. Previous attempts to resolve the challenge. State the reasons why these attempts were considered unsuccessful.
10. The ideal solution, that is, how the completely satisfactory situation should look like.

Optional. Describe:

1. The degree of changes your system can allow (small, medium, substantial, unlimited).
2. Measures for success.
3. Other factors (entities, people, conditions, regulations, etc.) that could be useful or should be considered while addressing the situation/challenge/objective.

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TRIZ-BASED SOFTWARE AS A FRONT-END TO AI CHATBOTS

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Abstract

This paper explores the benefits of utilizing TRIZ-based software as a front-end module (SuperPrompts) for AI chatbots.

The creation and further development of TRIZ since the mid-1940s should be considered the first successful attempt to build an artificial (parallel) way of solving inventive problems and creativity in general. However, for the first 40-50 years, TRIZ AI was handicapped by the absence of a critical component – an adequate software platform. The first attempt to develop software to support TRIZ procedures was made in the late 1980s; however, they were limited to the computerization of selected TRIZ knowledge-based tools and provided no more help than a conventional electronic book, with no actual intelligent features.

The next critical step was made in the early 1990s with the development of new software modules developed by Ideation International, including extended and restructured knowledge-based tools and brand-new analytical tools like Innovation Situation Questionnaire® (ISQ) and especially the Ideation Problem Formulator®. It provided the first TRIZ-based AI features like automatic recognition of contradictions and the generation of comprehensive sets of meaningful sentences describing promising directions for solutions (innovation), incorporating Ideality. Following these directions, the user could reach the most relevant sections of the refined and structured knowledge base facilitating idea generation based on suggested analogies.

Over 30 years of using these tools by thousands of users have shown that the most challenging and time-consuming parts of software-supported problem-solving were idea generation and concept evaluation. Recently, the solution to these issues could be utilizing two new emerging technologies: AI chatbots and PANN, a new type of artificial neural network developed with the help of TRIZ by Progress, Inc.

The presentation will demonstrate the benefits of utilizing Ideation analytical tools as a front-end module for AI chatbots for a real problem-solving project. Specifically, the presentation will compare different results obtained by downloading a) the original problem statement, b) the completed ISQ filled for this problem, and c) the directions for solutions generated by the Ideation Problem Formulator®.

Keywords: TRIZ, AI, SuperPrompt, ISQ, SAQ, Problem Formulator, Ideation Process, IBS, ESAM

1. Introduction

Since the mid-20th century, two independent branches of science have been developing – Artificial Neural Networks (ANN) and the Theory of Inventive Problem Solving (TRIZ).

Unfortunately, despite the first successful attempt at building ANN, the limitations of the original model and non-obvious errors in their basic design and methods of their training led to insufficient intelligence of these networks, the inability of additional learning in the process of use, and the massive cost of development and training. As a result, the evolution of ANN was slow and distorted for an extended period. Just in the last dozen years, with the efforts of hundreds of thousands of engineers and scientists worldwide and enormous costs, ANN reappeared as a fast-evolving technology.

At the same time, substantial progress in modeling creative activities was made in the mid-1990s by Genrich Altshuller, the creator of TRIZ [1].

The main reason for his success was a brand-new approach to creativity, suggesting that instead of copying the human way of thinking, reconstructing the creative output using refined human innovation experience documented in patents and other sources of technical information resulted in identifying patterns of invention and technological evolution. In fact, he started building an artificial, more streamlined (and economical) way to transform the initial situation with the problem into the desired solution.

For decades, ANN and TRIZ have been evolving in their separate ways, until the last decades when the authors got involved in developing a new type of ANN – Progress Artificial Neural Network (PANN) based on the new approach and new model of an artificial neuron. The recent emergence of AI Chatbots has made clear the following:

- In addition to allowing to clarify the immediate possible future TRIZ evolution to reassess its past in the light of AI explosion.
- Mutually beneficial relationship between TRIZ and ANN.

Given the above, we could characterize TRIZ as a contemporary working Practical Artificial Intelligence (PAI) tool [2].

At the same time, for the first 40-50 years, TRIZ PAI was handicapped by the absence of a critical component – an adequate software platform. The attempts to develop software to support TRIZ procedures started in the late 1980s (Minsk, Belorussia, project Invention Machine, and Kishinev, Moldova, project Innovation WorkBench⁴). Since 1992, when Kishinev TRIZ School transformed into the US company Ideation International Inc, Ideation has come with over a dozen professional and simplified software packages⁵.

From the beginning, Ideation software development focused on developing a new technology suitable for the purpose of successful computerization. This technology included the following new tools:

- Analytical – helping analyze the initial problem situation and formulating directions for solutions:
 - Problem Formulator ® (PF)

⁴ ® - Registered trademark of Ideation International Inc

⁵ See at www.ideationtriz.com

- Innovation Situation Questionnaire ® (ISQ)
- Situation Assessment Questionnaire (SAQ)
- Knowledge-based – knowledge extracted from patents and other sources of information representing the best innovation practices:
 - System of Operators⁶ (over 400) for solving technological problems
 - Set of Operators (over 100) for solving business, management, logistics problems, etc.
 - Set of Patterns of technological evolution.

2. Ideation Problem Formulator® - AI-enabled Analytical Tool

- Ideation Problem Formulator (PF) is a general-purpose AI-enabled analytical tool to convert complex situations into a comprehensive set of Directions for solutions (innovations), in particular:
 - Presenting problem situations in cause-effect relationships visualized on a diagram.
 - Besides functions, it can operate with any meaningful factors (parameters, flows, conditions, objects, etc.).
 - Allowing for visual re-organization and analysis of the diagram, unveiling (and correcting real-time) various discrepancies, mistakes, missing factors, and connections.
 - All the above using plain language.

Problem Formulator (Fig.1.) has the following AI-enabled features:

- Automatically recognizes and highlights contradictions.
- Automatically converts a visual diagram into a comprehensive set of possible Directions for Innovation (solution paths) by:
 - Using cause-effect relationships between factors depicted on the diagram.
 - Capturing (from the diagram) factors and cause-effect relationships between them to generate meaningful sentences - Directions for Innovation (Solutions).
- Automatically provides more detailed solutions paths within the generated Directions (suggesting Refined Directions⁷ and/or relevant groups of Operators).

⁶ Operator – generalized term for an Inventive principle, Standard solution or Method as indicated in Classical TRIZ. It stands for a recommendation for a change to the existing system that has a potential to resolve the problem.

⁷ Refined Directions - more specific recommendations within Directions for Innovation (Solutions) generated by the Problem Formulator. See more in [3].

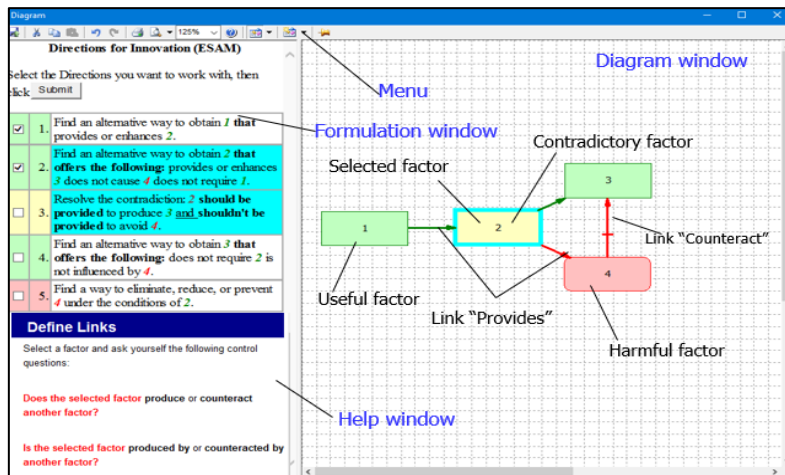


Fig.1.Problem Formulator interface

3. New Ideation Software to Work as a Front-End (SuperPrompts) to AI Chatbots

Two Ideation software have been developed recently with the purpose of simplified and more user-friendly interface and compatibility with newly introduced AI Chatbots:

- **Ideation Brainstorming software (IBS)** – a general-purpose AI-enabled analytical tool to convert complex situations into a comprehensive set of directions for solutions.
- **Express Situation Assessment and Management (ESAM)** – an AI-enabled analytical tool to address complex situations characterized by one or more of the following elements of VUCA (Volatility, Uncertainty, Complexity, Ambiguity).

Both software have similar properties as follows:

- Based on Ideation TRIZ (I-TRIZ) methodology.
- A component of Ideation Office of Innovation and Complexity Management Tools.
- Ideation Process includes three stages:
 - A. Situation Assessment Questionnaire (SAQ)
 - B. Generating Directions for Solutions (Innovation) and Brainstorming (Using Problem Formulator®)
 - C. Concept Development
- Effective as a SuperPrompt for AI Chatbots.

The software interface is shown below (Fig.2).

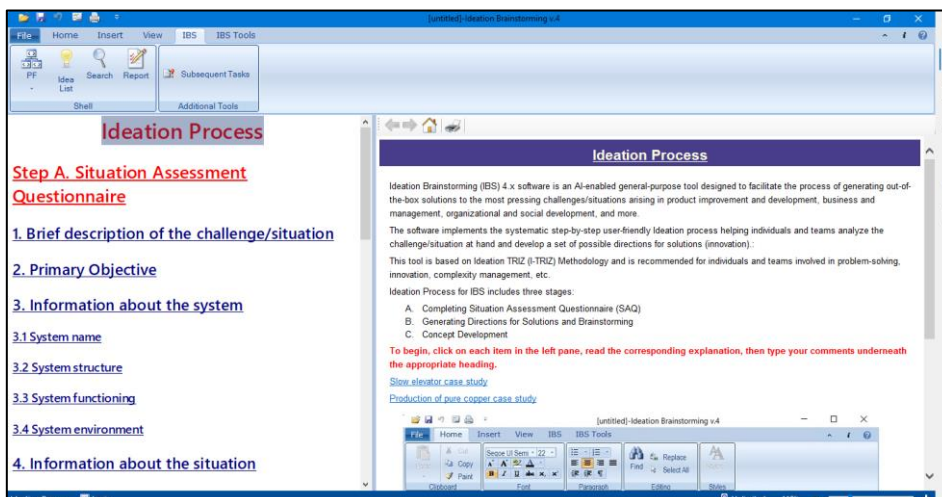


Fig.2. IBS or ESAM software interface

4. Ideation Situation Assessment Questionnaire

The Ideation Situation Assessment Questionnaire (SAQ) is a simplified version of the Innovation Situation Questionnaire® (ISQ)⁸. SAQ is a set of questions shown below (Fig.3).

- | | |
|--|--|
| <ul style="list-style-type: none">• Brief description of the challenge/situation• Primary Objective• Information about the system<ul style="list-style-type: none">• System name• System structure• System functioning• System environment• Information about the situation<ul style="list-style-type: none">• Challenge that should be resolved• Factors causing the problem/challenge• Consequences of the unresolved situation• History of the challenge | <ul style="list-style-type: none">• Ideal vision of the solution• Allowable changes to the system• Criteria for selecting solution concepts• Additional information• Project data<ul style="list-style-type: none">• Project timeline• Project team contact information |
|--|--|

Fig.3. List of SAQ questions

A list of the questions above that is convenient to use as a SuperPrompt while working with AI Chatbots is available in Appendix 1.

5. Case Study. The purpose and the method

1. The study intended to explore the effectiveness of using Ideation's new software as a Superprompt (front-end) to AI Chatbots.
2. The study has two parts:
 - Working with IBS or ESAM software, including:
 - Completion of the Situation Assessment Questionnaire (SAQ).
 - Using the Problem Formulator to build the Diagram and generate Directions for Innovation (Solutions).
 - Three sessions with ChatGPT-4, including:
 - Session 1 – working with the original problem statement.
 - Session 2 – completed Situation Assessment Questionnaire (SAQ).
 - Session 3 – working with selected Directions for Innovation (Solutions) with Refined Directions.
3. Obtained suggestions for each session with ChatGPT-4 have been divided into the following groups:

⁸ ISQ is an analytical tool designed to create a comprehensive picture of the original problem situation, a module of the professional problem-solving software Innovation WorkBench®.

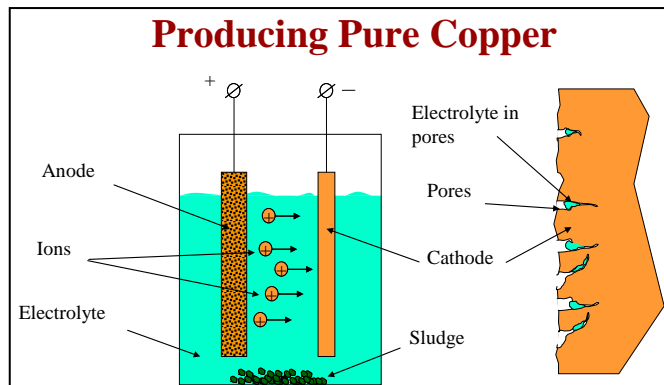
- General (obvious).
- Useful or somewhat useful.
- Interesting or creative.

6. Case Study 1. Using Ideation Brainstorming Software (IBS) with ChatGPT-4

6.1 Original problem description

Sheets of highly- pure copper are produced via the following electrolytic process: A piece of regular copper is placed into a tub containing electrolyte and connected to the d-c source's positive anode. A “seed” of pure copper is also put into the tub and is connected to the negative electrode (cathode). When current is applied, copper ions migrate from the anode and deposit on the cathode, while impurities precipitate to the bottom of the tub.

During this process, electrolyte enters the small pores that have developed on the surface of the copper sheets. The sheets are then stored before being shipped, during which time the electrolyte evaporates from the pores, leaving oxide spots on the surface of the copper. These spots detract from the product’s appearance, reducing its value and resulting in substantial losses.



To avoid this, the sheets are washed to remove the electrolyte from the pores before storage. Due to the small size of the pores, it is difficult to remove all the electrolyte. Besides, it increases costs and requires additional time. Thus, the problem was: How can the washing process be improved?

6.2 IBS: Ideation Process for Improving Pure Copper Production⁹

6.2.1 Step A. Situation Assessment Questionnaire (SAQ)

See the completed SAQ in the full report.

6.2.2. Step B. Generating Directions for Solutions and Brainstorming

1. Building the Diagram

⁹ See the full IBS report here: <https://docs.google.com/presentation/d/1q7msyD4aodzMMB-dUfh3S0rCsO8mv-hVT/edit?usp=sharing&ouid=102498674467750091976&rtpof=true&sd=true>

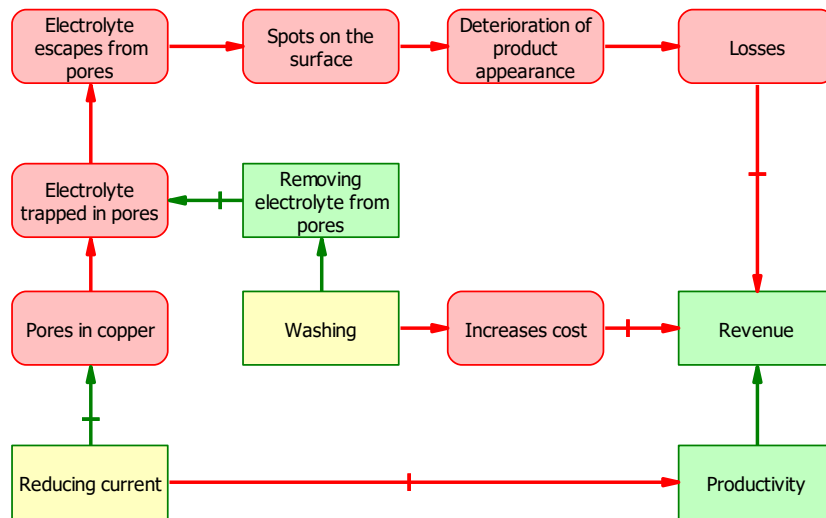


Fig.4. Diagram depicting the cause-effect description of the problem

2. Generate Directions

Directions generated – 14 (see in the full report).

6.3 Directions selected for uploading to ChatGPT-4

2. Find a way to eliminate, reduce, or prevent *Electrolyte escapes from pores* in order to avoid *Spots on the surface* under the conditions of *Electrolyte trapped in pores*.

Refined Directions: Find a way to counteract *Electrolyte escapes from pores*.

6. Find an alternative way to obtain *Reducing current* that offers the following: eliminates, reduces, or prevents *Pores in copper* does not influence *Productivity*.

7. Resolve the contradiction: *Reducing current* should be provided to counteract *Pores in copper* and shouldn't be provided to avoid counteracting *Productivity*.

Refined directions:

- Try to provide *Reducing current* at one zone and not to provide at another.
- Try to provide *Reducing current* at one time and not to provide at another.

6.4 Summary of the results

The summary¹⁰ of the results is shown below.

Table 1. Summary of the recommendations provided by Chat-GPT-4 for IBS

Session #	Session Description	Number of ChatGPT recommendations			
		Total	General (obvious)	Somewhat useful	Interesting (creative)
1	Original problem situation	4	1	3	0
2	Completed SAQ	7	2	5	0

¹⁰ See edited ChatGPT suggestions in the full report.

3	3 selected Directions (from 14 available)	7	0	6	1
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4. The number and especially the quality of the ChatGPT-4 recommendations steadily increased with the continuous use of software outcomes.
5. Just 3 of the 14 directions almost doubled the number of total ideas (7/4) compared to the original problem statement.
6. The interesting (creative) recommendation provided by the ChatGPT-4 during Session 3 (using the Direction for Innovation generated by the Problem Formulator with Refined Directions) was close to a 100% solution developed earlier by the TRIZ professional team.

7. Case Study 2. Using Ideation Express Situation Assessment & Management (ESAM) software with ChatGPT-4

7.1 Original problem description

A panic letter from a CEO of a mid-size paint-producing company received in early 2021:

"2021 is a terrible year for the paint industry. I'm not being dramatic. It is probably the worst year ever. Certainly, worse than the Covid year of 2020. This is not simply in terms of financial results, although you can see the results are worrisome.

In fact, the problems arise from the collision of myriad industry, economic and social issues, most of which you have heard about in the media. The paint industry seems to be an industry close to the locus of these many issues, due to our reliance on inputs from all over the economy, and the world.

1 - Our pricing was lagging material cost increases by ~75 days, though we have fixed that. It's a LOT of work to update hundreds of POs and prices after orders have been entered. We incentivized customers to place orders ASAP, and we told them we'd hold prices to the time of order. Honestly, we were too slow to raise prices, stuck in the mindset that we help our customers.

Bad idea, in hindsight. Not to mention the insufficient cover for LIFO "expenses."
 2 - Our production schedule is rarely able to be met. We are daily being delayed or denied raw materials, packaging, and deliveries, with a host of downstream consequences. We have canceled dozens of customer POs that have no hope of being made or shipped during the 2021 paint season. We are challenged to manage limited storage space, combined with the uncertainty that we will be able to get next month's raw materials, so take extra today.

By the way, these matters exist at our suppliers and our customers, though that is little comfort to our people."

7.2 ESAM: Ideation Process for the Paint company supply chain issues¹¹

7.2.1 Step A. Situation Assessment Questionnaire (SAQ)

See the completed SAQ in the full report.

7.2.2 Step B. Generating Directions for Solutions and Brainstorming

1. Building the Diagram

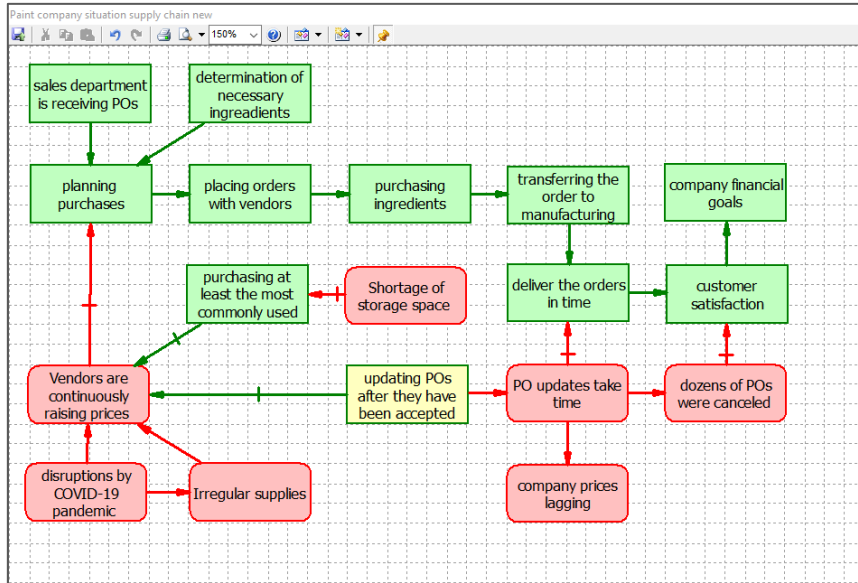


Fig.5. Diagram depicting cause-effect description of the problem

2. 2. Generate Directions

Directions generated – 19 (see in the full report).

7.3 Direction selected for uploading to ChatGPT-4

11. Find a way to eliminate, reduce, or prevent *company prices lagging* under the conditions of *PO updates take time*.

Refined Directions:

- Find a way to remove or modify the source of *company prices lagging*.
- Find a way to counteract *company prices lagging*.
- Protect your system *company prices lagging*.
- Increase your system’s resistance to *company prices lagging*.
- Convert *company prices lagging* into benefit.

¹¹ See full ESAM report here <https://docs.google.com/presentation/d/1rbDm-jzQ0ambPTk8ivzKOPY1bf0a6kdg/edit?usp=sharing&ouid=102498674467750091976&rtpof=true&sd=true>

7.4 Summary of the results

The summary¹² of the results is shown below.

Table 2. Summary of the recommendations provided by Chat-GPT-4 for ESAM

Session #	Session Description	Number of ChatGPT recommendations			
		Total	General (obvious)	Somewhat useful	Interesting (creative)
1	Original problem situation	6	4	2	0
2	Completed SAQ	7	4	3	0
3	One selected Direction (from 19 available)	5	3	1	1
4	The same Direction with refines	15	5	7	3

1. The number and especially the quality of the ChatGPT-4 recommendations steadily increased with the use of the software outcome.
2. Just one of the 19 directions produced more than double the total ideas (15/6) from the original problem statement.
3. Interesting (creative) ideas have been obtained with the use of Directions for Innovation (solutions) produced by the Problem Formulator with Refined Directions).

8. Conclusions

1. Today, various AI Chatbots became available to help find solutions to difficult challenges. However, the usefulness of a Chatbot response strongly depends on the quality of the questions.
2. The purpose of the study was to explore the effectiveness of using Ideation Brainstorming Software (IBS 4.x) and Express Situation Assessment (ESAM) as SuperPrompts (front-end) to AI Chatbots.
3. The study results have shown that the number and especially the quality of the ChatGPT-4 recommendations steadily increased with the sequential use of the software outcomes.
4. The study results have proved the use of IBS and ESAM software as Superprompts (front-end) to AI Chatbots beneficial, especially as it could compensate for the known deficiencies of available Chatbots.
5. Ideation AI-enabled Problem Formulator® software module is the most effective tool to address challenging situations. From its inception, Problem Formulator had several “smart” features, including:
 - Automatic recognition (highlighting) contradictions.

¹² See edited ChatGPT suggestions in the full report.

- Automatic capturing (from the diagram) factors and cause-effect relationships between them to generate meaningful sentences - Directions for Innovation.
- Automatic conversion of a visual diagram into a nearly exhaustive set of possible Directions for Innovation.

6. Problem Formulator is the main feature of TRIZSoft®, the Ideation Family of TRIZ-based Tools, including Ideation Office for Innovation Tools and Complexity Management.

7. Problem Formulator module can be especially beneficial for complex situations, which are often combinations of less complicated partial problems; the difficulties are in numbers, numerous, often unclear interconnections, unknown patterns, etc. Clarity of the situation (meaning understanding the nature and completeness of the list of partial problems) could be more important than the use of traditional problem-solving tools, as well-defined partial problems in complex life-related situations could often be resolved using a combination of common sense and related professional knowledge and/or experience.

8. IBS and ESAM software are available for a free 15-day trial (get IBS here: <http://oldsite.ideationtriz.com/download/setups/ibs5-15/ibs5.html>) and subscription.

Acknowledgments

Dr. Rada Granovskaya (1929-2022), a great friend and colleague – a world-renowned scientist and practitioner in psychology (psychology of creativity and innovation in particular) for explaining how our Problem Formulator technology reflects typical problem-solving thinking.

A global team of TRIZ-trained professionals that dedicated their time and efforts to find ways to use Ideation TRIZ to help organizations and individuals navigate the hardships and complexity caused by pandemics worldwide, especially the following members:

- Boudewijn Bertsch
- Bob King
- Dr. Sadegh (Ben) Babaii
- Dr. David Bonner

References

1. Altshuller, G. “Creativity as an exact science”. Translated by Anthony Williams. Gordon and Breach Science Publishers. 1984.
2. Zlotin, B. and Zusman, A. “TRIZ and Practical Artificial Intelligence”. Proceedings of the International TRIZ Conference ITC 2023: August 31, September 1-3, Graz, Austria.
3. Zlotin, B. and Zusman, A. “New Developments in the Application of TRIZ to Solving Problems in Complex Systems”. ETRIA World Conference TRIZ Future 2022, 27-29 September 22, Warsaw, Poland and online.

Appendix 1. Ideation Universal Problem-solving SuperPrompt (UPSS)

Name the system your situation relates to (product, process, technology, organization, etc.).

Describe:

1. Your challenge/situation, preferably in a single phrase.
2. The Primary Objective(s) of the situation resolution.

3. The system's components and structure. Be sure to indicate all essential elements and how they are connected.
4. What the system was designed for, and how it works.
5. Other systems that interact with your system.
6. The most challenging issue you are facing in pursuing your objective. If there is more than one, try to list them in order of importance.
7. The factors responsible for this challenge.
8. The consequences if the challenge is unresolved.
9. Previous attempts to resolve the challenge. State the reasons why these attempts were considered unsuccessful.
10. The ideal solution, that is, how the completely satisfactory situation should look like.

Optional. Describe:

- 6 The degree of changes your system can allow (small, medium, substantial, unlimited).
- 7 Measures for success.
- 8 Other factors (entities, people, conditions, regulations, etc.) that could be useful or should be considered while addressing the situation/challenge/objective.

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RESOLVING CONTRADICTIONS BETWEEN FUNCTIONALITY AND USABILITY IN TECHNICAL SYSTEMS

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Abstract

TRIZ has strong focus on functionality which is its core concept. Apart from functionality, usability is receiving lot of attention of designers of Technical systems. It would be interesting to know how functionality and usability interact and what is required for the two together to create superior technical systems.

This paper explores the nature of usability, how it comes into play in technical systems, why usability is important, how the usability- functionality contradictions originate and how they are different from other contradictions, what are some typical usability-functionality contradictions and methods of resolution. Lastly the inter-linking between functionality evolution, technology dispersal usability and aesthetics.

Keywords: *Technical systems, Functionality, Usability, Aesthetics, Technology dispersal.*

1. Introduction

Functionality of a technical system (TS) is one of the core concepts which contributes to building of the edifice of TRIZ.

TRIZ looks at functions rather than components of TS delivering those functions to arrive at breakthrough solutions for contradictions in TS to make them more efficient, simplified, cost efficient etc.

But how the functionality perceived or accessed by individual users during their interaction with the TS, is an area which needs more analysis and discussion.

There could be an implicit assumption that, firstly, functionality in a TS automatically increases its usability. Secondly there is no significant difference in accessing functionality of the TS by different individuals. Thirdly access to functionality is independent of the context in which the TS is being accessed.

There is no reason to assume that *all* individuals can access *all* TSs with same efficiency and under *all* circumstances.

Usability is that attribute of a TS which allows its intended user to access the functionalities of the TS correctly, with ease, efficiency and satisfaction.

Many functionally superior TSs have been rejected by the users because latter found using the TS cumbersome, tedious or functionality getting constrained in the context (super system environment) in which the TS is used.

Nancy Goodwin in her paper on functionality and usability[1] quotes of an instance of when an advanced communication system in a military was rejected as it was found too combursome by users who resorted to use of telephones.

Over a period of time designers of TSs in very diverse areas are finding need to resolve usability issues for success of the TSs.

There have been some attempts in addressing the topic of interface between TRIZ and Usability [2] [3] [4]. This paper attempts to initiate more discussion of Usability in the structure of TRIZ by discussing linkage between usability and functionality.

2. Functionality

It is well understood by the users of TRIZ. Functionality of a TS is its ability to change or maintain certain parameter of another object (target) which belongs to its super system.

As per one of the laws of evolution of technical systems- the law of systems completeness, there are 4 parts to any TS. The working unit- which provides the required function, the energy unit, the transmission unit and the control unit.

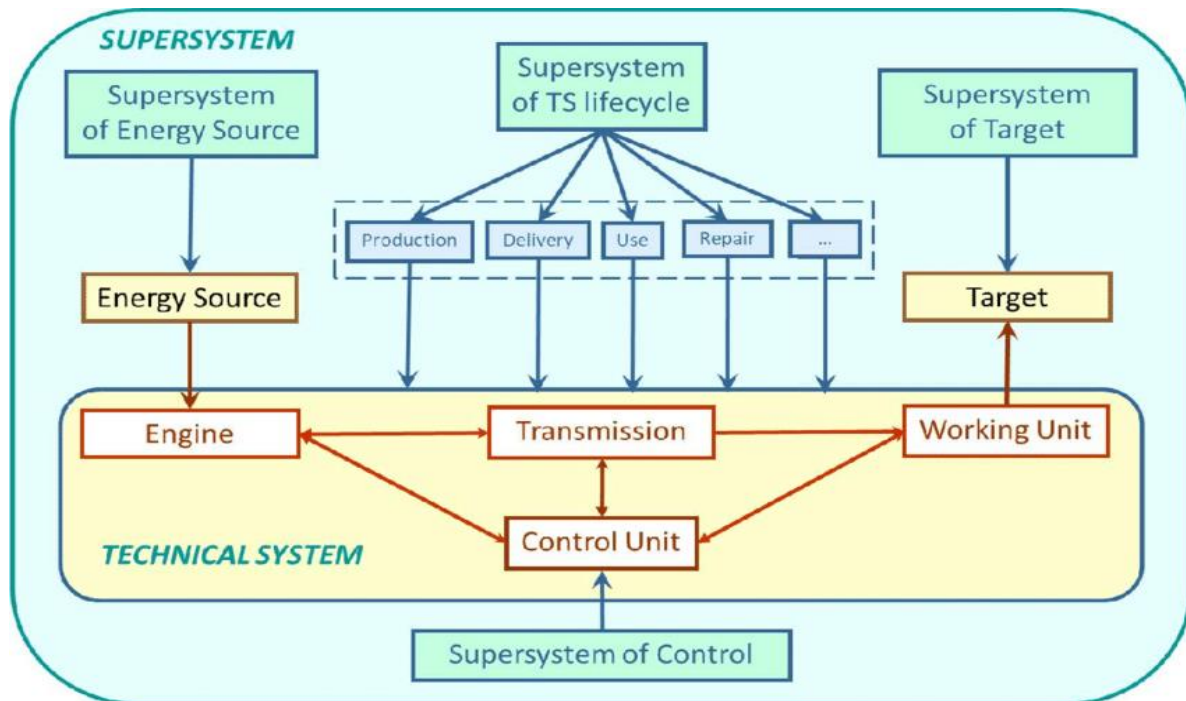


Figure1: Super systems of a Technical system.

Three parts among these interact with the super system, i.e the working part, the Energy part and the Control Part.

The working unit acts on the Object(Target) part of Super system.

The Energy unit receives energy from a source in the super system.

The ‘control’ part is the third one which interacts with super system.

There is also super system of TS life cycle as detailed in figure-1.

There is detailed discussion in TRIZ literature on super-systems of Energy, Super-system of Object (Target) and Super-system of TS lifecycle. But Super System of control is a less explored area. What are its constituents and how they interact with the TS and other super-systems?

Following is a simplified version of Super system of Control discussed in section on Human Technical system Interaction (HTSI) below.

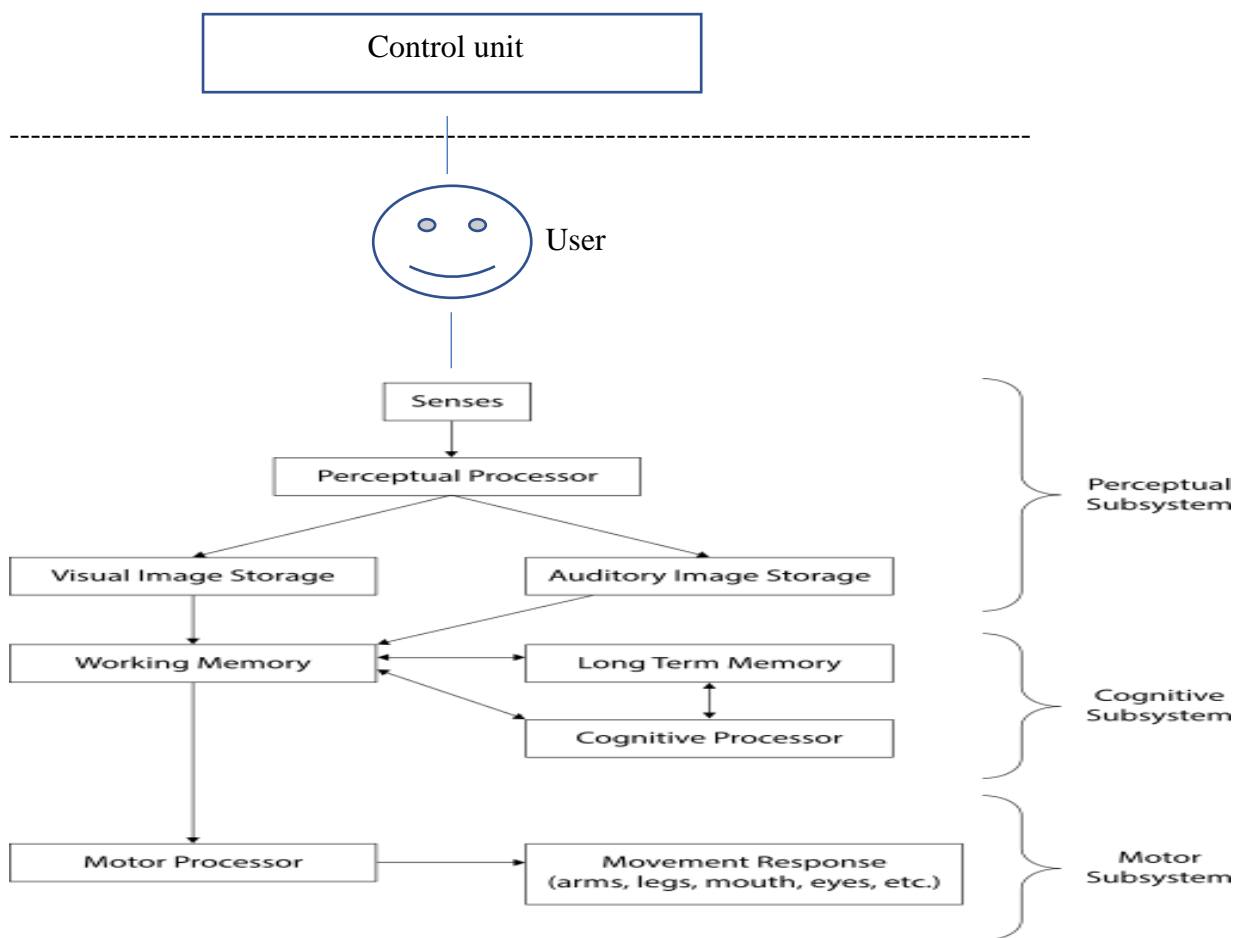


Fig.2. Super-system of Control of a TS

3. Human Technical system Interaction (HTSI)

Sometimes humans are present at all 3 nodes of TS(Energy,Target/Object,Control) which interact with the supersystem(like bicycle),in others at control and target nodes (like automobiles) or at control and energy (like all human powered TS).

But humans are present at control node of ALL technical systems.

This is true even of automated TS. These systems are programmed by humans to select information, modify it, make the subsystems work by themselves to deliver the required function.The entire automation is done by humans and the role of latter shifts to supervision and over-riding control as the automated system performs its job.

It would be unrealistic to assume that human-TS interaction which happens at the ‘control interface’ works *always* perfectly for *all* technical systems under *all* conditions.

The HTSI does not happen seamlessly. Humans understand TS through multiple filters of Perception, cognition which are internal to them and social, cultural which are external. All this is filtered into rational and emotional responses of varying type and degree and that goes into motor skills which then interact with the technical system.

The challenge for the designers is how to design TSs so that humans can engage efficiently and easily with them through constraints imposed by the above human limitations.

One extreme example of such design is the Dentist’s chair and subsystems associated with it. These have evolved to reduce kinematic load of dentist and the patient .They enable better usability of dentist’s main tool –the drill. Latter has evolved very little over years.

Thus only study of Functionality may not be enough to make superior technical systems which can be market leaders getting wide acceptance from users and making a difference to human life.

4. Usability

The concept of usability is not as concrete as that of functionality.

It can vary with the users. Even for a single user it will vary over time as she gets more familiar with ways in which the TS works.Training in use of TS also makes it more usable.

Usability is contextual and can be understood only in the context in which the user is working. For example, ‘remote’ for some air-conditioners do not have touch activated LEDs so they have low usability at night as barely awake user fumbles to see the buttons in the darkness.

Following are the five characteristics which TSs having usability have (as per ISO9241-11:2018) [5]

- **Error Tolerance:** Prevents serious errors. Warns of erroneous action. Helps reversibility of wrong action wherever possible. Support available for troubleshooting.
- **Effectiveness :**Supports user to complete the task accurately. Makes user aware of the processes at every stage.
- **Efficiency:** User can perform task quickly through easiest process.
- **Ease of learning :** New user can understand working of the TS easily. There is support throughout the usage.
- **Engagement:** User finds it comfortable pleasant to use.

Automation can increase usability in TS where a single function to be performed is complex and puts large demands on human faculties. But usability issues get transferred to the programming and control levels of automation. They are not eliminated- they change form and location (This has prompted software industry to study usability closely).

For TS with diverse multiple functions (of which Smartphone is an extreme example), automation can improve usability only to a certain extent.

The most important **test of usability** of a TS is how quickly it allows the user to internalize its functions at one's subconscious level as compared to other competing TSs.

This is similar to experience one has while driving car. Though one may be engrossed in conversation with a fellow passenger one is driving carefully and attentively.

The perception, cognition and bodily movements required for efficient control of the TS happen at sub conscious level of the user with minimal expenditure of physical and mental energy.

(Usability testing and Anticipatory failure analysis from usability perspective is not discussed here due to space constraint)

Importance of Usability: It is very important for success of a TS as compared to competing TSs for following reasons:

- User is able to complete task faster and with more accuracy. This leads to satisfaction and prevents frustration and confusion among users and creates trust.
- It helps to improve performance and productivity.
- It can result in brand loyalty, brand reputation and enhance customer acquisition and retention.
- Thus usability can give competitive advantage, increase revenue and profits.

Even if a TS is without competition, usability issues create user resistance in adoption who resort to older and (inefficient or costly) ways more due to familiarity and past comfort.

An internet service provider in India provided WIFI and TV channels in a single feed had obvious advantage of eliminating DTH subscription and save costs for the user. But the company found strong user resistance as access to different options through their 'remote' (where HTSI happens) was found complicated and not intuitive. The company lost the first mover's advantage.

Usability-functionality contradictions: Usability-functionality (U-F) contradictions (conflicts) happen at the HTSI because of the limitations of User in understanding and accessing a TS through various filters as explained in section 2 above.

Makers of the TS have strong understanding of how the TS works but an incomplete or sketchy insight of how the target user may engage with the TS and in what context. (They may even assume that the task of accessing the TS functionalities as a trivial matter). On the other hand user has incomplete or sketchy mental model of how TS works and so can have major concerns in accessing the TS. User takes for granted that context of usage and his own limitations are well understood by makers of TS.

This is the source of all U-F contradictions.

Familiarity (and/or training) may help user to better use the TS in case of U-F conflicts but it does not eliminate the conflicts.

For example, a vacuum cleaner had ‘Start/Stop’ button and ‘eject dust bag’ button side by side and of same color and size. Differentiator was alphabets on the buttons. In spite of familiarity and long usage, the error of pressing the ‘Eject’ button instead of ‘Stop’ can happen anytime while using the appliance.

All the U-F conflict happen when the TS does not have one or more of the 5 criteria of usability described earlier.

Few examples:

- In case of vacuum cleaner described above-a basic TS-has a U-F conflict because of poor effectiveness (poor support to the user to complete task accurately).
- If the consequences of wrong use of TS is very high, even simpler technical systems become much less usable because of reluctance of users as they fear making mistake. Medical syringes are simple and easily available TS but rarely used by ordinary individuals. In this case error tolerance of user is very low.
- High cognitive load from the super system (like driving on busy highway, during military operations, Nurses attending patients in an ICU) makes TS less usable. In these cases there is low engagement due to high super system load and low error tolerance due to high negative consequences of error.

U-F contradictions **have some unique characteristics.**

- These occur only in the context of HTSI.
- They occur due to human limitations internal to human mind and constraints imposed by external circumstances which reside in super system.
- These are not individual agnostic (as functionality contradictions tend to be).
- These occur only in certain context.
- A functionally perfect technical system can have one or more U-F conflicts (example of vacuum cleaner given above).

The **most common U-F conflict** happens in case of complex TSs having varied functionalities-with an intent to make them more usable in different ways. But that increases controls (buttons, knobs, levers, dials, screen, data and so forth) and that increases the load of cognition and timely action on the user. This makes the TS less usable because of human limitations as discussed earlier.

There is tendency among TSs to increase functionality and also merge with other systems. Thus this U-F conflict is increasingly seen in TSs and bound to increase in future.

This conflict or contradiction is typical physical contradiction and can be resolved by separation principles. Separation in relation (controls related to a single function, housed nearby with single color coding and/or shape). Separation in space (modules of different functions separated to avoid errors), Separation in time (different controls can be activated only in a certain sequence) etc.

In case of U-F conflicts with high super system load, many times satisfaction of opposite requirement is used in different ways.

For example, In India a major mode of retail payments is by scanning QR code with a payment app in smartphone. In busy shops and restaurants, the cashier wants to check on his smartphone if payment is received but there is no time due to rush of customers. So a device with voice prompt (using auditory signal instead of visual) was provided by a payment company to confirm receipt of money. It became a runaway hit. Now all banks and payment companies are offering this option to all traders.

In case of managing a Battle tank or fighter jet in war training in a simulated situation (do it in advance) is necessary apart from the efficiency of controls-as described earlier-to overcome U-F contradictions.

Likewise it can be demonstrated that all U-F contradictions can be resolved by TRIZ methods.

Large number of designers from multiple disciplines have already tackled different U-F contradictions successfully.

It is more efficient to take these solutions directly once the U-F conflicts are analyzed for absence of one or more usability criteria.

Specific tools to address U-F contradictions: Following are some of the ways in which above criteria have been used by the designers of TS to resolve U-F conflicts (contradictions) [6].

These can be drilled down further.

5.1 Error Tolerance:

- Good Affordance: Characteristics of TS/components that induces only correct use.
- Confirmation: Verification of intent before critical action is taken.
- Warning: Signs, prompts, alarms before imminent danger.
- Minimizing severe consequences of error. This includes the use of ‘weakest link’ (like fuse in an electric circuit).
- Factor of safety: Built in to manage the unknowns or extreme events.
- Redundancy- Using more elements than necessary to avoid failure or promote un-interrupted usage.
- Reversibility of error wherever possible.
- Good trouble shooting support.

5.2 Effectiveness:

- Ways to reduce the cognitive and kinematic load of the user.
- Clear indication of current status, possible future action and their consequences.
- Constraints on unrelated or disruptive actions.
- Low requirement to remember. Actions can be taken by recognition than recall.
- Easiest access to most frequently used and critical functions at all times.
- Usage under diverse conditions.

5.3 Efficiency:

- Layering – Functionality options are arranged in layers and presented progressively from simplest to advance to avoid information overload.
- Access is graduated in descending level of importance.
- Critical functions are highlighted and can be easily accessed always.
- Minimizing role of short term memory to chunks of 3 to 5 facts at one time.
- Intuitive functionality options.
- Little or no prior preparation required for use of the TS (point and shoot capability).
- Multiple times usage with minimal need of repairs or servicing.

5.4 Easy to learn

- Matching user's mental models.
- Using familiarity with earlier technical systems in the structure of technical system.
- Written, audio visual input for self- learning by users.
- Comprehensive 'help' options while working.
- Training (formal/informal)by experts/ influencers

5.5 Engagement: User finds technical system appealing enjoyable and satisfactory to use.

- Error Tolerance, Effectiveness, Efficiency and easy learning would contribute to satisfaction and enjoyment.
- Appeal comes not just from functionality but aesthetics especially where multiple options of the same TS are available.
- Branding and advertisements.

6. Aesthetics and usability

The TS should not only be functional and usable but it should appear friendly and inviting as compared to other competing systems and trigger an instant positive emotional response.(Applicable wherever HTSI is involved).This is particularly true in mature TS where many alternatives are available in the market.

Functionality, usability and aesthetics (in that order) form essential part of Main parameter of value (MPV) of all mature TSs.

Following is brief description of the elements can give aesthetic look to a TS. (These are also common principles of aesthetics in sculpture, architecture, paintings and fashion-design).

- Focal point: Part which draws immediate attention. This is usually the operating part of TS and highlighted in various ways.
- Balance: Spreading the 'visual weight' equally over the entire TS. Most common technique is called 'rule of thirds'.
- Proportion: It is one of the most important components of aesthetic design. Generally the 'Golden ratio' (1:1.618) and other 'Fibonacci ratios' are used. These ratios have strong linkage to aesthetics of natural things, drawing and paintings, sculpture, architecture etc.

- Contour Bias: Rounded features give more aesthetic look instead of sharp edges or jagged features. (Latter are also used in high powered motorcycles or SUVs, to give an impression of ‘mean machines’).
- Color: They influence aesthetics of TS significantly if used correctly. The usage is also contextual to the main useful function of the technical system. For items used by children the colors are bright with contrast. Whereas medical equipment colors are white, light blue or light yellow giving soothing feel. The nomenclature “white goods” show the influence of color on an entire class of TS.

7. Technology dispersal, functionality evolution, usability and aesthetics

Functionality evolution is a well-researched topic in TRIZ by many TRIZ experts like Alex Lyubomirsky, Simon Litwin and others.

There is detailed literature on how TS evolves along the S curve and details of innovations that happen at different stages one of such research paper is by Valeri Souchkov: Trends of Functionality Evolution [9].

All the literature describes ‘emergence’ of certain functionalities or ‘evolution’ of the TS.

However it is not clear as to what are the factors that lead to the ‘emergence’ of functionalities? And what drives the makers of TS to risk investment in ‘evolution’ of TS?

Driver of this change is market demand but that is not full answer.

Demand by whom and what do they exactly want?

For this it is important to understand nature of dispersal of technology in the society.

As a new TS is invented, its adoption in population is not immediate. Different people have different attitudes towards technology from tech-affinity to tech-phobia even tech-animosity. So the dispersal is gradual and follows normal distribution. This is as per the research of Everett Rogers, which is explained in his book ‘Diffusion of Innovation’ [7].

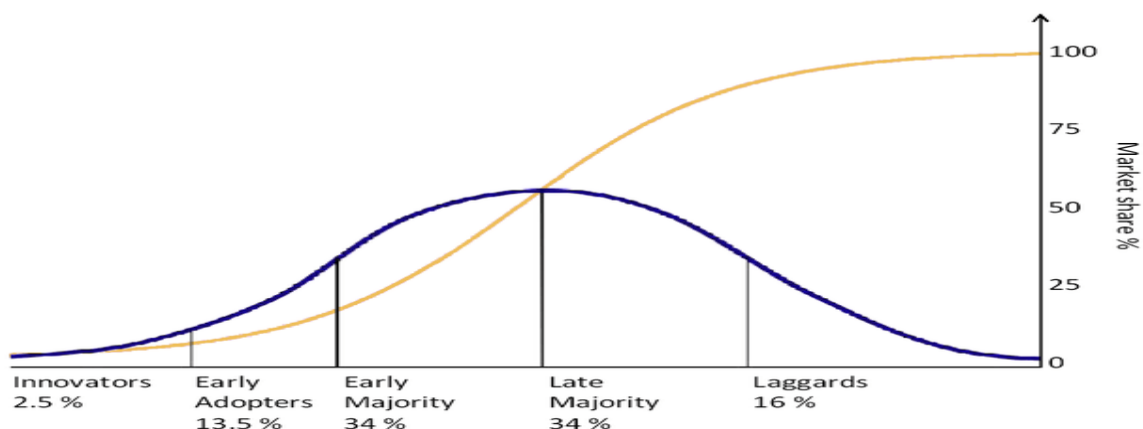


Figure 3: Dispersal of technology in the society.

According to him the technology dispersal happens in in 5 stages depending on users’ comfort with technology. Accordingly there are 5 groups of people adopting a new technical system.[8]

Innovators 2.5% ,Early adopters 13.5% , Early majority 34%, Late Majority 34%, Laggards 16%

(These percentages are indicative and may vary somewhat for different TS .Similarly the groups are also not water- tight. Further, the migration happens progressively and not in jumps).

The diffusion of TS in the society happens *by satisfying the usability demand of the next marginal class of users* to whom makers of the TS want to migrate to. (Space limitation prohibit a detailed discussion of the subject and is briefly explained here).

- **Innovators (2.5%):** Some of them are inventors of new TSs. They are venturesome and what to be first to try new innovation. They are willing to take risks and try new ideas. Poor usability of TS does not deter them. They work on it to make the TS safe and minimally useful. They keep on working on the TS even beyond this point.
- **Early Adopters (13.5%):** These are people who are opinion leaders and embrace change and new opportunities.They are very comfortable adopting new ideas. A new TS which is safe to operate is good enough for them to engage. They supplement efforts of innovators who are trying to improve the TS. Both groups contribute to improvement of user control, ergonomics (both usability characteristics) even though the main function is not improved [9]. Efforts of the 2 groups bring in basic level of efficiency and effectiveness in the TS.
- The transition from early adopters to early majority is a difficult one. For this it is important that the super systems of product (target), energy and life cycle of product to develop which are essential to large scale usage of the TS by early majority. This usage follows with a lag.
- **Early Majority(34%)** –These people are rarely leaders, but they do adopt new ideas before the average person.They make various demands. So a variety of auxiliary and additional functions get added to the TS [9]. By the time this segment of users is saturated the TS has become very complex and many variants are created. Aesthetics gradually gains importance as a part of MPV.
- **Late Majority (34%)**- These people are skeptical of change, and will only adopt an innovation after it has been tried by the early majority.They are techno-unfriendly. So trimming, feature transfer and automation are required simplify the system in order to attract them. The competition in the market has become intense by then. Advertisement and influencers are required to motivate them to buy TS of particular brand. For them learning to operate the TS is an issue and training (formal/informal) becomes important. They are also very cost conscious. A strong service network is required to build trust.
- **Laggards(16%)** - These people are bound by tradition and very conservative. They are very skeptical of change and are the hardest group to bring on board. They come as reluctant users when the TS has become commonplace in the society and has become to be seen as” necessity” rather than” novelty” or “comfort” or “luxury”.

Thus it can be seen that evolution of TS is a complex interplay between functionality, usability and aesthetics. The evolution is driven among other things by the usability needs of the incremental user class during technology dispersal.

8 Conclusions

From the above discussion we can conclude that.

- 1.1 Human Technical System interaction (HTSI) is always present at the ‘Control’ part of the technical systems.
- 1.2 Super system of control always involves humans. Humans access a TS through multiple filters and constraints which are internal to their mind or imposed by external circumstances.
- 1.3 It is not the underlying functionality of the TS which affected the user’s performance (ability to use the TS) but the ways and circumstances in which the TS could be engaged by the user. This makes of study of usability necessary.
- 1.4 There are 5 characteristics of usability and there are ways in which they can be built in the design of TS.
- 1.5 Asymmetry between producers and users in understanding of TS creates U-F contradictions which can be resolved by TRIZ methods.
- 1.6 U-F contradictions involve absence of one or more attributes of usability in TS.
- 1.7 There is an array of solutions on U-F conflicts evolved by designers of TSs in different areas which can be directly applied to U-F conflicts.
- 1.8 Aesthetics promotes individual’s engagement with TS and thus usability.
- 1.9 Human attitude towards technology varies greatly. This results in various usability demands by the next marginal class of users as the technology dispersal happens in the society. These usability demands a major driver of evolution of the TS along the S curve.

References

All the referenced material is freely accessible on the web and is sourced accordingly.

1. Nancy Goodwin: Functionality and Usability .Communications of the ACM. March1987 volume30.
2. Synergy between TRIZ and usability: A review by [Vanisri Batemanazan](#), [Azizah JaafarNorshita Mat Nayan & Rabiah Abdul Kadir](#) https://link.springer.com/chapter/10.1007/978-3-319-25939-0_45
3. “Analyzing the synergy between HCI and TRIZ in product innovation through a systematic review of literature. Shahoan chen,Khairul Manami Kamruddin, Shihua Yan. Hindawi Advances in Human-Computer Interaction Volume 2021, Article ID 6616962, 19 pages <https://doi.org/10.1155/2021/6616962>
4. [Exploiting TRIZ Tools in Interaction Design Stefano Fillippe and Daneilla Barattin. Procedia Engineering 171\(2015\)71-85](#)
5. <https://medium.com/symsoft/five-usability-factors-that-make-products-usable-573657edc9f2>
6. Universal Principles of Design- A book of compilation of 125 design principles by William Lidwell, Kritina Holden and Jill Butler
7. Everett Rogers: Diffusion of Innovation. 5 th edition .Free Press new York
8. <https://ondigitalmarketing.com/learn/odm/foundations/5-customer-segments-technology-adoption>
9. Valeri Souchkov. Trend of Functionality Evolution

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DEVELOPING SUSTAINABILITY ASSESSMENT METHODS FOR TRIZ MODELLING TOOLS BASED ON CIRCULARITY AND SDGS

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Abstract

The Sustainable Development Goals (SDGs) of the United Nations (UN) aim to address the world's most pressing social, economic, and environmental challenges and to guide international efforts towards future sustainable development. One of the frameworks for achieving many of the SDGs is the circular economy approach, which aims to create a regenerative and restorative economy, keeping resources in use for as long as possible and minimizes waste, pollution, and carbon emissions. The starting point for this paper was to utilize the power of TRIZ modelling and analysis tools to assist in identification of the most critical sustainability issues. In this paper, we introduce an approach to connect tools of TRIZ with strategies for achieving the SDGs like the mindset of circular economy.

In contrast to existing methods like Life Cycle Assessment or Carbon Footprint Analysis we aimed for an approach to identify potential for sustainability-innovations practically and quickly. To achieve this, we focus on processes and use cases instead of the product, opening the solution space for specific suggestions to innovate process steps and improve use case scenarios.

Based on the TRIZ Function Analysis for Processes and TRIZ Function Analysis for Products we developed a hands-on assessment to identify the most harmful steps in a process during production/manufacturing and potential harmful interactions based on use cases during usage phases. We will introduce a flexible quantification scheme that can be adapted to different sustainability factors, thus supporting users to work towards achievement of the Sustainable Development Goals.

Keywords: TRIZ Modelling, TRIZ Analysis Tools, TRIZ Function Analysis for Processes, Circular Economy, Cradle to Cradle (C2C), Sustainable Development Goals (SDGs), Sustainability Issues Identification, Life Cycle Assessment (LCA), Sustainability-Innovations.

1. Introduction and Background

In the wake of the creation of the VDI-standard 4521 [1] the VDI working group decided to expand its focus on how the TRIZ-tools described in the guideline could be applied to one of the most pressing global topics today: How can we mitigate the impact of the current way of producing and using products and services on the environment, thus threatening the livelihoods of humans and wildlife around the globe? How can TRIZ, as the gold standard for a systematic approach to solving tough problems, be utilized in the current environmental situation? Already, the term “sustainability innovations” has been coined [2], and TRIZ should be ideally suited to help creating them. As a result, several working groups have formed with different emphases.

The group of authors of this paper set out to specifically explore TRIZ modelling tools under the aspect of sustainability, if they can be readily used and how they might be modified to focus on reducing the environmental impact of products, processes, and services.

Although sustainability aspects are already “built in” at the core of the methodology (e.g. utilization of resources, definition of ideality, resolving contradictions), focussing on sustainability aspects has to be a conscious decision of the project team using those tools. Only conscious decision and goal setting can guide the users to reduce waste and utilize TRIZ tools mainly to decrease the usage of natural given resources by resolving contradictions etc. The significant improvements of Main Parameters of Value (MPV) of new offers should today focus also on reducing and solving the climate problems and help influencing customer’s purchasing decisions in "a green thinking and feeling way". We agree that the label “Innovation” should only be given if the sustainability aspects are considered from the ground up [3].

2. Product Lifecycle and Circular Economy

For a systemic view, we started our work by plotting the phases a primarily physical product goes through in its lifetime. In contrast to a classical linear product lifecycle as used in (traditional) Product Lifecycle Management (PLM) [4], the model shown in figure 1 reflects the circular economy attitude. It shows the brighter end of life options for a product, being reused, or recycled, thus providing input for realization of same or other products instead of being sent to landfill sites [5].

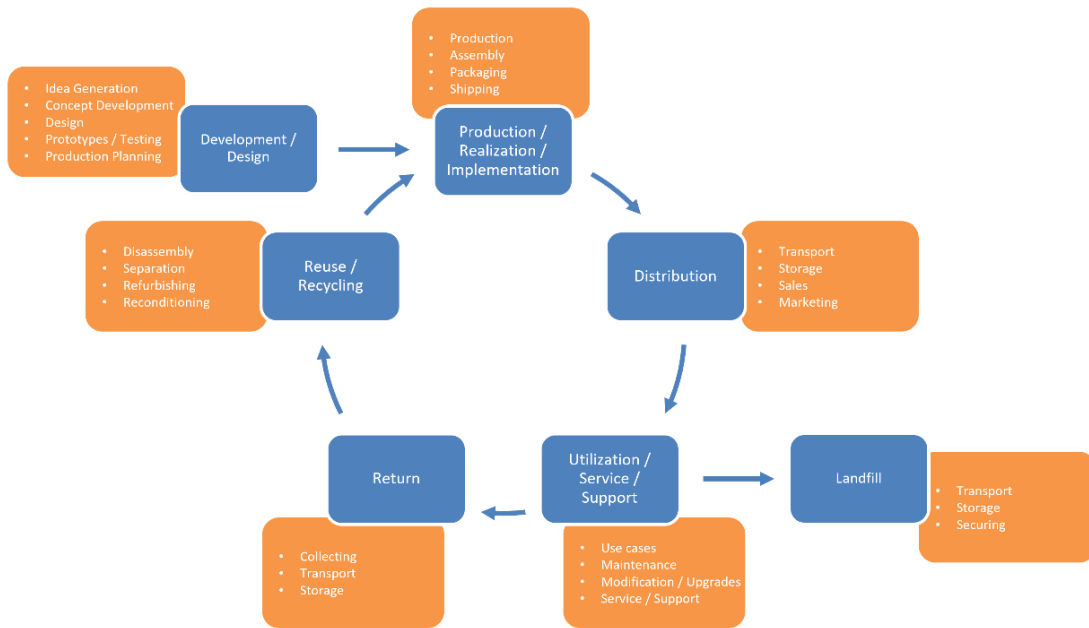


Fig. 1. Product Lifecycle with exemplary Sub-Phases

The phases considered are as follows:

- The **Development / Design** Phase is the “birth” of a product, including every effort to make the product ready for the market.
- **Production / Realization / Implementation** includes all steps necessary to create the physical product.
- **Distribution** reflects the steps necessary to bring the product to the market, respectively to the user.
- **Utilization / Service / Support** includes everything during the usage of the product. During usage, services and support might be necessary to maintain or enhance the ability of the product to perform its expected functions for the user.
- **Landfill** represents the complete loss of the product or parts of it when dumped.
- **Return** covers all actions needed to bring the product or part of the product from the user back to corporate players to be exploited further.
- **Reuse / Recycling** (including Disassembly / Separation) are actions that aim at feeding the product or parts of it back to Production / Realization / Implementation in any usable form.

Each phase of the life cycle can contain several sub-phases, depending on the type of product and usage. An exemplary collection of possible sub-phases and sub-processes for each life cycle phase is shown in Figure 1.

Not all phases have to be present when assessing a specific product. Depending on the specific case and concept, several shortcuts and interconnections between the shown phases are possible, e.g. direct reuse or redistribution of returned products or parts.

Especially for the phase “Return” and “Reuse / Recycling” the dedicated Cradle to Cradle (C2C) approach has extended the view on circular economy by defining a technical circle (Technosphere) and a biological circle (Biosphere). The C2C concept reflects an industrial flow

of materials, where recollected items feed technological processes, and a flow of biodegradable materials that serve as nutrients for regrowing resources, as shown in Figure 2 [6].

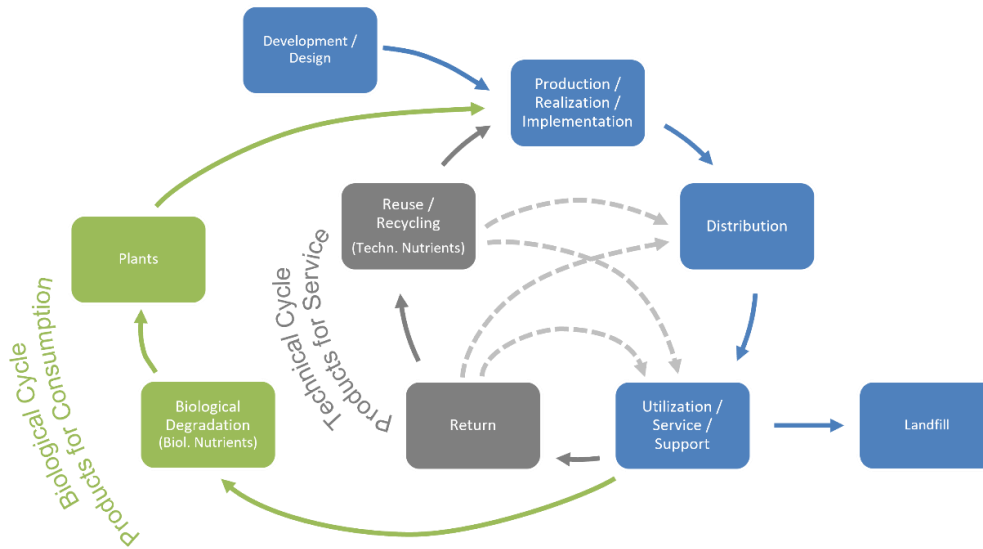


Fig. 2. Extended Life Cycle Representation with C2C-Approach

We decided that the aim, or the ideal system in TRIZ terms, of any product lifecycle should be to stay “in the loop” and generate closed circles wherever possible. Every “dead end” is considered as a total loss and should be avoided. However, circular approaches should as well be assessed in terms of negative side effects, e.g. potential monocultures as a result of growing demand of renewable resources, as well as the “rebound effect” or “Jevons paradox” [7, 8]. These challenges would best be addressed during the development / design phase, making use of the rethink and refuse steps of the “7R approach”: rethink, refuse, reduce, repurpose, reuse, recycle, rot.

3. Purpose of the Presented Approach

The existing environmental management systems [9, 10, 11] provide general recommendations and directions on planning and implementing measures to protect the environment. On the operative level, tools like Life Cycle Assessment (LCA) or the specific Carbon Footprint Analysis use a very detailed approach to evaluate the impact of a product or service as detailed as possible. Based on exhaustive databases, which are mostly integrated in software solutions and must be purchased, certain indicators are calculated for the assessed system. The results quantify the current product or service and can be used to compare different options, e.g., material alternatives or alternative production methods.

The presented approach, which is based on existing and proven TRIZ tools, is not intended as an alternative to those dedicated approaches. In contrast to the absolute results of LCA or CFA, the results of the presented method provide a relative rating of process steps compared to each other. It seeks to be a straightforward, hands-on approach based on estimations of subject matter experts and quickly identifies opportunities and scopes for action. However, it encourages the use of detailed data when and if they are obtainable, while not requiring those to produce meaningful results. Despite the hands-on attitude, the presented method can be scaled at will to drill down to any level of detail. The presented procedure should serve as an inspiration and should encourage users to start evaluating ways to improve the sustainability of their products and processes for continuous optimization.

4. Life Cycle Phase: Production / Realization / Implementation: Developing a TRIZ Sustainability Analysis for Processes

As the most suitable TRIZ modelling tool we chose the Function Analysis for Processes (FA-Process) as a base system. With respect to the life cycle model, we then identified the Production / Realization / Implementation phase as the most suitable starting point for a FA-Process aimed at sustainability aspects.

4.1 TRIZ Function Analysis for Processes

The Function Analysis for Processes is a TRIZ tool for the analysis of a given process with the aim of identifying options for improvement and further development. Subsequent tools that are usually used upstream of the FA-Process are the trimming rules for processes or problem-solving tools like contradiction analysis. FA-Process contains the following steps [12, 13, 14]:

- Process selection and scoping, definition of start and end of the process,
- Identifying operations (process steps),
- Identifying functions performed within the operations (sub-steps),
- Creating tabular and/or graphical function model for the process,
- Quantifying functionality/usefulness of each operation based on function categories,
- Quantifying cost of each operation,
- Visualization of functionality and cost in a portfolio diagram,
- Selection of next steps, e.g., trimming of functions and/or operations, application of problem-solving tools.

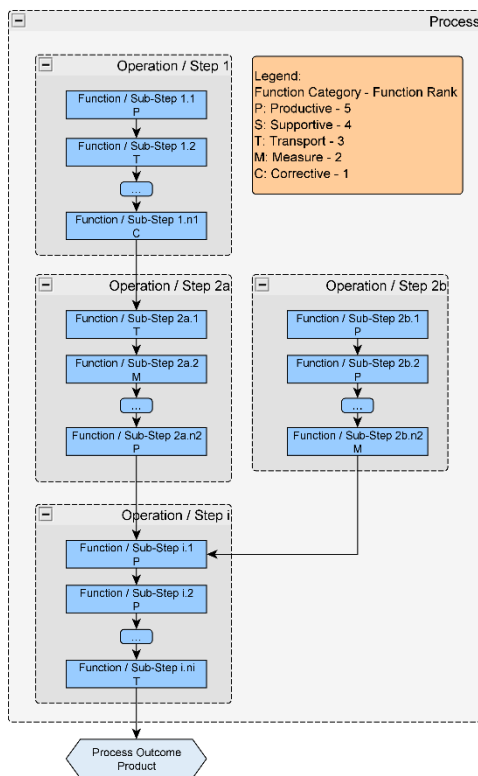


Fig. 3. General Scheme of a Graphical Function Model

Table 1. General Scheme of a Tabular Function Model

Process	Operation / Process Step	Function / Sub-Step	Function Category ^a	Function Rank (FR) ^a	Functionality Sum of FR per Step	Normalised FR per Step	Cost per Step	Normalised Cost per step
Process Name	Step 1	Sub-Step 1.1	P	5	FR1	FR1 / max(FR1, FR2a, FR2b, ... FRi)	C1	C1 / max(C1, C2a, C2b, ... Ci)
		Sub-Step 1.2	T	3				
		...						
		Sub-Step 1.n1	C	1				
	Step 2a	Sub-Step 2a.1	T	3	FR2a	FR2a / max(FR1, FR2a, FR2b, ... FRi)	C2a	C2a / max(C1, C2a, C2b, ... Ci)
		Sub-Step 2a.2	M	2				
		...						
		Sub-Step 2a.n2	P	5				
	Step 2b	Sub-Step 2b.1	P	5	FR2b	FR2b / max(FR1, FR2a, FR2b, ... FRi)	C2b	C2b / max(C1, C2a, C2b, ... Ci)
		Sub-Step 2b.2	P	5				
		...						
		Sub-Step 2b.n2	M	2				
...	
Step i	Sub-Step i.1	P	5	FRi	FRi / max(FR1, FR2a, FR2b, ... FRi)	Ci	Ci / max(C1, C2a, C2b, ... Ci)	
	Sub-Step i.2	P	5					
	...							
	Sub-Step i.ni	T	3					

^aFunction Category and associated Rank exemplary and randomly chosen

4.2 Sustainability Assessment and Quantification Scheme

While the calculation of the functionality or usefulness of each operation can be conducted by using the common function categories and ranks listed in figure 3, the calculation of the cost of each function or operation is up to the user. Often, the process time is used as an indicator of the cost: The longer a step or sub-step takes, the more it costs. Of course, other metrics and indicators can be used. FA-Process then normalizes the sum of function rank and cost for each process step, resulting in a relative assessment of the process. The “worst” process step with the least value for normalized functionality and/or highest normalized cost can then be identified, usually by plotting functionality over cost in a portfolio-diagram (see figure 7).

4.2.1 Process Input

As we wanted to target the sustainability aspect, we decided to use the ratio of input and output as an indicator for the “environmental cost” of a process. Each process step, and consequently each sub-step, requires different types of input to achieve the desired outcome. Looking through the TRIZ lens, we took the 6 types of resources as a guideline:

- Substances
- Fields (energy)
- Time (including manpower)
- Space
- Information
- Function

When applied as input for a production process, we concentrated on the most obvious resource types substances, fields (energy), time and space. For the sake of the scope of this paper, only substances will be discussed in detail.

In terms of sustainability, only a fraction of the input is utilized and adds to the value, e.g. the final outcome of the process. During each step and sub-step, several “unused” output and losses are generated. We considered those losses of any kind as harmful waste or loss, following the concept of ideality which would suggest a 100% conversion of process input into the outcome or product. This approach can also be visualized by a Sankey diagram. In the diagram shown, the input is valued at 100%, 87% of it going into the product, 9% and 4% are specific “losses”. If specific data, e.g. mass or volume of the input/output is available, the exact data can also be used.

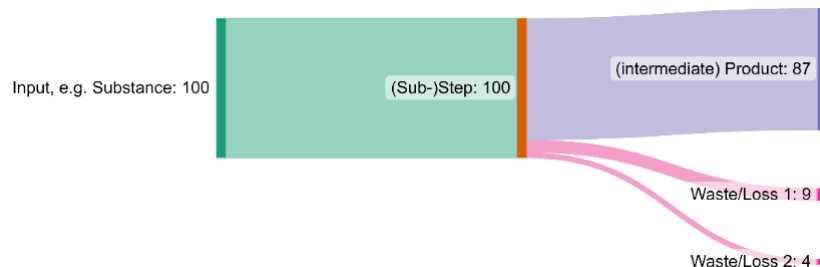


Fig. 4. Sankey Diagram of Input and Output of a Process Step

We further divided the substances in the following categories that are commonly used as input for a production process:

- Raw materials
- Semi-finished products

- Purchased parts
- auxiliary substances

These categories serve as a guideline, making a complete assessment of input easier. They can easily be modified and adjusted for specific applications.

4.2.2 Process Loss / Waste

The environmental impact of the loss or waste of each step or sub-step strongly depends on several factors. The definition of these factors was not easy and required a significant amount of time, involving discussions and testing of several attempts. Finally, we came up with the following classifications of the losses. Those were used to eventually calculate a sustainability indicator, reflecting the harm of each step:

- Amount or Percentage of loss (Amount)
- Aggregate state (State)
- Potential impact / toxicity (Impact)
- Cyclicity indicator depending on source and destination (Cyclicity)

Each factor will be introduced and explained.

The **amount or percentage of loss** can obviously be used as a general indicator of the efficiency of each step or sub-step. The lower the amount of loss / waste, the better. In our quantification scheme, the amount of loss serves as a direct factor for calculating the harm.

The **aggregate state** was used as an indicator of the difficulty in dealing with the loss. We assumed that different aggregate states can be handled easier than others when being collected or controlled. The following states were defined and assigned a value. The higher the value, the more difficult to handle or contain is the loss.

- Solid 1 point
- Liquid 2 points
- Fine dust / nebulized liquid 3 points
- Gas 4 points
- Field / Radiation 5 points

The **potential impact** on the environment addresses the toxicity of a loss. Three categories were defined and assigned a value. The higher the value the worse. However, a loss can also be potentially supporting, e.g. when a loss can be used as nutrition or fertilization in a biological circle. The value is used as a factor in the calculation of the harm.

- Potentially supporting factor 0.5
- Neutral factor 1
- Potentially toxic factor 2

The most complex indicator to define was the **cyclicity indicator**. As the cyclicity can evolve into a very complex task, we finally decided to limit ourselves to the following assessment matrix, with which a value for cyclicity of the loss can be selected:

		Destination			
		Reuse	Recycling	Energy (burning/ compost...)	Landfill
Source	Reused	1	2	4	8
	Recycled	2	4	8	16
	Virgin	3	6	12	24

Fig. 5. Cyclicity Assessment Matrix

The user can select one of three possible sources that depend on where the input comes from:

- **Reused source**
The input that was used for the assessed (sub-)step has been used before and is used with minor modifications (repaired, refurbished, reconditioned...). In terms of sustainability, this is the most beneficial source, resulting in the lowest values for the harm.
- **Recycled source**
The input of the (sub-)step comes from a recycling process. This can also include regrowing inputs from controlled cultivation or inputs from controlled sustainable production.
- **Virgin sources**
This category includes previously unused resources that are taken from the environment or from uncontrolled production. Virgin input can also be regrowing resources from uncontrolled cultivation like natural forests.

As the second variable, several destinations have been identified:

- **Reuse**
As the best option in terms of sustainability and as the ideal vision of circularity, the loss of the (sub-)step can directly be reused by any other process. As an example, wood chippings from a wood drilling process step that are directly used as insulation material.
- **Recycling**
The loss is fed into a subsequent recycling process, providing input for any other production process. E.g., wood chippings that are used to produce chipboard.
- **Energy**
This destination includes all options to convert the loss into energy sources, e.g., burning for heat or power generation, or being used as a biological energy source as e.g., compost.
- **Landfill**
The worst option is when the loss of a process (sub-)step is just dumped to the environment without any further utilization.

For a better understanding, a brief example is provided: A process involves cutting sheet metal, resulting in 3% offcut which is collected and sold to a scrap yard. For the cutting step, the input is sheet metal that is bought from a steel mill. Following the outlined scheme, the source (sheet metal) can be categorized as “virgin”, as only an insignificant amount of re-

melted metal is allowed in the sheet metal alloy. The destination can be indicated as “Recycling”, as the scrap will eventually be re-melted. The value of cyclicity according to the assessment matrix would be 6.

We are aware that the assessment matrix does not provide an exact and complete objective classification in all situations. It is moreover a tool to conduct a semi-objective evaluation of how close an evaluated process step is to an ideal closed circle. If used consciously and responsibly, the scheme is a useful assistance for subject matter experts. Also, the values given can be adjusted to decrease the weight of the circularity indicator for the overall harm. We have chosen a relatively strong bias towards a closed loop, doubling the value with worsening destination and adding the base value with worsening source.

To calculate the **overall harm** of a (sub-)step, we settled on the following formula. This formula has to be considered a preliminary suggestion, as different mathematical relations are possible to reflect various relationships between the factors used in the calculation. We decided to keep the calculation very simple:

$$\text{Harm} = [\text{Amount} + \text{Cyclicity}] \times \text{State} \times \text{Impact} \quad (1)$$

With the above stated quantification scheme, the following limits result:

$$\text{Max Harm} = [100 + 24] \times 5 \times 2 = 1240 \quad \text{Min Harm} = [\rightarrow 0 + 1] \times 0.5 \times 1 \approx 0.5 \quad (2)$$

Using the sheet metal cutting example, the overall harm of this process step is calculated as follows:

$$\text{Amount} = 5\%$$

$$\text{Cyclicity} = 6$$

$$\text{State} = \text{Solid} = 1$$

$$\text{Impact} = \text{Neutral} = 1$$

$$\text{Harm} = [5 + 6] \times 1 \times 1 = 11$$

We decided to conduct a case study to test the assessment method. The process chosen was a simplified production process of a non-electric bicycle.

5. Case Study: Bicycle Production Process

First, the bicycle production process was analyzed and split into 4 main steps, which were further divided into several sub-steps. In the second step, we analyzed the substances that go into each sub-step, aided by the substance categories defined in 0. Then we roughly estimated the percentage of loss or waste of each sub-step. The values represented have no factual background and are exemplarily chosen. Each sub-step can generate multiple losses or waste. Additionally, we used the aggregate state of the loss as an order grid to aid later quantification. The graphical representation of the analysis is shown in figure 6.

The tabular function model for this process has also been created as an excel sheet accordingly. The tabular model contains the classification of the quantification scheme introduced in 0 with the calculations of harm for each sub-step as well as calculation of normalized functionality and normalized harm for each step. These values can be used to quickly identify the “worst” process (sub-)steps relative to the other steps. The tabular function model as well as the portfolio diagram for the case study is shown in figure 7.

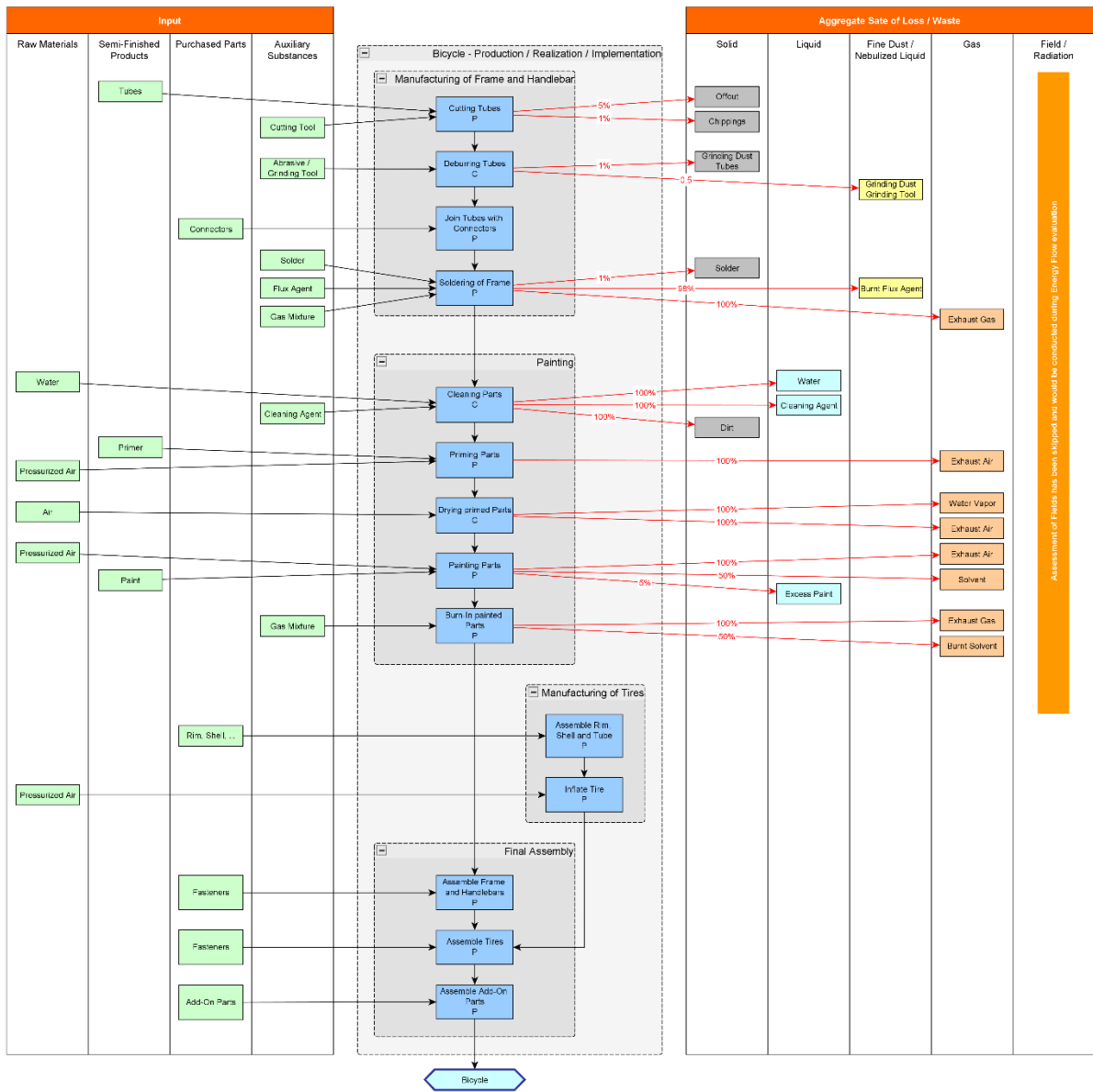


Fig. 6. Graphical TRIZ Sustainability Analysis for Processes, Bicycle Example

Step / Operation	Sub-Step / Function	Function Category	Function Rank	Input Substance	Substance Type	Output Waste / Loss	Amount in %	Source	Value	Destination	Value	Cyclicly	Aggregate State	Value	Impact	Value	Harm	
Manufacturing of Frame and Handlebar	Cutting Tubes	Prod	5.00	Tubes	Semi-Finished Products	Offcut	5.0%	Recycled	2	Recycling	2	4	Solid	1	Neutral	1	9	
				Cutting Tool	Auxiliary Substances	Chippings	1.0%	Recycled	2	Recycling	2	4	Solid	1	Neutral	1	5	
	Deburring Tubes	Cor	1.00	Abrasive / Grinding Tools	Auxiliary Substances	Grinding Dust Tubes	1.0%	Recycled	2	Landfill	8	16	Solid	1	Neutral	1	17	
	Join Tubes with Connectors	Prod	5.00	Connectors	Purchased Parts	Grinding Dust Grinding Tools	0.5%	Virgin	3	Landfill	8	24	Solid	1	Pot. Toxic	2	49	
	Soldering of Frame	Prod	5.00	Solder	Auxiliary Substances	Solder	1.0%	Virgin	3	Landfill	8	24	Solid	1	Pot. Toxic	2	50	
				Flux Agent	Auxiliary Substances	Burnt Flux Agent	98.0%	Virgin	3	Landfill	8	24	Dust / Nebulized Lix	3	Pot. Toxic	2	732	
				Gas Mixture	Auxiliary Substances	Exhaust Gas	100.0%	Virgin	3	Landfill	8	24	Gas	4	Pot. Toxic	2	992	
Painting	Cleaning Parts	Cor	1.00	Alter Cleaning Agent	Raw Materials	Water	100.0%	Virgin	3	Recycling	2	6	Liquid	2	Pot. Supporting	0.5	106	
					Auxiliary Substances	Cleaning Agent	100.0%	Virgin	3	Recycling	2	6	Liquid	2	Pot. Toxic	2	424	
						Dirt	100.0%	Virgin	3	Landfill	8	24	Solid	1	Neutral	1	124	
	Priming Parts	Prod	5.00	Primer	Semi-Finished Products	Exhaust Air	100.0%	Recycled	2	Recycling	2	4	Gas	4	Pot. Supporting	0.5	208	
					Pressurized Air	Raw Materials	Exhaust Air	100.0%	Virgin	3	Landfill	8	24	Gas	4	Pot. Supporting	0.5	208
	Drying Primed Parts	Cor	1.00	Air	Raw Materials	Water Vapor	100.0%	Recycled	2	Recycling	2	4	Gas	4	Pot. Supporting	0.5	208	
									Virgin	3	Landfill	8	24	Gas	4	Pot. Supporting	0.5	248
	Painting Parts	Prod	5.00	Paint	Semi-Finished Products	Solvent	50.0%	Virgin	3	Landfill	8	24	Gas	4	Pot. Supporting	0.5	148	
				Pressurized Air	Raw Materials	Exhaust Air	100.0%	Recycled	2	Recycling	2	4	Gas	4	Pot. Supporting	0.5	208	
						Excess Paint	5.0%	Virgin	3	Landfill	8	24	Liquid	2	Pot. Toxic	2	116	
Burning in Painted Parts	Prod	5.00	Paint	Semi-Finished Products	Exhaust Gas	100.0%	Virgin	3	Landfill	8	24	Gas	4	Pot. Toxic	2	992		
				Gas Mixture	Auxiliary Substances	Burnt Solvent	50.0%	Virgin	3	Landfill	8	24	Gas	4	Pot. Toxic	2	992	
Manufacturing of Tires	Assemble Rim, Shell, Tube	Prod	5.00	Rim, Shell, Tube	Purchased Parts		0.0%	Recycled	2	Recycling	2	4	n.n.	0	Neutral	1	0	
	Inflate Tire	Prod	5.00	Pressurized Air	Raw Materials		0.0%	Recycled	2	Recycling	2	4	n.n.	0	Neutral	1	0	
Final Assembly	Assemble Frame and Handlebars	Prod	5.00	Fasteners	Purchased Parts		0.0%	Recycled	2	Recycling	2	4	n.n.	0	Neutral	1	0	
	Assemble Tires	Prod	5.00	Fasteners	Purchased Parts		0.0%	Recycled	2	Recycling	2	4	n.n.	0	Neutral	1	0	
	Assemble Add-on Parts	Prod	5.00	Add-on Parts	Purchased Parts		0.0%	Recycled	2	Recycling	2	4	n.n.	0	Neutral	1	0	

Step / Operation	Sub-Step / Function	Sum Function Rank	Function Rank normalized	Sum Harm / Step	Normalized Harm / Step
Manufacturing of Frame and Handlebar	Cutting Tubes				
	Deburring Tubes				
	Join Tubes with Connectors				
	Soldering of Frame	16.00	94%	1854	55%
Painting	Cleaning Parts				
	Priming Parts				
	Drying Primed Parts				
	Painting Parts				
	Burning in Painted Parts	17.00	100%	3374	100%
Manufacturing of Tires	Assemble Rim, Shell, Tube				
	Inflate Tire	10.00	59%	0	0%
Final Assembly	Assemble Frame and Handlebars				
	Assemble Tires				
	Assemble Add-on Parts	15.00	88%	0	0%

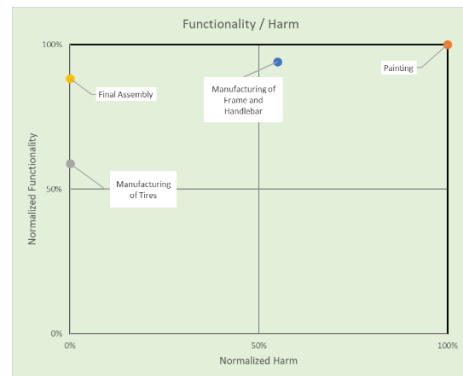


Fig. 7. Tabular TRIZ Sustainability Analysis for Processes, Bicycle Example

After working through this case study, we formulated the following framework for conducting a Sustainability Process Analysis based on the TRIZ FA-Process.

1. Initial Situation:
 - a. Who performs the analysis?
 - b. What is the product/service/subject of the assessment?
 - c. Clarification of the aim of the analysis.
2. Which life cycle phase is assessed?
3. Which process(es) exist in this phase?
4. (Graphical / tabular) Analysis of the process
 - a. Start/end of process
 - b. Identification of steps (operations)
 - c. Identification of sub-steps (functions)
5. Classify functionality of each sub-step
6. Identification of Input into steps / sub-steps
7. Identification of losses of each step/sub-step
8. Evaluating harm of each loss: Amount, cyclicly, state and impact

Optional:

9. Calculate normalized functionality and normalized harm for each step
10. Draw portfolio diagram of functionality / harm
11. Define next steps

The assessment can also be cut short after step 8 if enough insight is already generated. The graphical representation can already serve as a starting point for problem solving and take action to improve the process, e.g. by generating ideas for alternative inputs or alternative process- (sub-) steps that do not produce the identified losses and waste. Also, the trimming rules for processes can already be applied after step 8.

6. Identifying Sustainability Issues in other Life Cycle Phases

Currently we are looking into other life cycle phases, especially the utilization / service / support phase seemed to be a valuable subject for assessing sustainability issues. E.g., the use of washing machines, dishwashers etc. are suitable for being represented as processes.

However, we also wanted to explore further TRIZ modelling tools and their suitability to be directed at sustainability challenges. We decided to test the TRIZ function analysis for products (FA-Product), as this analysis tool is capable of clarifying the interactions of components of a given system with each other and with supersystems while performing its main function(s) [15]. These interactions can be specifically examined regarding potential or actual harm that is caused, either on other system components or on supersystems. For a start, we investigated the bicycle case study, the results shown in this paper represent work in progress.

6.1 Life Cycle Phase: Utilization / Service / Support – Use-Case Bicycle

In the lifecycle phase Utilization / Service / Support, several scenarios can occur. This phase can also contain multiple use cases depending on user groups, environment, and different usage situations. However, especially if we are assessing physical products during use, the FA-Product can be used as usual to model different use cases. We realized that if we are focusing on sustainability topics, wear and tear is one of the main reasons why pollution and waste is created. Starting from break dust of bicycles and cars up to the need to exchange used-up consumables.

Considering this aspect, the interactions between the components which produce wear can be highlighted. Typically, the “usual suspects” for wear are interactions that reflect actual touching parts with relative movement. As a first basic starting point, the interaction matrix of FA-Product can be used to highlight potential wear partners. Eventually, the graphical function model (figure 8) is highly suitable in visualizing causes for negative environmental impact of the assessed use case.

Each component can be an assembly of any complexity. Hence components can be marked in the graphical function model that bear potential wear in themselves or are used up due to their functionality. Figure 8 shows several highlighted interactions and components indicating sustainability issues. Of course, harmful interactions that are inherent to the systems functionality are also valuable indicators. After identifying those troublesome components and interactions, subsequent tools can then be employed to work on the identified problems. For instance, a cause-effect-chain analysis can be conducted to dive deeper into wear mechanisms, or detailed function models of components (e.g., by building nested function models [16]) can be used to investigate subsystems further. Of course, any problem-solving tools of TRIZ can be used to directly tackle identified problematic interactions or contradictions.

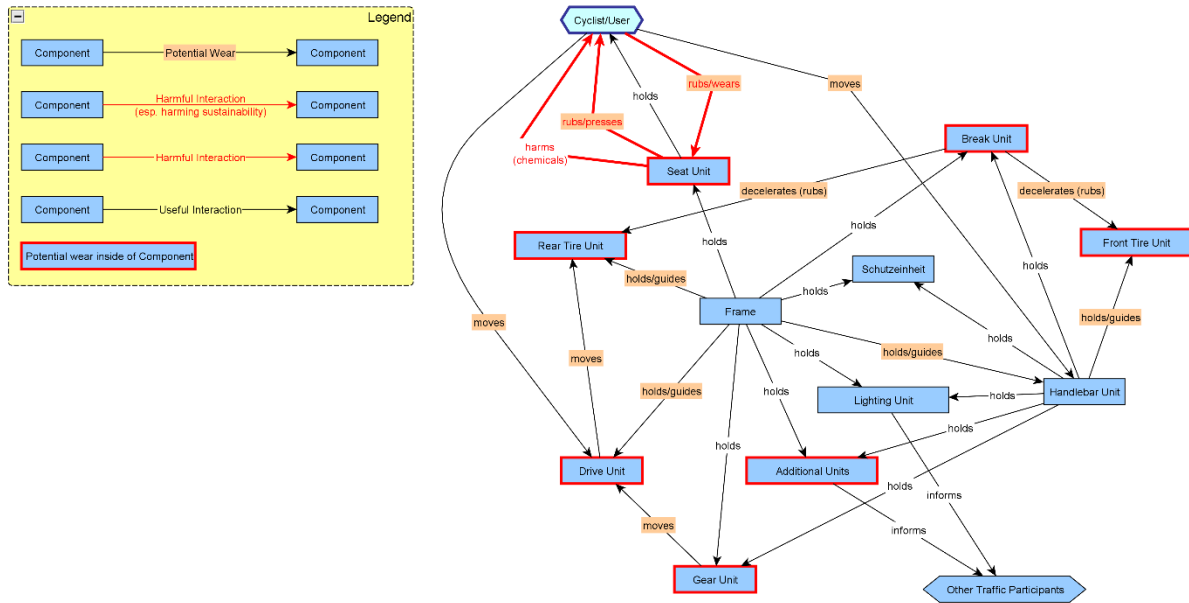


Fig. 8. TRIZ Sustainability Analysis for Products / Bicycle Example

This modification of the FA-Product represents the current state, and we will continue to look for further additions to TRIZ tools to support their applicability to sustainability challenges.

7. Conclusion and Outlook

Although TRIZ as a toolset of algorithms, concepts and methods is potentially capable of solving inventive problems in any context [17], enriching, and extending the tools for specific contexts like sustainability can significantly lower the threshold to actually using the tool.

The presented assessment methods are a valuable starting point, providing straight-forward and hands-on approaches to the analysis of processes and products to lower their environmental impact. This enables small companies and startups to quickly assess situations without having to use costly and time-consuming tools.

We are sure that there are even more options to expand TRIZ tools to be directly used for sustainability topics. Also, linking or embedding TRIZ tools to existing environmental management tools and sustainability concepts bear great potential for accelerating the implementation of the SDGs and increasing the probability for a livable future environment.

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References

1. VDI 4521 – Part 1,2 3. Inventive problem solving with TRIZ, Verein Deutscher Ingenieure e.V. 2018-2021

2. Scherb, B., Miecznik, B., Lang-Koetz, C., Vetter, J., Gronauer, B., Schnittker, F.: VDI-Handlungsempfehlung, Nachhaltigkeitsinnovationen entwickeln und umsetzen, VDI Verein Deutscher Ingenieure e.V., 2023
3. Maja Goepel, re:publica 2022: Her mit der besseren Zukunft, https://youtu.be/Ylql_4epV-Y, last accessed: June 13th, 2023
4. Stark, J.: Product Lifecycle Management: 21st Century Paradigm for Product Realisation, Springer; 2nd ed. 2011, ISBN 10: 0857295454
5. Lacy, P., Long, J., Spindler, W.: The Circular Economy Handbook, Palgrave Macmillan London, 2020, ISBN 978-1-349-95967-9
6. The Ellen MacArthur Foundation, <https://ellenmacarthurfoundation.org/circular-economy-diagram>, last accessed: June 13th, 2023
7. Owen, D.: The Efficiency Dilemma, <https://www.newyorker.com/magazine/2010/12/20/the-efficiency-dilemma>, last accessed: June 13th, 2023
8. https://en.wikipedia.org/wiki/Jevons_paradox, last accessed: June 13th, 2023
9. DIN e.V. (Hrsg.), Environmental management systems - Requirements with guidance for use, DIN EN ISO 14001:2015-11, Beuth-Verlag, 2015
10. European Union, EMAS (Eco-Management and Audit Scheme), <https://www.bmuv.de/themen/nachhaltigkeit-digitalisierung/wirtschaft/unternehmensverantwortung/-/zertifizierung/emas> , last accessed: June 13th, 2023
11. VDI 4605, Evaluation of Sustainability, Verein Deutscher Ingenieure e.V., 2017
12. Ikovenko, S.: Level 3 Training Manual. 2019
13. Nähler, H., Gronauer, B., Bertocelli, T., Beckmann, H., Chrząszcz, J., Mayer, O.: Modeling Software in TRIZ. In: Nowak, R., Chrząszcz, J., Brad, S. (eds) Systematic Innovation Partnerships with Artificial Intelligence and Information Technology. TFC 2022. IFIP Advances in Information and Communication Technology, vol 655. Springer, 2022, ISBN 978-3-031-17287-8
14. Nähler, H., Gronauer, B., Bertocelli, T., Beckmann, H., Chrząszcz, J., Mayer, O.: Modelling of Software and IT systems in TRIZ. In: Mayer, O. (eds) TRIZ-Anwendertag 2022. Springer Vieweg, 2022, ISBN 978-3-662-66200-7
15. Ikovenko, S., Przymusiala, M., Yatsunenkov, S., Barkan, M. G., Karendal, P., Kobayakov, S., Obojski, J., Vintman, Z.: State-of-the-Art TRIZ, Theory of Inventive Problem Solving. Novismo Ltd. 2019. ISBN 978-83-65899-05-7
16. Naehler, H., Gronauer, B., Using Enhanced Nested Function Models for Strategic Product Development, in: Coordination and Integration of TRIZ tools, Collection of Scientific Papers. TRIZ Developers Summit Library. Issue 6. Kiev, 2014
17. Koltze, K., Souchkov, V.: Systematische Innovation: TRIZ-Anwendung in der Produkt- und Prozessentwicklung, Hanser, 2017, ISBN-10 3446451

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IMPERCEPTIBLE DETECTION OF FLUORESCENCE – TOWARDS A PROOF-OF- CONCEPT PROTOTYPE

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Abstract

A method for detecting fluorescent markers developed using TRIZ methodology was presented during the TRIZfest-2021 conference. While observing fluorescence induced by ultraviolet radiation is used in several application areas, the unique requirements for the proposed approach were the imperceptibility of the detection and its applicability in normal ambient light conditions. The generated solution employs a weak modulated ultraviolet beam and image processing system capable of isolating and amplifying the fluorescent response of the activated markers. The substantiation phase of the project covered simulation using publicly available images taken in normal light conditions and under ultraviolet radiation. This paper describes the next project stage, aimed at designing a physical proof-of-concept prototype of a system implementing the devised method. Its primary focus is on using TRIZ thinking – especially the function and resource perspectives – to improve the original solution concept, making the prototype system easier to build and more energy-efficient. A systematic approach to incremental prototyping is also presented, which may interest both TRIZ researchers and practitioners.

Keywords: TRIZ, ultraviolet, fluorescence detection, human perception, prototyping, Proof-of-Concept

1. Introduction and previous work

1.1 The problem

Fluorescence is a phenomenon of a very short emission of electromagnetic radiation after providing an object with additional energy. It is widely used to observe visible or infrared radiation emitted in response to ultraviolet radiation (UV light). If we neglect other interactions between light and matter, the object partially reflects and absorbs the incident UV beam [1]. The absorbed energy elevates some electrons to unstable higher energy states, so they return immediately to their ground states, and for many substances, this causes fluorescent light emission. The color (spectrum) of the generated light depends on the chemical composition of the activated parts of the object [2].

Banknotes, passports, and other documents are protected against forgery with various markers imprinted with fluorescent dyes, which remain invisible in ambient light and may only be seen when illuminated (energized) with UV light. The detection is performed visually by the user,

and because the fluorescent light is relatively weak, as compared to daylight and office light, the examined document is typically observed in a darkened place (as shown in Fig. 1).

The visual assessment of the markers (their presence, locations, shapes, and colors) confirms or denies document authenticity. Such an examination is used in similar forms in airports, banks and other places where documents or banknotes are checked. Since the markers are observed with the naked eye, any person seeing the object illuminated by UV light may see the results of the examination.

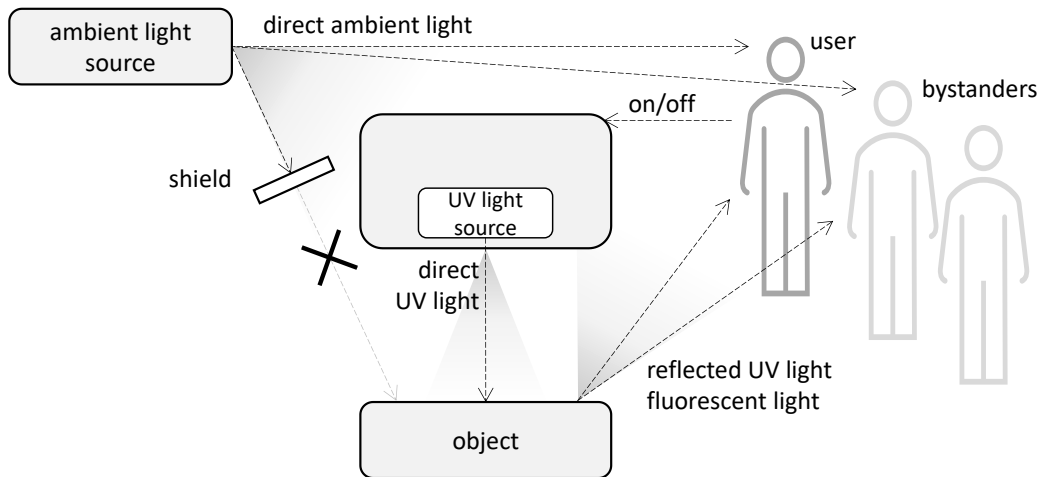


Fig. 1. A typical approach to the detection of fluorescent markers – a shield is used to block the ambient light impeding the observation, and the results may be visible to others (adapted from [3])

Such an explicit approach is inappropriate when the detection results must be delivered solely to the user, imperceptibly to others, including those under examination. This may be the case of a hidden screening of people to look for spots on the skin or clothes of an assailant left by a pepper gel or a hidden screening of banknotes to identify those marked in a specific way (e.g., passed as a ransom). Because of the covert nature of the process, it must be performed without changing the location or appearance of the examined objects. Therefore, the activation UV beam, the reflected UV light and emitted fluorescent light must not be visible to the bystanders witnessing the examination.

1.2 The solution

The process of analyzing the problem situation and generating solutions with TRIZ tools is described in [4]. The system was analyzed using Function Analysis, and the physical contradiction was formulated as follows:

- *the optical changes must be visible to the user to enable the detection of the markers, AND*
 - *the optical changes must not be visible to the bystander to keep the detection imperceptible.*
- After revealing key disadvantages through Cause-Effect Chains Analysis, the key problems were formulated, then one of the generated solution ideas was substantiated using computer simulation [3, 4], and a patent application was filed, covering the method and device.

The object is illuminated with a UV beam so weak that the reflected UV light and generated fluorescent light are invisible to humans in ambient light conditions. The activation beam is modulated so the examined object may be observed with and without UV light. This variability is essential to confirm that optical changes come from UV-induced fluorescent light. A camera

acquires and sends the object images to an image processing system, which extracts and amplifies weak color changes. Finally, the outcome is communicated to the user through an output device (see Fig. 2). The result may be an image displayed for a visual assessment, or an audio signal may be emitted in headphones when a specific response is recognized.

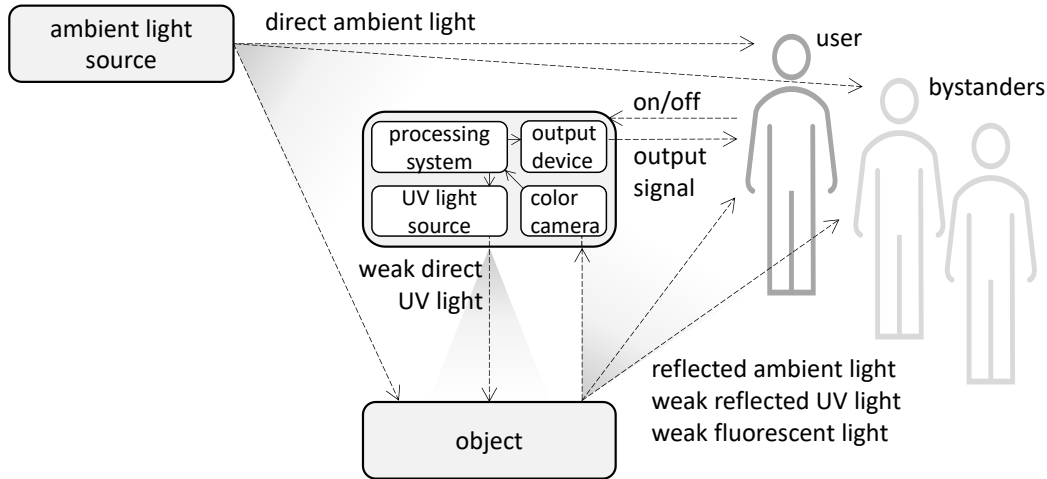


Fig. 2. Imperceptible detection of fluorescent markers in ambient light – modulated UV light induces fluorescent light too weak to be seen with the naked eye, which is acquired by a camera and extracted by an image processing system to inform the user through an output device (adapted from [3])

1.3 The detection process

The proposed detection process involves the following steps:

1. The user turns the detector on.
2. The processing system waits for a trigger from the user or starts detection automatically.
3. Two reference images, as close in time as possible, are acquired from the video stream generated by the camera, representing the observed scene with the UV beam on and off.
4. The OFF image is subtracted pixel-wise from the ON image to obtain a differential image.
5. The differential image is processed to amplify the intensities of the pixels representing fluorescent markers.
6. The system decides if the detected pattern qualifies as a hit or miss (optional step).
7. The output device communicates the result to the user with a respective modality.
8. The user turns the detector off, or the control returns to step 2.

1.4 The solution substantiation

The core of described method (steps 3-5) was validated by computer simulation using images of banknotes and documents taken in normal ambient light and under UV light [3, 4]. The image processing was implemented using Adobe Photoshop Elements application, and the results were evaluated visually and by comparing average intensities. The experiments covered restoring markers from gradually darkened UV light images and from daylight images combined with UV light images in various proportions by additive mixing. Moreover, the visibility of blinking caused by the UV beam was assessed by emulating the objects' appearance with animated GIF images built from multiple snapshots for various beam intensities and modulation variants.

It was shown that the markers might be recognized even when as small as 1% of the UV light image was added to the daylight image, while changes as big as 40% of the UV light image added to the daylight image may be difficult to spot if the transitions are sufficiently smooth. Although the markers' representations revealed using differential images were not identical to images taken under UV light, the similarity was sufficient to recognize the markers reasonably.

2. Improving the solution with TRIZ

The simulation experiments confirmed the general concept of image processing and proved the ability to transform invisibly small changes resulting from fluorescent light added to the ambient light image to easily recognizable patterns. Nevertheless, they incurred several simplifications concerning image acquisition and the samples selected [3], which should be addressed.

Typical activities performed in the substantiation phase of a TRIZ project cover identifying and solving secondary problems and maximizing benefits resulting from the changes introduced to the system. We will therefore review original project decisions regarding the devised detection process and system implementation approach.

2.1 Describing ideal solution

One of the advantages of TRIZ is the ability to direct solution search toward the ideal solution. The purpose of the system under consideration may be described as (1) *to inform the user about fluorescent markers* (2) *detected in ambient light conditions* (3) *without informing bystanders about the detection process and its results*. The first part indicates the main useful function of the detector, while the remaining parts reflect two crucial application requirements. Image processing may be described as *extracting and amplifying imperceptibly small color changes*.

The Ideal System serving such a purpose may be described as *fluorescent markers manifesting themselves in ambient light conditions solely to the user and without any cost or harm*. In other words, the more components, energy or effort are needed, the less ideal the system is.

2.2 Reviewing detection process

The original detection method is expected to produce correct results as long as the pixels of the same coordinates in two reference images represent the same area of the scene pictured. This condition is satisfied for static scenes observed with a fixed camera or when the changes in the projection of the scene onto the image sensor resulting from the relative camera movement are below single-pixel resolution. Such a requirement is challenging even in a laboratory environment, and expecting unnoticeable changes in relative pixel locations between ON and OFF reference frames in real-world applications seems unrealistic (see Fig. 3).

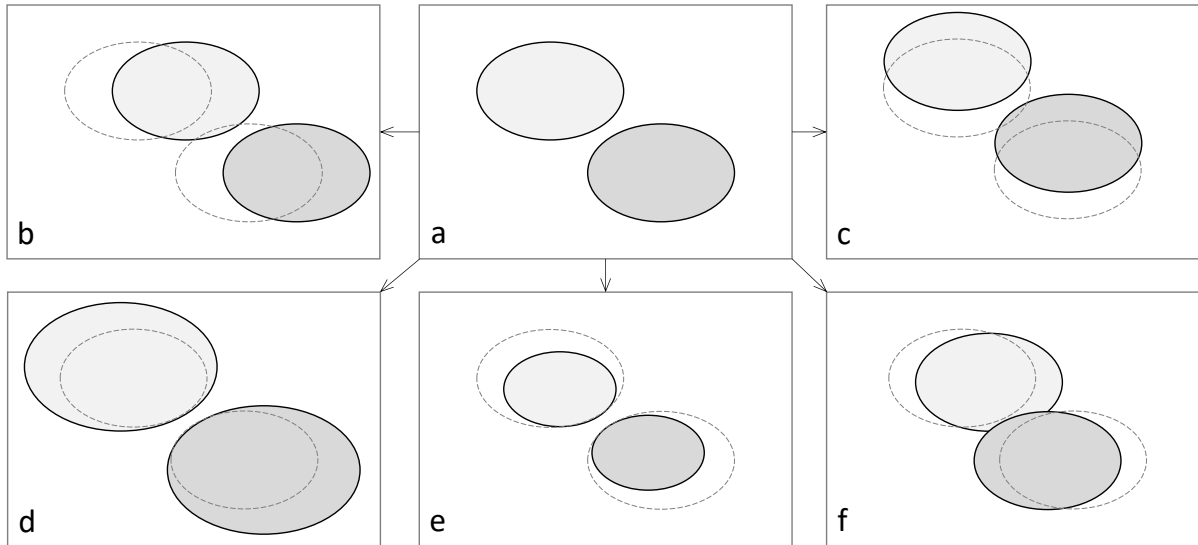


Fig. 3. Changes in a sample image (a) resulting from horizontal and vertical camera movement (b, c), a movement toward and away from the objects (d, e) and relative movement of the objects (f)

If the objects in the scene do not move with respect to each other between the acquisitions of the reference frames, then the coordinates of all pixels in the image change following the same rules. The simplest case is when the scaling of the objects is retained, and all pixels are shifted on the sensor in the same way (as in Fig. 3b, 3c). Moving the camera forward or backward will change the scales of objects, which is very likely for fluorescent marker detection performed at a relatively small distance from the examined area (see Fig. 3d, 3e).

While the constraint of negligible geometry changes between the reference frames might be alleviated by using a camera with a very high framerate, such a camera would generate a huge amount of data and require a sufficiently fast processing unit. Therefore, a cheaper and more practical approach would be to allow for small changes in the scene images acquired by the camera for the ON and OFF frames and adjust (align) the images before the subtraction.

Assuming that differences are caused by changed locations of specific objects in the field of view, we may identify corresponding objects in the reference frames and transform the coordinates of the respective pixel groups in one frame to match the other. On top of this, distortion introduced by the lens may result in nonlinear changes of pixel coordinates due to the "cushion" or "barrel" effect, even for simple scrolling or panning. Consequently, the generic approach seems to identify and match the objects between reference images using specific properties derived from these images, such as the edges representing objects' boundaries. This paradigm is used by the Scale-Invariant Feature Transform (SIFT), Speed-Up Robust Feature (SURF), Robust Independent Elementary Features (BRIF) and other methods [5].

The results of rephrasing the original description of the process to characterize elementary operations using the framework of the Function Analysis for Processes are presented in Tab. 1. Steps 3 and 4 are split to reflect the acquisition of the reference frames in different conditions and matching geometry of the reference images before they are processed pixel-wise. Steps 4a, 4b and 5 are considered normal performance with high computation cost, and the categorization of steps 3a and 3b (insufficient / high cost vs. normal / low cost) is discussed below.

Table 1. Characterization of the operations constituting the detection process

Operation	Type	Level	Cost
1. The user turns the detector on.	supporting	normal	low
2. The user or a timeout triggers the detection cycle.	supporting	normal	low
3a. Processing system acquires the reference image from the video stream with the UV beam turned on.	productive	insufficient or normal	high low
3b. Processing system acquires the reference image from the video stream with the UV beam turned off.	productive	insufficient or normal	high low
4a. Processing system aligns the reference images to match the coordinates of respective pixels.	corrective	normal	high
4b. Processing system subtracts the OFF image from the ON image pixel-wise to obtain a differential image.	productive	normal	high
5. Processing system processes the differential image to reveal the fluorescent markers.	productive	normal	high
6. Processing system qualifies the result as a hit or miss (optional step).	measurement	normal	low
7. The output device communicates the result to the user with a respective modality.	productive	normal	low
8. The user turns the detector off, or the control returns to step 2.	supporting	normal	low

2.3 Reviewing system structure

To implement the described process, we use the following system components (see Fig. 4):

- the *UV light source* to provide the marker activation beam (*direct UV light*),
- the *camera* to acquire images of the observed scene,
- the *processing system* capable of performing required image processing,
- the *output device* to inform the *user* about the detection results,
- the *energy source* powering the whole system,
- the *switch* to control the *UV light source* (at least by turning it on and off).

There are also several supersystem components necessary for successful detection:

- the *object* under examination,
- the *fluorescent light* generated by the *object* under UV illumination informs the *camera*,
- the *user* who controls the detector operation and interprets the results.

The other supersystem components, on the contrary, make the detection more challenging:

- the *bystander* must be kept unaware of the detection process and its results,
- the *ambient light source* generates *direct ambient light*,
- *direct ambient light* illuminates the *object*, masks *fluorescent light* and *reflected UV light*, and informs the *user* and *bystander* (so they can see the *ambient light source*),
- the *reflected ambient light* informs the *user* and *bystander* (so they can see the *object*),
- the *reflected UV light* and *reflected ambient light* inform the *camera*.

As the *reflected UV light* and *fluorescent light* generated by the activated areas of the *object* are, by design, too weak to be visible to the naked eye, they only affect the *camera*. Besides,

direct UV light and *direct ambient light* are assumed not to reach the *camera*. That is why no functions are indicated in the diagram between the *reflected UV light* or *fluorescent light* and the *user* or *bystander*, as well as between *direct UV light* or *direct ambient light* and the *camera*.

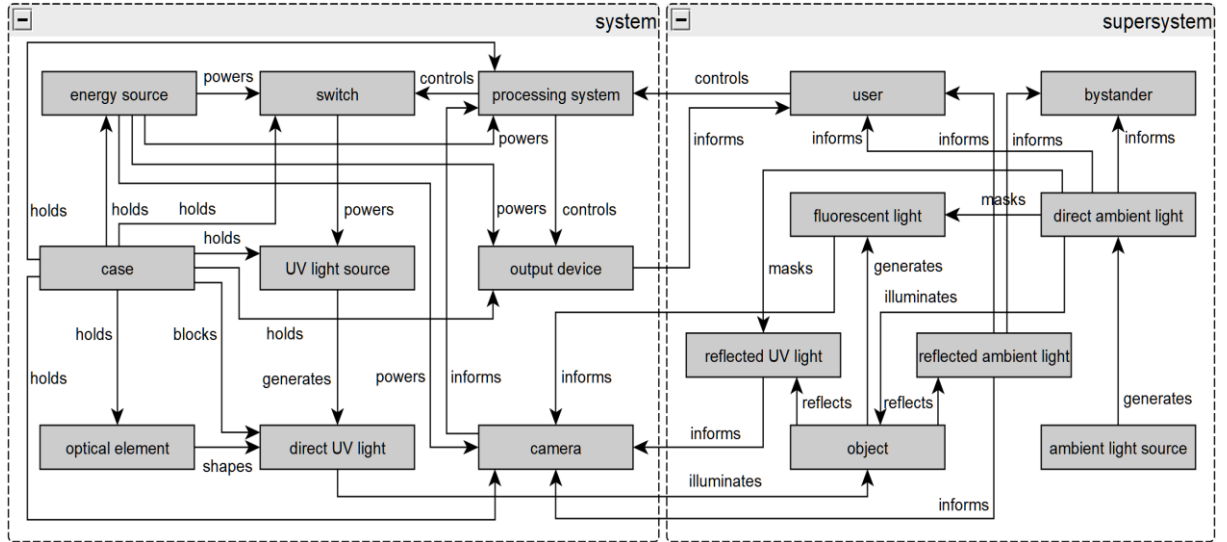


Fig. 4. Function diagram of an integrated device performing imperceptible detection of fluorescent markers in ambient light; *case* and *optical element* are omitted in the description (adapted from [4])

3. Designing Proof-of-Concept prototype

A Proof-of-Concept (PoC) prototype aims to materialize the concept for verifying whether the devised approach yields usable outcomes in realistic circumstances. Therefore, we will focus on prototyping the method (process) rather than a specific implementation (device), keeping in mind the critical success factors of imperceptible detection:

- the markers must exist on the object,
- the markers must be reachable to the activation beam and visible to the camera,
- the activation beam must have sufficiently high energy to induce fluorescence,
- the resulting color changes must be sufficiently large to be registered by the camera,
- the color changes must be sufficiently small or slow not to be noticed by bystanders.

The target system version is supposed to use smart glasses as a base system capable of acquiring and analyzing images in real-time and displaying the results to the user invisibly to other people. As commodity smart glasses are not equipped with a built-in UV light source, it must be provided as an add-on device. The possible choices include using an external UV emitter with the off-the-shelf smart glasses or developing custom smart glasses (which seems far more risky).

Attaching the UV light source to the smart glasses would simplify mechanical coordination between the emitter and the camera by aligning their optical axes, thus freeing the user from taking care of this aspect. On the other hand, a separate UV emitter may be convenient in some application scenarios, and such a configuration gives better chances for using different energy sources for the glasses and emitter. Moreover, many blinking UV lamps are available on the market, and using existing resources from the supersystem is appropriate for the first and transitional stages of the S-curved system evolution [6].

An autonomous UV emitter requires modulation parameters to be recognized directly from the video stream by detecting the frames with the minimum and maximum intensity of the beam. The application area facing a similar challenge is optical pulse detection based on minuscule changes in skin color caused by blood flow which requires computationally intensive spatio-temporal filtering [7]. These complex operations are not required if the processing system controls the modulation, and such an approach is preferred as simpler and faster.

Instead of analyzing the video stream to acquire appropriate reference images, we may grab two back-to-back still images with the UV beam switched on and off. Such an approach saves energy and increases process performance since every acquired picture is used in processing. Consequently, the choice between autonomous and controlled UV emitter implies the image acquisition steps (3a and 3b in Tab. 1) to be either insufficient / high cost or normal / low cost.

Considering the presented analysis, it was decided to use a smartphone or tablet instead of smart glasses for the PoC prototyping with the following improvements introduced to the original detection process:

- simplified image acquisition – acquiring still ON and OFF images rather than analyzing the video stream on the fly simplifies the process and decreases the energy required by the image processing system,
- simplified beam modulation – generating single pulses only during the acquisition of ON reference images rather than a continuous wave decreases the energy required by the UV emitter,
- simplified time regime – the detection cycles may be triggered asynchronously (as they are not constrained by periodical beam modulation), so the variable processing time required for matching reference images with unknown numbers of objects is acceptable.

3.1 Smartphone as a system platform

A typical smartphone integrates almost all components required to implement the prototype, with only the UV light source missing from the original component list:

- a built-in energy source – a battery that may be charged (also during system operation),
- a camera (usually more than one) able to acquire photos and videos in different formats,
- processing units (typically from 4 to 8 general-purpose cores and a graphics processor),
- output devices, such as display(s), speaker(s), headphones, vibration motor, and others.

Several software development frameworks are available, together with graphics libraries that support creating image-processing applications, especially for the Android operating system. This combination makes an Android smartphone an attractive system platform for prototyping.

3.2 Internal UV emitter

One of the main TRIZ guidelines is identifying available resources and investigating their possible applications. We need a UV light source, and what we have in a smartphone is a white LED (Light Emitting Diode) used as a photo flash and flashlight. However, a white LED is typically manufactured using a blue or UV LED activating a fluorophore prepared in such a way that the output beam appears white. Hence, blocking the visible range of the white beam may leave a weak residual UV component for some LEDs [8]. For smartphones using such LEDs, the required UV beam may be supposedly obtained using an external filter without any hardware modifications. Unfortunately, none of the smartphones examined during this paper's

preparation could induce fluorescence with its flashlight, which looked reddish through a ZWB2 UV bandpass filter rather than purple, as for UV LEDs.

Another approach is to replace the white onboard LED with a low-power UV LED, which seems a viable option, but it requires precise de-soldering and soldering of tiny surface-mount LEDs on a crowded phone circuit board, risking the failure of the whole device. Additionally, such a modification would result in the loss of the manufacturer's warranty and the inability to take photos with white light, thus limiting the cameras' usefulness in other applications.

It also seems possible to use two onboard light sources: white LED + UV LED mounted inside the phone case instead of the existing flashlight LED. However, this would require meticulous changes in hardware and low-level software. On top of this, while several integrated multi-color LEDs are offered, including UV LEDs of different wavelengths, no white LED combined with a UV LED was found, so this variant seems futuristic.

3.3 External UV emitter

Using an external emitter for detection appears attractive, as the phone can be carried, e.g., in a pocket, with the camera seeing the area of interest, and taken by hand upon receiving the signal indicating detection of markers, e.g., through wireless headphones. The activating beam should be invisible to the naked eye in normal lighting conditions, and the UV light source can be discreetly mounted in the headgear, clothing, bag, etc.

Among the wired connections available in a smartphone, we have a USB port and a coaxial audio jack for connecting a headset. Such a set usually includes stereo headphones with a microphone and volume control, and it also works as the antenna for FM radio. Wireless interfaces are available for WiFi and BLE (Bluetooth Low Energy), and some phones also have an IrDA (Infrared Data Association) port supporting two-way transmission using infrared radiation. The audio jack and IrDA used to be popular, but nowadays, they mainly appear in specialized smartphones featuring some extra capabilities.

We must equip the external emitter with a controller handling the transmission through a compatible hardware interface to use any of the mentioned connections. In addition, using standard communication protocols implies additional programming during the system development and additional delays during system operation resulting from overheads on the transmitting and receiving side. One might also consider using acoustic signals produced by the speaker, optical signals produced by the LED flashlight and phone vibration for emitter control. For the adequate flow of control signals, it is necessary to have an interface with the appropriate sensor (microphone, photoelement, etc.) on the UV emitter side.

3.4 Comparison of candidate configurations

A lineup of the mentioned configurations is presented in Tab. 2. The advantages are labeled using an implicit ordinal scale so that "common" is considered better than niche, "wireless" is better than wired, "simple" is better than complex, "all-in-one" is better than partitioned and "low-energy" better than regular. The latter advantage is additionally annotated with "+" as being crucial for a battery-operated device. Similarly, the noticeability of transmission is emphasized among the drawbacks with "-" as disqualifying.

"Hidden flash" stands for a setup with a light sensor attached to the LED flashlight and connected to the UV beam controller with a wire or located in the controller and connected to the flashlight through an optical fiber. In either case, a material link is required between the

smartphone and the beam controller. "Direct flash" stands for a configuration where these devices are optically coupled without connecting anything to the smartphone. "Integrated" denotes the configuration with the white LED replaced by a UV LED, "filtered" denotes using the original white LED with an external filter blocking visible light, while "autonomous" denotes a standalone emitter. Finally, "native" describes an imaginary futuristic configuration with a UV LED preinstalled by the smartphone manufacturer.

Table 2. The comparison of the analyzed configurations of UV emitter control

interface	pros	cons
USB	common, low-energy ⁺	needs receiver, delays
BLE	common, wireless, low-energy ⁺	needs receiver, delays
WiFi	common, wireless	needs receiver, delays
IrDA	wireless	needs receiver, delays, directional
audio jack	simple, low-energy ⁺	needs receiver
speaker	common, wireless, simple	needs receiver, easy to jam, noticeable ⁻
vibration	common, wireless, simple	needs receiver, easy to jam, noticeable ⁻
hidden flash	common, simple, low-energy ⁺	needs receiver
direct flash	common, wireless, simple	needs receiver, directional, noticeable ⁻
integrated	all-in-one, low-energy ⁺	voids warranty, removes flashlight
filtered	all-in-one, simple	needs research
autonomous	common	high computation cost
native	all-in-one, simple, low-energy ⁺	

These configurations are mapped in Tab. 3, accordingly to the number of pros and cons, and with the inherited +/- annotations. Despite the roughness of such a simplified assessment, it allows for a quick differentiation of the considered variants, reflecting their applicability and relative attractiveness. This ranking may be further refined by rejecting the variants requiring noticeable signals and introducing weights reflecting the importance of particular characteristics. As stated in section 2.1, the all-in-one design increases ideality, while extra processing required for handling autonomous emitter decreases ideality.

Table 3. The analyzed configurations mapped accordingly to the numbers of pros and cons, with the most promising variants located in the shaded quadrant

3	native ⁺	hidden flash ⁺	BLE ⁺	speaker ⁻ , vibration ⁻ , direct flash ⁻
2	audio jack ⁺ , filtered ⁺		USB ⁺ , Wi-Fi, integrated ⁺	
1	autonomous		IrDA	
0				
pros/cons	0	1	2	3

3.5 Adaptive emission control

In the simplest case, the emitter may switch UV emission of constant intensity on and off. However, the visibility of the activation beam depends on the viewing conditions, so adaptive adjustment of the beam intensity to the ambient light would make it possible to enhance the system performance. The intensity may be increased in bright ambient light to improve the detection effectiveness and reduced in dimmed light not to reveal the detection to bystanders.

The human eye perceives rapid visual changes more easily than slow ones, so it seems possible to increase detection effectiveness by replacing pulse modulation with smooth changes in the beam intensity. The experiments described in [3] showed that for gradual changes, the maximum intensity level could be 8 times higher than for an imperceptible beam modulated as a square wave with a period of 400 ms and a 50% duty ratio. These results seem a sufficient justification for considering increasing and decreasing the beam's intensity smoothly.

4. Implementing Proof-of-Concept prototype

4.1 Incremental prototyping approach

BLE interface was eventually chosen for prototyping due to its wireless, low-power operation and popularity. Developing and manufacturing a UV torch with a BLE interface is easier and less risky than building or reworking smart glasses. Also, buying a BLE-controlled UV torch and downloading an application to turn the owned smartphone into a fluorescence detector seems a more realistic scenario than buying such a torch with smart glasses. Therefore, a smartphone-based detector seems to be a candidate budget variant of the full-flavor detector using smart glasses, with a dedicated BLE-controlled emitter compatible with both versions.

The prototype implementation was successively redefined using the below outline to organize efforts incrementally and support the early detection of possible deficiencies (see Fig. 5).

- (1) we aim at smart glasses with a camera, a custom BLE-connected UV emitter and a software application as a professional product version,
- (2) we aim at an *Android smartphone or tablet* with a custom BLE-connected UV emitter and software application as a budget product version and a PoC prototype of (1),
- (3) we aim at an Android smartphone with a *custom USB-connected UV emitter* and software application as an entry product version and a PoC prototype of (2),
- (4) we aim at an Android smartphone with a custom USB-connected UV emitter and *simplified software application* as a PoC prototype of (3),
- (5) we aim at a *Windows PC with a camera*, custom USB-connected UV emitter and simplified software application as a PoC prototype of (4),
- (6) we aim at a Windows PC with a camera, *commodity USB-connected UV emitter* and simplified software application as a PoC prototype of (5).

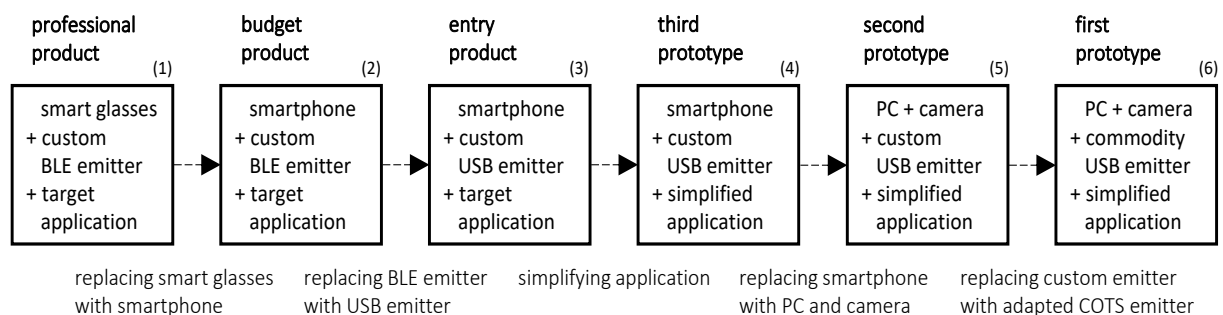


Fig. 5. Successive simplification of the PoC implementation concept

4.2 First prototype

To implement the first PoC prototype, we used the setup comprising:

- PC running Windows 10 as the system platform,
- Logitech BRIO Ultra HD Business USB webcam,

- BlinkStick Nano [9], a commodity USB LED controller adapted to drive UV LEDs,
- Custom control program managing UV emitter operation and image acquisition,
- Adobe Photoshop Elements application for processing reference images.

The BlinkStick Nano uses two WS2812 modules containing RGB LEDs integrated with a programmable controller capable of driving each LED with 256 intensity levels using PWM (Pulse-Width Modulation). One of these modules was replaced for prototyping with a WS2811 circuit containing a compatible PWM controller driving three UV LEDs (see Fig. 6).

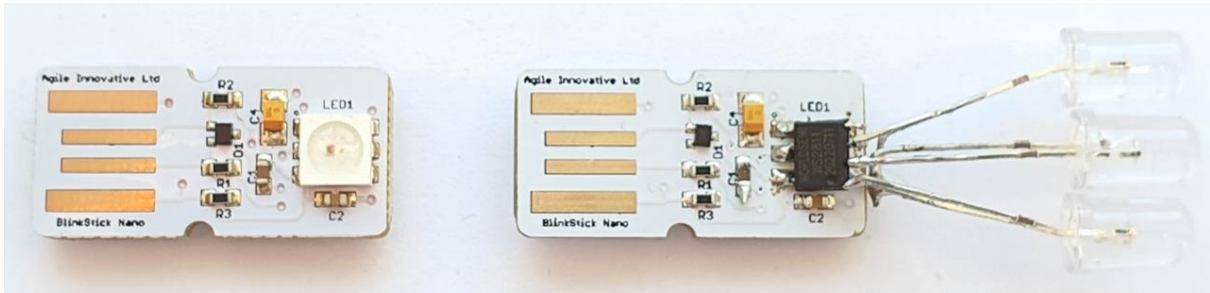


Fig. 6. Original BlinkStick Nano device (left) and its adapted version having RGB LED module with an integrated PWM controller replaced by a standalone controller and three UV LEDs (right)

The VBA (Visual Basic for Applications) program embedded in an Excel worksheet controls UV LEDs using libraries provided for BlinkStick for Windows. Similar libraries are also available for Android, so the emitter should work correctly with any Android smartphone featuring a USB OTG (On-The-Go) port. The camera is controlled using VideoCap SDK ActiveX [10].

4.3 Sample results

The control program allows for setting specific UV beam intensities and acquiring single images or a sequence of images with predefined beam intensities. Image matching and processing functions are not implemented in the current version, so the observed objects must remain still, and the acquired images were processed manually using Adobe Photoshop Elements.

A piece of a black foam sheet was sprayed with pepper gel and then washed and dried. This sample was photographed in the described installation with a color background. Fig. 7 presents the images obtained with 25% UV light intensity, as higher intensities brought a noticeable purple glow to the ON images. The activation beam seems imperceptible to the naked eye, while fluorescent spots can be easily recognized after image processing.



Fig. 7. The sample object observed in ambient light with UV light (a) and without UV light (b), and the final image (c); the differential image is not shown since it appeared entirely black

5. Summary and further work

We have presented how a solution idea may be reshaped to make it easier for PoC prototyping. Additionally, the analysis allowed for refining the original solution concept making it simpler and more energy-efficient. On top of this, the incremental prototype redefinition revealed two candidate product variants having, supposedly, bigger market potential than the initial one. These outcomes have been achieved by looking at the system from the perspective of required functions and available resources rather than specific components.

The first prototype confirmed the ability to detect fluorescent markers in ambient light using a weak UV activation beam inducing imperceptibly small color changes in the appearance of the observed objects. The following project stages should be developing the second prototype and then porting the solution to the Android smartphone platform to verify the third prototype.

References

1. Valeur, B., Berberan-Santos, M.N. "Molecular Fluorescence: Principles and Applications", 2nd ed., Wiley-VCH Verlag GmbH & Co. KGaA: Weinheim, Germany, 2012.
2. Löttsch 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.
3. Chrzęszcz J. "Using Off-the-Shelf Graphic Design Software for Validating the Operation of an Image Processing System", *Sensors* 2021, Article number: 5104. doi:10.3390/s21155104.
4. Chrzęszcz J. "Imperceptible Detection of Fluorescence – Using TRIZ to See the Invisible". In: Souchkov, V. (ed.): Proceedings of the 16th MATRIZ TRIZfest-2021 International Conference, pp. 83-97.
5. Karami, E., Prasad, S., Shehata, M. "Image Matching Using SIFT, SURF, BRIEF and ORB: Performance Comparison for Distorted Images". 2015 Newfoundland Electrical and Computer Engineering Conference, <https://arxiv.org/ftp/arxiv/papers/1710/1710.02726.pdf> .
6. Lyubomirskiy, A., Litvin, S. Ikoenko, S., Thurnes, C.M., Adunka R. "Trends of Engineering System Evolution (TESE): TRIZ paths to innovation", TRIZ Consulting Group, 2018.
7. 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.
8. Allain, R.: "How to Make UV Light Out of Your Phone's LED Flash", *WIRED* (2016), <https://www.wired.com/2016/12/make-uv-light-phones-led-flash/> .
9. BlinkStick Nano, Agile Innovative Ltd, <https://www.blinkstick.com/products/blinkstick-nano>.
10. VideoCap SDK ActiveX, <http://www.viscomsoft.com/popular-solution/117/videocap>.

[all online publications last accessed on May 31st, 2023]

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CAUSE AND EFFECT CHAIN ANALYSIS - THE ESSENCE OF UNDERSTANDING WHERE THE PROBLEM OCCURS. CASE STUDY.

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Abstract

This paper presents a case study of the application of Cause and Effect Chain Analysis as a method for understanding the root cause of a problem. The methodology of the analysis is described in detail, including the steps involved in identifying potential causes, assessing their significance, and determining their interrelationships. The results of the case study demonstrate the effectiveness of this approach in providing a comprehensive understanding of the underlying causes of a problem and highlighting potential areas for improvement. The study highlights the importance of considering multiple factors and their interconnections in order to accurately diagnose and address complex problems. The findings of this research contribute to the growing body of literature on the importance of root cause analysis in TRIZ problem-solving and offer practical insights for organizations seeking to improve their problem-solving processes.

The author's analysis revealed several interesting observations, such as the existence of multiple contributing factors to the problem under study and the importance of considering both internal and external factors in the analysis. The author also identified the potential for this method to be combined with other root cause analysis techniques for an even more comprehensive understanding of complex problems. Additionally, the author suggests that future studies could focus on the effectiveness of the Cause and Effect Chain Analysis method in different industries and organizational settings, as well as the potential for automation of the analysis process through the use of artificial intelligence and machine learning. Overall, the author believes that the Cause and Effect Chain Analysis has great potential for widespread application in various fields and encourages further development of this method for more effective problem-solving.

Keywords: CECA, TRIZ, The Iceberg of Ignorance, External TRIZ consultant skills

1. Introduction

1.1 Introduction to the concept of Cause and Effect Chain Analysis

Cause and Effect Chain Analysis is a TRIZ analytical tool that aims to identify the root cause of a problem by tracing its effects back to their underlying causes¹³. This analysis is often used in various fields, including business, engineering, and healthcare, to identify the factors that contribute to a particular problem and to develop effective solutions.

The underlying principle of Cause and Effect Chain Analysis is that every effect has a cause, and that cause, in turn, has another cause, and so on, forming a chain of causes and effects. The analysis aims to identify the key factors in this chain, starting from the most immediate and obvious causes and tracing them back to their underlying causes until the root cause is identified.

The analysis typically involves the use of a diagram called a "cause-and-effect diagram," "fish-bone diagram," or "Ishikawa diagram," named after its inventor, Kaoru Ishikawa. The diagram consists of a horizontal line representing the problem to be solved, with several "bones" branching off from it, each representing a potential cause. The main "bones" are typically labeled as people, process, equipment, materials, environment, and management, although these categories can be modified to suit the specific problem being analyzed.

Once the diagram is constructed, the analysis proceeds by identifying the most immediate and obvious causes and asking "why" until the root cause is identified¹⁴. For example, if the problem is a high rate of customer complaints, the most immediate and obvious causes might be poor customer service or product defects. Asking "why" repeatedly might reveal that the poor customer service is due to insufficient training or understaffing, while the product defects are due to inadequate quality control processes.

The ultimate goal of Cause and Effect Chain Analysis is to identify the root cause of a problem so that it can be addressed directly, rather than just treating the symptoms of the problem. This approach can lead to more effective and efficient solutions, as well as more lasting improvements.

1.2 Importance of this analysis for problem-solving

Cause and Effect Chain Analysis is a powerful problems identification tool that has several important benefits for individuals and organizations. Here are some of the key reasons why Cause and Effect Chain Analysis is important¹⁵:

¹³ Litvin S., Lyubomirsky A. "Analysis of cause-and-effect chains of undesirable effects". Methodological Guide (in Russian). IMICenter, 1998.

¹⁴ Abramov O., Kislov A. "Cause-Effect Analysis of Engineering System's Disadvantages". Methodological Guide (in Russian), Algorithm, Ltd., 2000.

¹⁵ Abramov O. "TRIZ-Based Cause and Effect Chains Analysis vs Root Cause Analysis". Proceedings of the TRIZfest-2015 International Conference, Seoul, South Korea, pp. 288295, MATRIZ 2015.

1. Identifying the root cause: One of the primary benefits of Cause and Effect Chain Analysis is that it helps identify the underlying cause of a problem. By tracing the chain of causes and effects, organizations can pinpoint the root cause of the problem and focus their efforts on addressing it directly. This can lead to more effective and efficient solutions and long-term improvements.
2. Promoting collaboration: Cause and Effect Chain Analysis typically involves multiple stakeholders, such as employees, managers, and customers. By bringing these stakeholders together to identify the root cause of a problem, organizations can promote collaboration and build consensus around the best course of action. This can help improve communication and teamwork, as well as foster a culture of problem-solving and continuous improvement.
3. Preventing future problems: By identifying the root cause of a problem and addressing it directly, organizations can prevent similar problems from occurring in the future. This can lead to cost savings, improved efficiency, and enhanced customer satisfaction.
4. Improving decision-making: Cause and Effect Chain Analysis provides a structured framework for problem-solving that helps individuals and organizations make more informed decisions. By identifying the key factors contributing to a problem, organizations can make data-driven decisions that are more likely to lead to successful outcomes.
5. Enhancing quality and safety: Cause and Effect Chain Analysis can be particularly valuable in industries where quality and safety are critical, such as healthcare and manufacturing. By identifying the root cause of problems, organizations can improve their quality control processes and reduce the risk of safety incidents.

In summary, Cause and Effect Chain Analysis is a great analytical tool that can help organizations identify the root cause of problems, promote collaboration, prevent future problems, improve decision-making, and enhance quality and safety. By using this analysis, individuals and organizations can become more effective problem-solvers and achieve better outcomes.

1.3 Outline the key principles and steps involved in the analysis

The Cause and Effect Chain Analysis (CECA) is a structured method for localize problems that involves identifying the root cause of a problem by tracing its effects back to their underlying causes. The CECA process involves several key principles and steps that must be followed to ensure a thorough and effective analysis. Here is an outline of the key principles and steps involved in the CECA process¹⁶:

1. Identify the problem: The first step in the CECA process is to clearly define the problem that needs to be solved. This should be done in a way that is specific, measurable, and relevant to the organization's goals and objectives.

¹⁶ Andersen B., Fagerhaug T. "Root Cause Analysis: Simplified Tools and Techniques". 2nd Edition, Milwaukee, Wisconsin, USA, ASQ Quality Press, 2006.

2. Define the scope: Once the problem has been identified, the next step is to define the scope of the analysis. This involves specifying the boundaries of the problem and identifying any constraints or limitations that may impact the analysis.
3. Gather data: The next step in the CECA process is to gather data related to the problem. This may involve collecting information from various sources, such as customer feedback, employee surveys, or process data.
4. Construct the cause-and-effect diagram: The cause-and-effect diagram is a visual representation of the chain of causes and effects that lead to the problem. This diagram typically includes several "bones" branching off from the problem, with each bone representing a potential cause. The main bones are typically labeled as people, process, equipment, materials, environment, and management.
5. Identify the immediate causes: The next step in the CECA process is to identify the most immediate and obvious causes of the problem. This is done by brainstorming and using other creative problem-solving techniques to identify potential causes.
6. Trace the chain of causes: Once the immediate causes have been identified, the CECA process involves tracing the chain of causes back to their underlying causes. This is done by asking "why" repeatedly until the root cause of the problem is identified.
7. Verify the root cause: Once the root cause has been identified, it is important to verify that it is, in fact, the underlying cause of the problem. This may involve testing hypotheses or conducting further research to confirm the cause.
8. Develop solutions: Finally, the CECA process involves developing solutions to address the root cause of the problem. These solutions should be practical, feasible, and effective, and should be evaluated to ensure that they address the underlying cause of the problem.

In summary, the CECA process involves several key principles and steps that must be followed to ensure a thorough and effective analysis. By following these principles and steps, organizations can identify the root cause of a problem and develop practical solutions to address it.

2. Case study

2.1 Initial situation

In the Beverage company X, an issue was identified with mold growth in a plastic bottle of orange juice, which was causing customer complaints and quality issues. The initial situation involved a high number of customer complaints related to the quality and taste of juice from that brand.



Fig. 1. Orange juice bottle, that affected a mold growth inside.

The company recognized that this issue had the potential to harm its reputation and affect customer loyalty, and therefore decided to launch internally a Cause and Effect Chain Analysis (CECA) project to identify the root cause of the problem and develop solutions to address it.

The CECA project team was formed to address the issue, and the project was divided into several stages. The first stage involved gathering data and conducting a root cause analysis to identify the underlying causes of the leakage issue. This involved collecting data on customer complaints, product testing results, and production processes, as well as conducting interviews with employees involved in the production process.

Each department was given the task of finding what could be the source of the problem. Quality Control identified the number, origin of each of the cases reported by consumers and linked them to a specific production lot. Production people checked once again whether all procedures had been followed during the production of a given batch of juice. It was analyzed whether there were any deviations or changes in parameters. Microbiologists analyzed data on chemical, microbiological and acidity parameters of ingredients. The group responsible for packaging analyzed statistical data on quality measurements of bottles and caps based on technical documentation. The testing group checked all present reports against results from previous years.

The next stage involved developing and testing potential hypothesis solutions to address the root cause of the problem. This included generation new proposals of quality control measures, improving the design of the caps, and modifying the production processes to ensure that the mold are not appears.

Proposals for solutions were then to be presented to the management at a joint meeting, where each department, based on its analyses, was to present what should be done. This multi project approach should demonstrate in the assumption the importance of using structured problem-solving methods like CECA to identify and address complex problems, and highlights the value of taking a proactive approach to quality control and customer satisfaction.

2.2 CECA process

The Cause and Effect Chain Analysis (CECA) process was used by the company to identify the root cause of the leakage issue that was affecting their beverage products. The CECA process involves a structured approach to problem-solving that aims to identify the underlying causes of a problem by tracing its effects back to their source. Unfortunately, at the joint meeting of the departments presenting the results of the CECA analysis, no clear root causes of the problem were identified. More focused on the fact that the analyzed parameters agree with the assumed

ones, the measurement results are within the assumed tolerances, and the tests performed were positive.

Here is a summary one of the department involved in the CECA process:

Define the problem: Possible leakage between cap and bottle.

Identify the scope: Analysis of the measurement results of bottles and caps with the applicable technical documentation.

Gather data: Data was gathered on the production processes, quality control measures, and customer complaints related to the leakage issue.



Fig. 2. Plastic cup design drawing and model.

Construct the cause-and-effect diagram: A cause-and-effect diagram was constructed to visually represent the chain of causes and effects that led to the leakage issue. This diagram included potential causes such as defective cap seals, overfilling of bottles, and insufficient testing and quality control measures.

Identify the immediate causes: The next step was to identify the most immediate causes of the leakage issue, such as defective cap seals.

Trace the chain of causes: The CECA process involved tracing the chain of causes back to their underlying causes by asking "why" repeatedly until the root cause was identified.

Verify the root cause: Once the root cause was identified, it was verified by conducting further research and testing hypotheses.

Develop solutions: Finally, the CECA process involved developing and implementing solutions to address the root cause of the leakage issue, such as improving quality control measures, modifying the production processes, and improving the design of the caps.

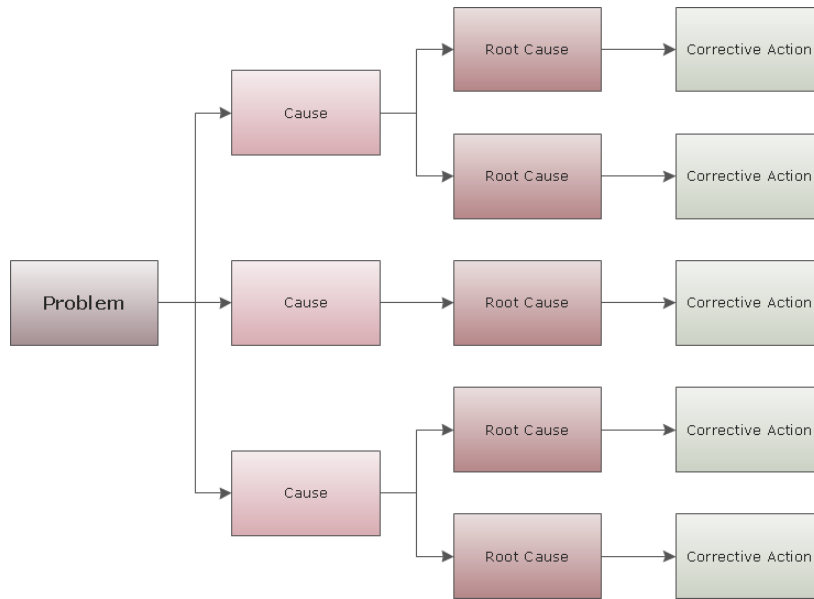


Fig. 3. The idea of build CECA diagram.

This approach of carrying out the CECA analysis by one department turned out to be insufficient. As a result of asking more questions, the group quickly entered the competence of another department. (R&D, production, testing, packaging, quality, laboratories etc.) The theoretical reasons demonstrated during this analysis must have met with a defensive reaction from another department during the presentation of all departments meeting. As a result, instead of focusing on the substantive aspect of the problem, it was shown that it is elsewhere.

2.3 The root cause of the problem

In order to motivate the squabbling departments, the hiring of an external consultant was necessary. The new CECA interaction this time was implemented in an one interdepartmental team.¹⁷ After agreeing on rules, schedule, and how to work, the original problem was addressed again. An investigative team consisting of experts in food safety, quality control, packaging, manufacturing, testing and microbiology was appointed to conduct a thorough analysis of the issue. The team followed a systematic approach that included the following steps:

1. Visual inspection and sampling: The team visually inspected the affected bottles and collected samples of mold colonies. They documented the appearance, amount and location of the mold and jointly ordered additional tests. The samples were sent to the laboratory for further analysis.

2. Root Cause Analysis: The CECA process involved cross-departmental identification and analysis of potential factors that contributed to mold growth. The investigation team investigated various areas of the production and warehousing chain, including:

¹⁷ Obojski J, Kaplan L. "TRIZ Problem Solving: Consulting vs. Facilitation" Proceedings of the TRIZfest-2017 International Conference, Kraków, Poland, pp. 798233, MATRIZ 2017.

A. Sources of Moisture: The team found that some batch bottles exhibited condensation, suggesting a potential source of leakage. They inspected the production line and discovered a faulty cooling system, resulting in excess moisture in the bottles.

B. Risk of contamination: The team reviewed hygiene practices during production and packaging. They found that inadequate cleaning of bottling equipment allowed the presence of organic matter that served as a food source for mold spores.

C. Quality Control Measures: The team evaluated quality control protocols, including cleanliness checks, monitoring procedures, and employee training. They identified deficiencies in equipment maintenance that were reducing the effectiveness of sanitation processes.

D. Packaging design and material: The investigation team examined the design of the bottle and the composition of the plastic. They found that the bottle had intricate seams and crevices that were difficult to clean thoroughly, providing ideal conditions for mold to grow. In addition, the plastic used was characterized by higher moisture permeability, allowing moisture to penetrate over time.

E. Environmental factors: The team reviewed transport and storage conditions. They found that the orange juice bottles were exposed to high temperatures during shipping, and that inadequate climate control during storage led to increased humidity levels.

3. Correlation and Conclusions: After collecting and analyzing all the data, the research team identified correlations and interactions between various factors. They concluded that mold growth was due to a combination of moisture ingress from a faulty cooling system, organic contamination, inadequate sanitation, poor packaging design, and unfavorable environmental conditions during transportation and storage.

Recommendations and corrective actions: Based on their findings, the team proposed a number of recommendations and corrective actions to prevent future cases of mold growth. They included:

- Cooling system repair to prevent excess moisture in bottles.
- Implementation of rigorous cleaning and sanitizing procedures to eliminate organic contamination.
- Improved quality control measures, such as improved equipment maintenance and employee training.
- Optimization of packaging design to minimize gaps and use of plastic with lower moisture permeability.
- Improved climate control during transport and storage to minimize temperature and humidity fluctuations.

The final conclusions about mechanism of mold growth in a plastic bottle of orange juice was caused by combination of several factors, including: the design of the cap and bottle seal, existence of mold spores, moisture, nutrients, blackout, oxygen, temperature 15-27°C, time of presence external forces during the production process, and methods and procedures of quality control.

2.4 Observations and obstacles

During the Cause and Effect Chain Analysis (CECA) process on the mold growth in a plastic bottle of orange juice issue, there were some surprising human behaviors that were observed.

One of the most notable was the reluctance of some employees to report defects or issues with the production process.

Despite the company's emphasis on quality control and continuous improvement, some employees were hesitant to report issues because they felt that it would reflect poorly on them or their department. This reluctance to report issues led to a delay in identifying the root cause of the leakage issue, which could have been addressed earlier if employees had felt comfortable reporting defects or issues.

Another surprising human behavior during the CECA process was the tendency to focus on individual incidents or occurrences rather than looking at the larger picture. Some employees were more concerned with addressing specific incidents of leakage rather than identifying the root cause of the issue and implementing long-term solutions.

This tendency to focus on individual incidents rather than the larger problem can be problematic, as it can lead to the implementation of short-term solutions that do not address the root cause of the issue. This can result in the issue resurfacing in the future, which can be costly and time-consuming to address. This behavior was amplification of the situation that we called The Iceberg of Ignorance. The top level of management rely on the numbers, KPI's and general information about the strategic activities. As a results they assumed that a few issues that they knows about it give them rights to go ahead because the risk is under control. From that perspective everything is according the best practices, rules and risk mitigation behavior. In reality that is an effect of filtering bad news by upper managers levels. Let's see how it works.

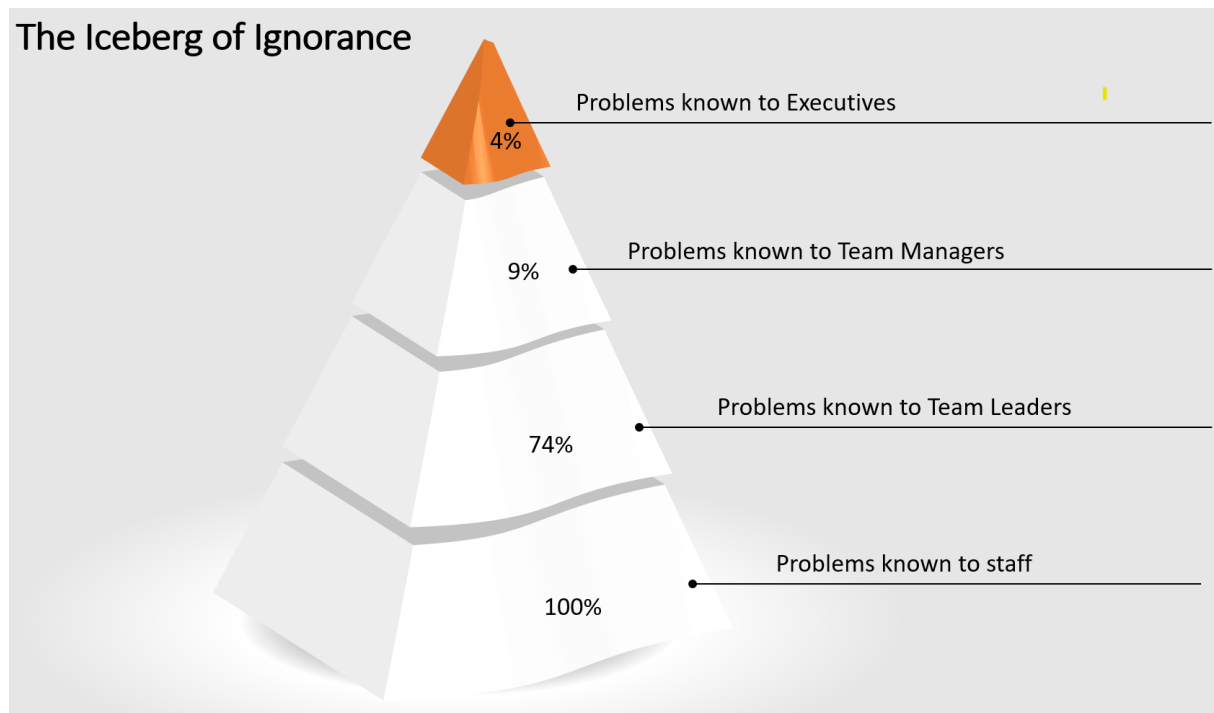


Fig. 4. The Iceberg of Ignorance effect.

Staff who dealing with real process and knows about all problems, from some reasons some of them keep it in secret to avoid punishment or losing a face etc. That portion of true situation is delivered to Team Leaders. They from similar reasons made own correction of the reality. In that case problems related with execution, control of employee should be presented in more positive way to avoid potential bad impact for their position. As a chart shown the lost what

Stuff know and Team Leaders about problems is about 26%. Very often they did a similar tasks, and feel the reality of this kind of work.

The next level is getting reports by Team Managers, and here we observe the biggest loss of information about the real problems. From the chart we can calculate the loss of known problems in range of 65%. That gap is explained from totally different background of TM. Here we have white color workers that understand language of PM and don't need knowledge about process, machines and operations issues.

The Iceberg of Ignorance effect¹⁸ is a phenomenon that highlights the vast disparity between what leaders perceive and what employees actually experience within an organization. Coined by consultant and author Sydney Yoshida in the late 1980s, the concept compares organizational issues to an iceberg, with the visible portion representing the problems known to management, and the larger, submerged portion symbolizing the hidden problems concealed from their view.

According to research, the Iceberg of Ignorance effect suggests that top-level executives are often unaware of a significant portion of workplace issues, which are more visible and known at lower levels of the organization. This knowledge gap can impede effective decision-making and hinder the resolution of critical problems. The reasons behind this information asymmetry vary, including hierarchical barriers, ineffective communication channels, and a lack of employee engagement.

To address the Iceberg of Ignorance effect, organizations must foster open lines of communication and encourage feedback at all levels. Creating a culture of transparency, trust, and collaboration allows employees to share their experiences, concerns, and suggestions without fear of retribution. Implementing regular feedback mechanisms, such as surveys, suggestion boxes, or town hall meetings, can help surface hidden issues and ensure they are addressed promptly.

By acknowledging and addressing the Iceberg of Ignorance effect, organizations can bridge the gap between leadership and employees, leading to improved decision-making, increased employee satisfaction, and a more productive and harmonious work environment.

That dangerous situations had place in beverage company during investigation about the leakage issue. Firstly the top white color try to deal with situation believes that all computer data. KPI's and own knowledge will be enough to fix it and close the topic. As a results after a few rounds of CAECA they got a lot tough questions that there are no answers in charts, data and KPI's.

Despite these challenges, the CECA process ultimately proved to be an effective tool for identifying the root cause of the leakage issue and developing targeted solutions to address the issue. By engaging employees in the process and emphasizing the importance of quality control and continuous improvement, the company was able to improve the quality of their products and reduce the number of customer complaints related to the leakage issue.

¹⁸ Nadja El Kassar (2018) What Ignorance Really Is. Examining the Foundations of Epistemology of Ignorance, *Social Epistemology*, 32:5, 300-310, DOI: 10.1080/02691728.2018.1518498

In conclusion, the CECA process can uncover surprising human behaviors during the identification of root causes of problems. To avoid these behaviors, it is important to establish a culture of transparency, accountability, and continuous improvement. By doing so, employees will feel comfortable reporting issues and focus on identifying the root cause of problems to develop effective long-term solutions.

To overcome the Iceberg of Ignorance effect and avoid problems arising from a lack of knowledge within beverage company organization, several strategies was implemented:

1. Encourage open communication: Create a culture that values open and honest communication at all levels. Encourage employees to share their insights, concerns, and ideas without fear of reprisal. This can be done through regular team meetings, suggestion boxes, or online platforms where employees can provide feedback anonymously.
2. Establish multiple feedback channels: Implement various feedback mechanisms, such as surveys, focus groups, or one-on-one meetings, to gather information from employees at different levels of the organization. This ensures a diverse range of perspectives and helps uncover hidden issues that may not be immediately apparent to top-level executives.
3. Flatten hierarchical structures: Foster an environment where hierarchical barriers are minimized, and employees feel comfortable speaking up to share their knowledge and experiences. Encourage cross-functional collaboration and promote a sense of ownership and responsibility among all employees.
4. Conduct regular assessments: Implement regular assessments or audits to evaluate the organization's overall health, identify potential knowledge gaps, and uncover underlying issues. This could include reviewing employee satisfaction surveys, analyzing turnover rates, or conducting internal audits to assess operational efficiency.
5. Invest in employee development: Provide opportunities for continuous learning and development for employees at all levels. Offer training programs, workshops, or mentoring initiatives to enhance their skills, knowledge, and expertise. This empowers employees to contribute more effectively to the organization and helps bridge the information gap.
6. Embrace technology and data: Leverage technology solutions, such as employee engagement platforms or data analytics tools, to gather and analyze data regarding organizational performance, employee sentiment, and key performance indicators. This enables leaders to make informed decisions based on accurate and up-to-date information.

By implementing these strategies, organization eliminate and the Iceberg of Ignorance effect and create an environment where knowledge is shared, problems are identified and resolved, and decision-making is more effective and informed.

3. Conclusions

Based on the findings and process of Cause and Effect Chain Analysis (CECA) of mold growth in a plastic bottle of orange juice issue, the following conclusions and recommendations can be made:

1. The CECA process was an effective tool for identifying the root cause of the issue, which allowed for targeted solutions to be developed and implemented.

2. The root cause of the problem was related to the design of the cap seal, which was not able to maintain a proper seal under certain conditions.
3. The mechanism of the mold growth was caused by the cap seal becoming dislodged or damaged during the production process, which allowed juice degradation the bottle.
4. Improving the design of the cap seal to improve its ability to maintain a proper seal under different conditions was a key solution to address the root cause of the mold growth issue.
5. Implementing new quality control measures to identify and remove defective cap seals before they are used in the production process was another important solution to reduce the likelihood of the mold growth issues.
6. Modifying the production process to reduce the pressure and force exerted on the cap during production was also an important solution to address the root cause of the mold growth issue.
7. The CECA process can be applied to other quality control and production issues to identify the root cause and develop effective solutions.
8. Investing in quality control measures and production processes can improve the quality of products and reduce customer complaints, which can have a positive impact on the company's bottom line.
9. Engaging employees in the CECA process can improve their understanding of quality control and production processes and lead to a culture of continuous improvement.
10. Regularly reviewing and updating quality control measures and production processes can help prevent issues from occurring and ensure that the company is producing high-quality products that meet customer expectations and avoid the Iceberg of Ignorance.

In conclusion, the CECA process was an effective tool for identifying the root cause of the of mold growth in a plastic bottle of orange juice and developing targeted solutions to address the issue. By implementing solutions related to the design of the cap seal, quality control measures, testing and production processes, the company was able to improve the quality of their products and totally eliminate of customer complaints related to this customer dissatisfaction problem at all.

The CECA process and its solutions can be applied to other quality control and production issues to offer generally value for end customers. The methodology knowledge, experience and data as were presented sometimes is not enough. As was shown in case study there is a need of „magic factor”. Beverage company has all crucial „puzzles” but from others, internal reasons the output was not satisfy to eliminate the problem. The key decision was hiring external TRIZ consultant who properly understand the internal blockers and big picture of the problem, placed puzzles in proper way. After that team was able bring solution faster and better.

Leveraging the unique insights and skills of external consultants, organizations can leverage their expertise to drive innovation, overcome challenges, and ultimately achieve sustainable growth in an ever-evolving business landscape. Adopting a collaborative approach can prove to be a winning formula for organizations seeking rapid success.

References

1. Litvin S., Lyubomirsky A. “Analysis of cause-and-effect chains of undesirable effects”. Methodological Guide (in Russian). IMICenter, 1998.
2. Abramov O., Kislov A. “Cause-Effect Analysis of Engineering System’s Disadvantages”. Methodological Guide (in Russian), Algorithm, Ltd., 2000.
3. Abramov O. “TRIZ-Based Cause and Effect Chains Analysis vs Root Cause Analysis”. Proceedings of the TRIZfest-2015 International Conference, Seoul, South Korea, pp. 288295, MATRIZ 2015.
4. Andersen B., Fagerhaug T. “Root Cause Analysis: Simplified Tools and Techniques”. 2nd Edition, Milwaukee, Wisconsin, USA, ASQ Quality Press, 2006.
5. Obojski J, Kaplan L. ”TRIZ Problem Solving: Consulting vs. Facilitation” Proceedings of the TRIZfest-2017 International Conference, Kraków, Poland, pp. 798233, MATRIZ 2017.
6. Nadja El Kassar (2018) “What Ignorance Really Is. Examining the Foundations of Epistemology of Ignorance, Social Epistemology”, 32:5, 300-310, DOI: 10.1080/02691728.2018.1518498.

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The International TRIZ Conference ITC-2023

“CREATE PRODUCTS” A GAMIFICATION CONCEPT WITH TRIZ ELEMENTS FOR VET SCHOOLS IN AUSTRIA

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Abstract

Members of the Austrian Federal Working Group "Entrepreneurship for Engineers", established by the Austrian Ministry of Education, Science and Research, developed a board game for one of the earliest steps in innovation management – the task how to generate ideas for further product development.

The purpose or goal was to develop a board game for product development for engineering students (first task group - students at Higher Colleges for Engineering in Austria) that answers the following question: How should an attractive board game for product development look like, that has to fulfill several requirements for the usage in a class teaching environment?

After two years and six meetings a prototype for an idea generation game is ready for prototyping use. The players can learn four different creativity techniques (including their pros and cons) – while playing the game.

The result is the board game, named "Create Products", where 3 or 4 groups of 1 to 3 members can take part in a competitive game. Four creativity techniques - brainstorming, emotive words, inventive principles and trends of evolution – can be experienced by the players. The aim is to get them interested in creativity techniques and advanced innovation tools like TRIZ.

The paper and the presentation show how the board game “create products” works and give an insight in the activities of the Austrian Federal working group “Entrepreneurship in Engineering Education” and the international working group “EiEE” of IGIP (International Society for Engineering Pedagogy).

Keywords: board game, inventive principles, trends, entrepreneurship, creativity, gamification,

1. The Austrian Federal Working Group „EEE“ – Entrepreneurship Education for Engineers

Entrepreneurship education is part of the curricula of the Austrian Technical Colleges (ISCED 55). A variety of different compulsory subjects provide basic entrepreneurship education components in the curriculum. In addition to that, all curricula offer an optional subject, which provides specified and focused entrepreneurship education. The decision if students can participate in this subject has to be made by the school management.

The Austrian Federal Ministry for Education established an expert group in 2010 to encourage and foster entrepreneurship education at the Technical Colleges, also named as Higher Colleges for Engineering (short „HTL“). The main objective of the expert group is to support and promote all entrepreneurship related school activities.

At the HTL's creative and innovative teachers meet young interested students with excellent ideas for marketable products and services. Teachers for technical subjects need to have at least a university degree and a four years working experience before they start teaching. So we can assume that they are more familiar with entrepreneurship teaching than others are. "Entrepreneurship Education" should motivate, help and lead students and teachers in design thinking and product development.

1.1 Entrepreneurship Education and the Austrian Federal Working Group EEE

The Austrian Federal Ministry of Education established a federal working group "Entrepreneurship for Engineers" (Entrepreneurship Education at Higher Colleges for Engineering) in 2010. Members of this working group are teachers from all nine federal states in Austria.

The Austrian Colleges for Engineering define their concept of "Entrepreneurship Education for Engineers" as follows: Entrepreneurship Education for Engineers include ...

- .. the usage of the technical and technological know-how of their students (their abilities to design and build products)
- .. the extension of a basic, fundamental economic knowledge (These 2 points mean strengthening their professional skills.)
- .. the building up and increasing of methodological competences, especially in the areas of innovation & creativity
- .. the enlargement of these skills with social and personal skills (teamwork, project management, self-confidence, power of persuasion, ...)

The most important objectives of entrepreneurship education - Entrepreneurship Education for Engineers – in vocational technical schools are

- to awake in students the enthusiasm to believe in their ideas and
- to motivate them to work on these ideas.

In the first years the activities of this working group resulted in several initiatives, e.g.:

- Development of an "Entrepreneurship for Engineers" guide. Describing the tasks, goals and organizational structure of the working group, the competences of an entrepreneur and educational goals in teaching entrepreneurship subjects
- Offering several "EEE" seminars at pedagogical colleges for teachers. Seminars about methods and tools for innovation and creativity methodologies (also with some elements out of TRIZ and Systematic Innovation)
- Assistance of the establishment of Junior Achievement companies and further more

One important step in the further development of the working group was the decision to set up a certification concept for schools and students especially for Colleges for Engineering, which is described in the next chapter.

Another aspect, which increasingly became the focus of the working group, was the search for new playful approaches to bring the topic of entrepreneurial thinking closer to the students. There are successful and well-known business games in the field of business education, which are acquired and used at a number of Austrian schools through the initiative of the working group. However, these are mostly aimed at understanding business processes and operational key figures. For example „Factory“ and „Global Strategy“ (bti, Germany) or „Apples and Oranges“ (Celemi, Sweden).

For the area of product development and therein for the topic of methodical creativity or problem solving, no playful approaches could be found that seemed to be usable in the affected schools. As a result, some members of the working group decided, after approval from the ministry, to work on their own game concept. The result of this work is described in the chapter 3 on the game "Create Products".

1.2 „EEE“-Certification Concept for Colleges for Engineering in Austria

In order to ensure that the entrepreneurship activities of the school sites are realistic, practice-oriented and scientifically justified, it was decided that several institutions work together both in the certification process as well as during the audit of the school sites.

The following stakeholders form the set of organizational units for the certification process:

- Certification organization (unit): IGIP Austria - International Society for Engineering Pedagogy): IGIP Austria is responsible for the definition and compliance of the process and the granting of certificates
- Scientific partner (unit): Graz University of Technology, Austria & University of Advances Sciences Vienna
- Operational unit: Federal Working Group „EEE“ (Austrian Federal Ministry of Education)
- Quality Assurance (unit): An Entrepreneurship for Engineering "mentor": an experienced entrepreneur, who has to accompany the school over the whole schoolyear
- Auditing group (unit): 4 members from
 - the Federal Working Group EEE
 - the scientific partner (University of Technology Graz and/or University of Advances Science Vienna)
 - the certification unit (IGIP Austria)

After a successful audit the school site gets the Certificate "Competence Center for Entrepreneurship Education in Engineering certified by IGIP Austria" and the school is allowed to certify their students within the valid time frame of 3 school years.

Following this procedure two Entrepreneurship for Engineering certificates – for the two target groups - have to be distinguished and defined:

- (1) Certificate for the school site
- (2) Certificate for the students

For both target groups – the school site and the students - criteria for the Entrepreneurship for Engineering certification have been defined, in which the criteria for the school site is again separated in criteria for the school management and teachers and criteria for the Entrepreneurship for Engineering godparent.

- A) certification criteria for the school site
 - A1) certification criteria for the school management and the teachers

- A2) certification criteria for the Entrepreneurship for Engineering mentor
- B) certification criteria for the students

In both lists of criteria mandatory and optional criteria are classified. All mandatory and a defined number of optional criteria have to be fulfilled in a schoolyear.



Fig. 1: Logo Competence Center Entrepreneurship Education in Engineering

1.3 EEE-Certified Colleges for Engineering

Until end of 2022 ten HTLs (Higher Colleges for Engineering) achieved the EEE-certificate. Nine schools are spread across the Austrian. One is in Albania, where the Austrian Ministry of Education runs an Austrian school specializing in information technology. Three schools have already completed the first recertification, which is required after 3 years.

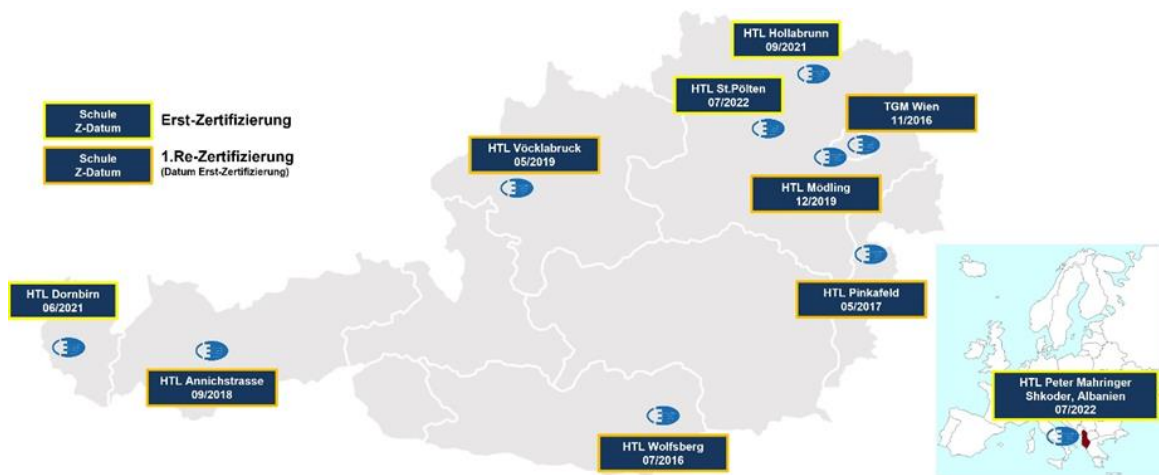


Fig. 1: 10 Austrian Higher Colleges for Engineering with EEE-Certification (December 2022)

2. The International Working Group EiEE (Entrepreneurship in Engineering Education) of IGIP (International Society for Engineering Pedagogy)

2.1 IGIP – History and Aim

The International Society for Engineering Pedagogy IGIP was founded in 1972 at the University of Klagenfurt (Austria) by Adolf Melezinek.

The aims of the International Society for Engineering Pedagogy (IGIP) are

- improving teaching methods in technical subjects

- developing practice-oriented curricula that correspond to the needs of students and employers
- encouraging the use of media in technical teaching
- integrating languages and the humanities in engineering education
- fostering management training for engineers
- promoting environmental awareness
- supporting the development of engineering education in developing countries

IGIP is cooperating with other societies dedicated to engineering education, such as IEEE Education Society, ASEE (the American Society of Engineering Education), SEFI (the European Society for Engineering Education), or IFEEES (the International Federation of Engineering Societies).

(Source: https://igip.org/IGIP_mission.php)

Every year IGIP organizes an international conference named „ICL - International Conference on Interactive Collaborative Learning“ together with partners.

2.2 The International IGIP Working Group EiEE and the ICL Conference

In 2016 the authors of this paper together with some other persons offered IGIP the idea to run a so called Special Session „Entrepreneurship in Engineering Education“ at the ICL conference and the trial was quite successful. So the special session "EiEE" was also offered in the following years. And in 2028 the IGIP Executive Committee decided to support the formation of the new working group „EiEE“.

The "EiEE" session has since taken place at each of the annual conferences (2023 for the eighth time) and is a permanent part of the event. Organizers are the authors of this paper.



Fig. 3: Homepage IGIP Working Group EiEE: https://igip.org/IGIP_working-groups_EiEE.php



Fig. 4: Homepage ICL/IGIP Conference 2023 - <https://icl-conference.org/current/>

The aims of the IGIP working group EiEE are to promote the discussion of goals and experiences to reinforce entrepreneurial education at engineering educational institutions (higher colleges for engineering, universities of technology, universities of applied sciences) and to establish an international network with the specific focus on entrepreneurship education for engineers.

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The EiEE working group aims to provide a platform to discuss the following questions:

- What are the specifics in entrepreneurship for the educational systems of engineers?
- Which content should be taught? Which teaching/learning methods should be applied?
- What do all the initiatives of the EC, etc... mean for the education of engineers?
- Which experiences can be shared within the IGIP community?
- Which role can and/or should IGIP perform?

Topics of Interest:

- educational goals
- educational contents & approaches
- best-practice examples
- national, european & international initiatives and projects
- funding programs in the fields of entrepreneurship & innovation management for engineers
- challenges for the teacher's role in Entrepreneurship Education (What makes a good entrepreneurial teacher?)

Chair: Stefan Vorbach, University of Technology Graz, Austria; Co-Chairs: Jürgen Jantschgi, Higher College for Engineering Wolfsberg, Austria, & Wolfgang Pachatz, Austrian Federal Ministry of Education, Science and Research, Vienna

(Source: https://igip.org/IGIP_working-groups_EiEE.php)

3. The Boardgame "Create Products"

The starting point for the development of a special board game in the field of product development was the agreement on a common understanding of the product development process by the three people involved. These three members of the Austrian Federal Working group EEE are Mr Franz Erkner-Sacherl (HTL Bulme Graz) , Mr Erich Scheffl (HTL Hollabrunn) and Mr Jürgen Jantschgi (HTL Wolfsberg).

One of the members of the game development team, Mr. Franz Erkner-Sacherl, worked out an overview-picture for an innovative, project orientated product development process. In this picture the impact of lessons out of the curricula from colleges for engineering in Austria on the process steps and needed methods and competences are illustrated.

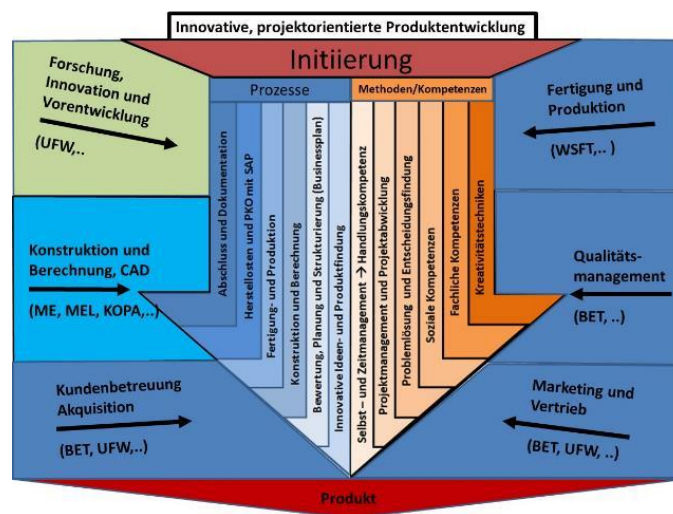


Fig. 2. "innovative, project orientated product development processes – methods - specific lessons at colleges for Engineering (Austria) Concept Franz Erkner-Sacherl, 2014 (german)

The first step in this process (in the middle of the grafic) is called "Innovative Ideen- & Produktfindung" – in English "innovative idea- und product generation".

Having this process together with some other models in mind the game development team started to work out a concept for a game focusing on one of the first steps in product development: A game to increase the interest in and the knowledge of creativity techniques.

3.1 Requirements and limitations

One important factor for the development of the board game "Create Products" was taking into account the requirements and limitations of the school environment:

- The game should be playable within a sequence not longer than 50 minutes (sometimes 2 combined lesson will be possible, that means a duration about 100 minutes)
- The preparation to start the game should last not longer that 5 minutes.
- The explanation of the game should not last longer than 15 minutes – it should be understandable in 10 minutes
- The number of players (students) should be between 8 to 12 participants.
- The game should be playable for teams (and/or for single persons)

- The waiting time for the "non-playing" participants should be a minimum or they should be included somehow in the game (scoring, ...)
- It should be playable on 1 table
- Participation should make fun and should make the player interested in the creativity techniques, used in the game

At the beginning of the game development the different point of views - including their different backgrounds of the four "developers" - caused several discussions about the overall concept of a "game for product development or innovation management".

After two years and six meetings the "game development group" realised a prototype for the idea generation game

3.2 Playground design & Course of the game

The playground is very similar to familiar boardgames like DKT or "Mensch ärgere dich nicht", which are very well known in Germany and Austria.

Players have to roll the dice and move their play figures on the playground, like on a street. The fields on the playground-street have numbers from 1 to 8, representing product-numbers. These products are defined for starters or can be defined from the players before starting the game.

If the play figure reaches a field with a "P-Joker", the player / team can choose one of all available products on his/their own.

All creativity cards (they have to be well mixed before the game starts) are laying stacked with the backside above. The one on the top defines the creativity technique and the specific random word / inventive principle or trend of evolution. So with these two steps the product and the creativity technique is defined.

Now the team has a certain time for generating ideas for a possible further product development for the selected product with the selected creativity technique. Due to the fact that the different creativity techniques have different a difficult level, the time – as well as the scoring - for generating ideas is different for the four techniques.

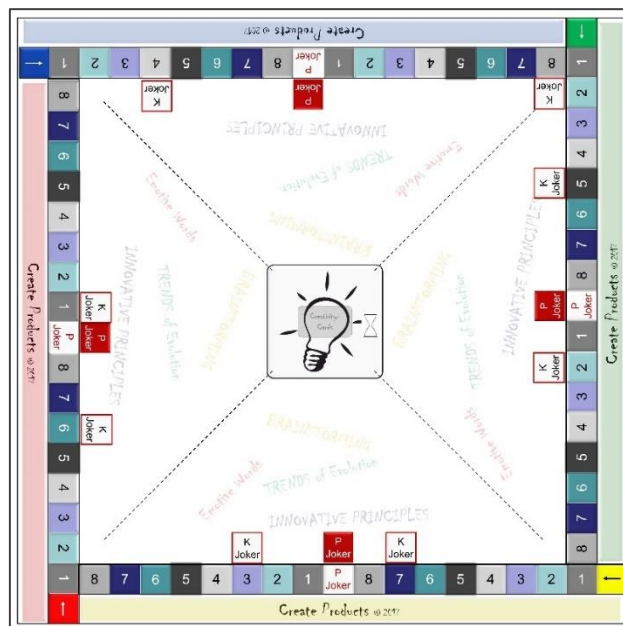


Fig. 4: Playground "Create Products"

Each team selects a secretary that has to fill out the idea card.

IDEENKARTE <i>Create Products</i>						
Runde	Team	Produkt	Methode	Faktor	IDEEN	Punkte
1						
Idee-Beschreibung			Idee-Skizze			
Begründung (neuer Markt, neue Funktion, neues technisches Feature, ...)						Punkte/ P. Abzug

Fig. 5: Idea card "Create Products" (german)

3.3 Creativity techniques & evaluation of ideas

The following four creativity techniques were selected and for them 60 creativity cards have been prepared:

- Brainstorming
- Random/emotive words
- TRIZ – Trends of Evolution
- TRIZ – Inventive Principles

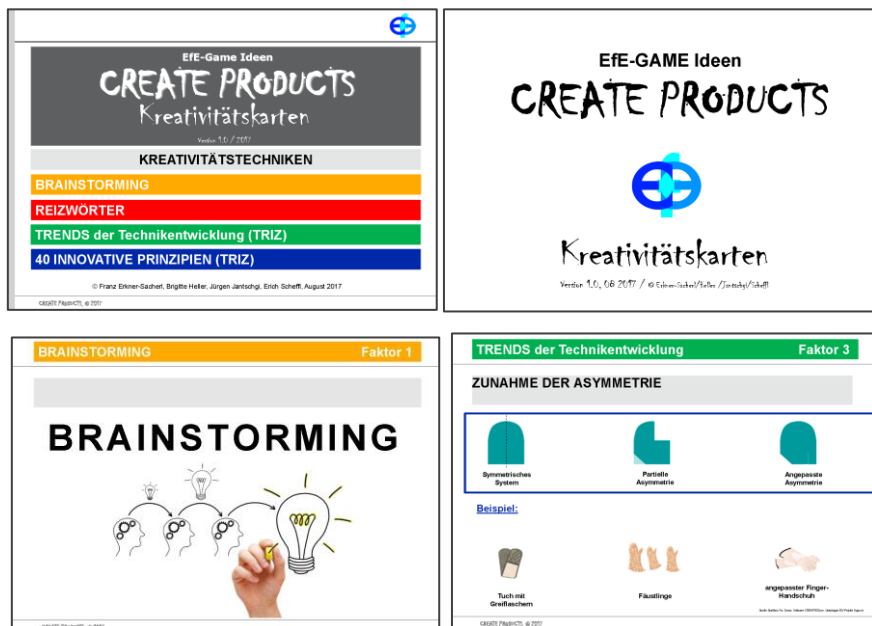


Fig. 8: Example of Creativity Cards "Create Product" (german)

For the ideas that have been generated in each play round the idea maps are filled out. Herewith the total point number can be calculated / determined.

For each idea the team receives the following points of evaluation

Table 1. Creativity techniques, Board game "Create Products"

Method	Number cards	Degree difficulty	Factor
Brainstorming	10	1 - Easy	1
Random words	20	2 - Medium	2
Inventive principles (TRIZ)	10	3 – Difficult	3
Trends (TRIZ)	20	3 – Difficult	3

The remaining teams evaluate whether the ideas are permissible (corresponds to the method). The idea may be defended and/or are explained. The evaluation can maximal last 10 seconds for each idea. The team with the most points after a defined number of rounds is the winner!

4. First Tests, Questionnaire and Feedbacks

The game "Create Products" was tested from the developers during the last year with different kind of players, mainly with students at Universities of Technology and students at Higher College for Engineering in Austria.

In order to get a structured feedback from the "players" a questionnaire was designed. The questionnaire used for collecting a first feedback was structured in the following seven topics:

- Top 1: Game Structure & Understanding Playing Cards
- Top 2: Gameplay & Duration
- Top 3: Content and Knowledge Acquisition
- Top 4: Didactic aspects
- Top 5: Number of players / teams
- Top 6: Fun & Game Repeats
- Top 7: Recommendation & Target Group(s)

For each topic the former players answered two to three questions. A summary of the answers – calculation as percentage - are listed below: (Note: For this first evaluation 30 players filled in the questionnaire)

Top 1: Game Structure & Understanding Playing Cards.

- 1-1 The intelligibility of the playing surface: 20% very good / 60 % good
- 1-2 The intelligibility of the playing cards: 70 % good

Top 2: Gameplay & Duration.

- 2-1 The intelligibility of the gameplay: 10 % very good / 70 % good
- 2-2 The duration (one game round): 10 % very good / 60 % good
- 2-3 rating or points awarded: 30 % very good / 30 % good / 30 % bad

Top 3: Content and Knowledge Acquisition.

- 3-1 The comprehensibility of the overall goal (product development & idea generation): 60 % very good / 40 % good

- 3-2 Teaching Simple Creativity Techniques: Brainstorming & Stimulus: 80 % very good / 20 % good
- 3-3 The imparting of creativity techniques from TRIZ: innovation principles & trends in technology development: 70 % very good / 30 % good

Top 4: Didactic aspects.

- 4-1 Are the contents suitable for this didactic concept (board game): 40 % very good / 60 % good
- 4-2 Further explanations and further learning materials should be kept separate from the game: 20 % very good / 40 % good / 20 % bad

Top 5: Number of players / teams.

- 5-1 The ideal number of teams (currently max 4): 80 % - 3 !
- 5-2 The ideal number of team members - your opinion: 90 % - 3 !

Top 6: Fun & Game Repeats.

- 6-1 The fun factor of the game: 40 % very good / 50 % good
- 6-2 Probability to play this game more often - Game motivation: 10 % very good / 80 % good

Top 7: Recommendation & Target Group (s).

- 7-1 Would you consider this game suitable and recommendable for an education and training institution? 90 % very good / 10 % good
- 7-2 For which target group is the game most suitable age: 10 % age 13-15 / 60 % age 16-19 / 30 % age > 19

5. Conclusions

Developing a board game for the early “idea generation” phase of the product development process was fun and a very interesting learning curve for the development team.

After prototyping and testing the product - the board game "Create Products" - one conclusion of the development team is that the concept of gamification can work very well for the idea generation phase in the product development process.

The interest of the students to deal more intensively with methods in the field of creativity and problem solving can be encouraged by getting to know the methods (especially TRIZ tools) in a playful way. This should also increase interest in problem analysis methods.

Several options for further development have been discovered during the testing and elaboration of the board game. It's a work in progress.

Cooperation between international associations in the fields of engineering education and engineering pedagogy (like IGIP) and in the field of methodical product development (like TRIZ associations such as MATRIZ Official) should be promoted, since many common goals can be pursued better in this way. Unfortunately, there are currently no or only very few connections between these organizations, since many of the people involved do not know each other.

“Play is fundamentally important for learning 21st century skills, such as problem solving, collaboration, and creativity.”, American Academy of Pediatrics

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The International TRIZ Conference ITC-2023

RESOURCE ANALYSIS FOR HIDDEN THREATS IDENTIFICATION

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Abstract

The method of resource analysis for direct problems in order to identify hidden threats is considered. It is proposed to analyze the resources, taking into account the time interval and conditions for which selected resource is used.

Keywords: *resource, hidden threats, direct approach, inverse approach.*

1. Introduction

Currently, there are two critical issues in TRIZ regarding resources:

- 1 How to find a large number of resources?
- 2 How to extract hidden resources?

There is a gap in TRIZ regarding the verification of the resources used for the potential danger that they may hide in themselves.

This idea was prompted by the following, possibly fictional story posted on the Darwin Awards website [1] :

«The accident occurred as the two men were in a frog-gigging trip. Truck's headlights malfunctioned. The two men concluded that the headlight fuse on the older model truck had burned out. As a replacement fuse was not available, one of them noticed that the 22 caliber bullet from his pistol fit perfectly into the fuse box next to the steering wheel column. Upon inserting the bullet, the headlights again began to operate properly and the two men proceeded their ride.

After traveling approximately 20 miles and just before crossing the river, the bullet apparently overheated, discharged and struck driver in the right testicle. The vehicle swerved sharply to the right, exiting the pavement and striking a tree...»

Let's not go into deep discussions about their mental abilities, but consider this situation from the point of view of TRIZ.

2. Theory

Hill-like scheme is the most appropriate illustration of the problem solving process. (Fig. 1). The scheme main idea is transformation real problem into a model, changing the model on the generalized level and then obtaining real solution [2].

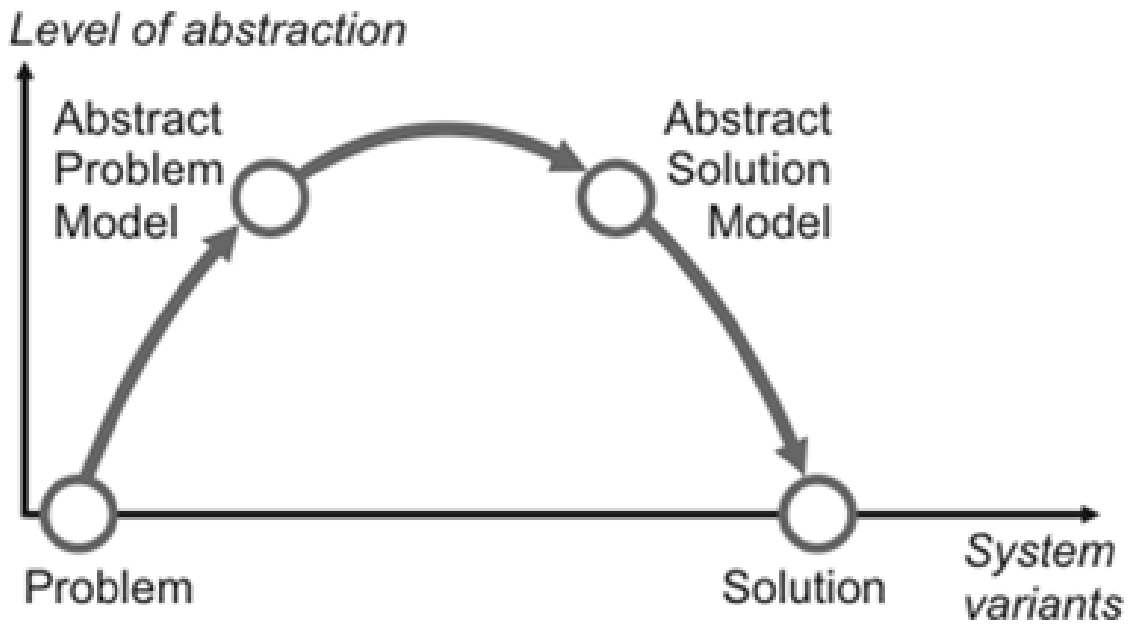
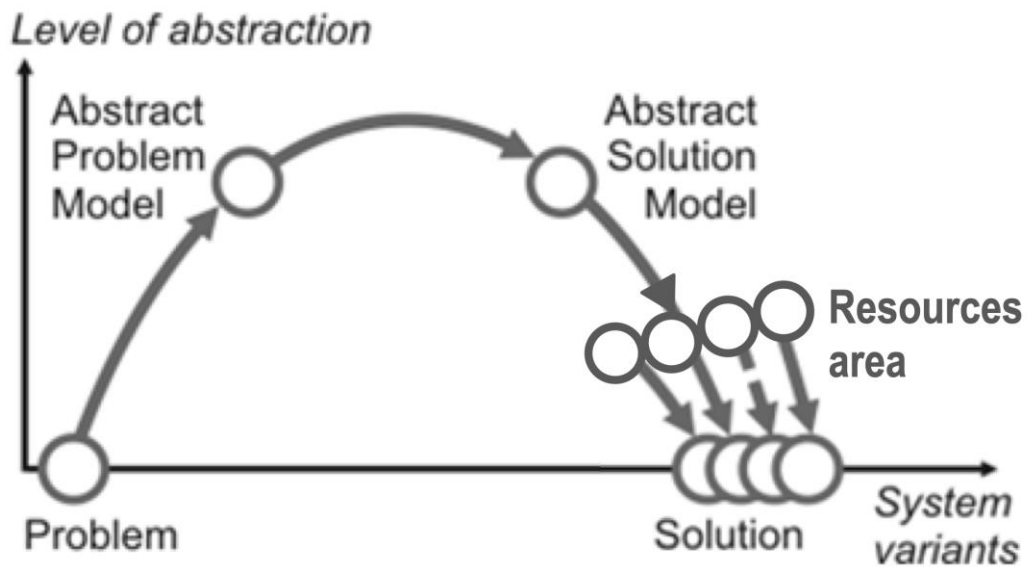


Fig.1 Hill-like scheme



Nikolay Shpakovsky supplemented this scheme with various variations of resources. (Fig 2)

Fig.2 Multi-resource hill-like scheme

3. Discussion

There was a problem - the fuse was burned out. The search for resources revealed an existing resource - 22 caliber bullet. It had several attributes that satisfied the requirements for the resource: dimensions and conductivity. For a while, the problem was solved, because they managed to drive from a few tens of meters to several miles. They did not take into account the hidden threat that was contained in the resource.



Fig.3 - Guide to Fuse Replacement :)

The essence of an inventive solution to any problem is the following: To make the *best* use of the *most appropriate* resource in the *right* place and in the *right* time. According to initial situation with fuses the term *right time* needs to be clarified - how many miles they need to pass? The figure 3 illustrates a humorous fuse replacement guide [3]. Despite the obvious inconsistency of these variants, they can be used in some temporary solutions.

According to TRIZ the resource classification is following:

- Material (substance)
- Energy (Field)
- Information
- Space
- Time
- System
- Operator (stakeholders)

Some danger factors of resource is described in Failure Anticipation Analysis (or in Anticipatory Failure Determination). But there is still a gap in verification of some resources.

4. Results

The author proposes to use these checklists to check resources for hidden threats, as well as supplement them with a check on the size-time-cost operator. System resources are supposed to be checked for the presence of a harmful system. In non-technical TRIZ, the greatest potential will be the development of checklists for checking human resources (resources of operators, stakeholders) for the presence of hidden threats.

Acknowledgements

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References

1. <https://www.snopes.com/fact-check/the-bullet-fuse/>
2. <https://www.gnrtr.com/Generator.html?pi=216&cp=3>
3. <https://external-preview.redd.it/hMyKCqho5V2kdvWONItMBwbE4nh7Y5zUFfZs5FhSjk.jpg?auto=webp&v=enabled&s=479b2bd44666cb9ace6020f30040dc7d1b9bc64f>

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SOLVING TRIZ PROBLEMS WITH TRIZ

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Abstract

Many TRIZ people agree with the authors of the MATRIZ Official founding letter that “TRIZ development stagnated in the past several years. At the same time an appreciable number of new problem-solving methodologies have emerged in different parts of the world recently. And the demand for this type of services is growing exponentially. However, we firmly believe that TRIZ problem-solving tools for inventive and innovative challenges are superior to any other problem-solving methodology developed so far”. So does the author of the paper. Partially.

There have been some meetings and discussions how to promote and disseminate TRIZ knowledge, what to do to find more customers interested in TRIZ trainings and TRIZ projects. There were some ideas proposed, but we still see no results. If we are really so good at solving problems as we claim, let us prove it by solving TRIZ problems with TRIZ tools.

According to our own definition TRIZ is an engineering system, so we can analyse it as we do it with any other system. Trends of engineering systems evolution apply to TRIZ itself, so expecting that TRIZ will always remain unchanged contradicts with TRIZ fundamentals. Genrich S. Altshuller perfectly knew that an engineering system, in order to be used and popular, to remain alive, must evolve to keep up with expectations of changing world. The author does not agree with the claim that TRIZ development stagnated. On contrary, we can observe a development of individual TRIZ tools. They are modified, being completed and updated, partially trimmed or merged with other systems, therefore they can seem unrecognizable at the first sight, but they are used, effective and popular. The paper collected some samples to prove that the claim “TRIZ is dying” (as some people say) is greatly exaggerated.

There is also a challenge for TRIZ associations – in 2023 a simple copying the frames of the TRIZ association established by Altshuller is a way to nowhere. An association is also an engineering system and its evolution should not surprise any person with at least basic level of TRIZ knowledge. The paper includes also some insights about associations in XXI century.

Keywords: *TRIZ, tools, development, change, engineering system, challenge, association*

1. Two Ways of Stagnation

In some people’s opinion the TRIZ development slowed down or even stopped in the past few years. Some TRIZ specialists even say “TRIZ is dying”. Such claims can be understood in two ways:

- The popularity of TRIZ shrinks, i.e., the number of training decreases, the number of certificates does not increase, there are no new projects, no new markets, no conferences or meetings, customers disappear. TRIZ competitors perfectly mastered the art of selling, or they just have better offers for the customers.

- New ideas ceased to appear: there are no new tools developments, there are no ideas to improve the existing tools, no new publications, no ideas of new applications.

Are there really any reasons to worry?

2. Numerical Data

MATRIZ Official, The International TRIZ Official Association, issued 643 certificates (L1: 558, L2: 50, L3: 34 and L4: 1) between 22 September 2022 and 07 May 2023. for people in 23 countries [1]. As the association was founded last year, there is no earlier data to compare and evaluate the popularity of TRIZ, but the certificates data are also available on other websites and the number of certified specialists still increases. The total number of certificates registered by the “old” MATRIZ is over 37 000, while in 2014 it was about 17 000 [2]. The total number of all TRIZ courses and workshops around the world is difficult to estimate, but the certified ones are only a part of them. 26 publications related to TRIZ appeared in the first 18 weeks of 2023 on only one of the social networking sites for scientists and researchers, while the total number of TRIZ-related publications gathered on this site is 4514 [3]. There are many TRIZ-related events (conferences, webinars, meetings, training, workshops, etc.) held in 2023: Google search shows over 600 000 results to “TRIZ events 2023” [4].

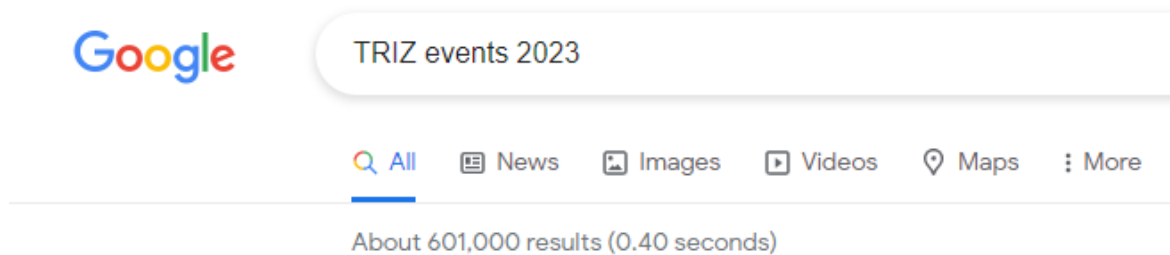


Fig. 1. Google search results for “TRIZ events 2023”, a section of the screenshot

The Amazon “books” category shows about 600 items related to “TRIZ” and the list comprises translations of G.S. Altshuller’s books as well as new publications [5]. Some of them are really worth attention, some of them seem not to discover anything original, but the number of publications is so big that it is impossible to study them all.

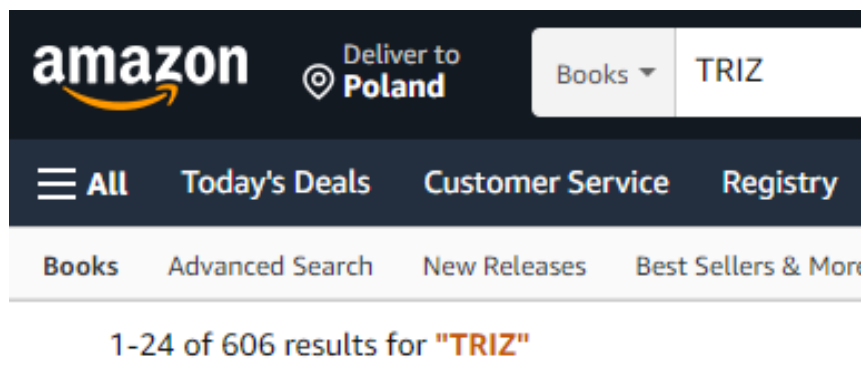


Fig. 2. Amazon search results for “TRIZ” in “Books” section, a section of the screenshot

Taking into consideration all the numbers shown above, the situation with TRIZ seems not to be disturbing. Do all those people still write, discuss and practise the existing TRIZ tools only and nobody has any new ideas? Probably not.

However, something must be wrong if a group of experienced TRIZ Masters, the best problem solvers, decided to express their concern about the current situation. One question arises immediately: does TRIZ community use their own tools to solve problems with TRIZ? Let us check.

3. TRIZ on the S-curve

TRIZ itself is an engineering system, it evolves according to the same rules as all the other engineering systems do, and TRIZ specialists are aware of it. No system has ever emerged as a perfect one, an ultimate version of itself. The history of TRIZ is a history of changes and the best example here is the most advanced classical tool, ARIZ, the Algorithm of Inventing Problem Solving. The path to the ARIZ-85B, the latest version of the algorithm, refined by G.S. Altshuller, leads from the rough ARIZ-56, through ARIZ-59, ARIZ-61, ARIZ-64, ARIZ-65, ARIZ-68, ARIZ-71, ARIZ-75, ARIZ-77 and ARIZ-82 [6]. Either the list of 40 inventive principles did not appear suddenly: at the beginning in 1956 there were only 5 of them, the next 18 were developed in 1958, then the next new principles were added in 1964 and the list was completed in 1971 [7].

TRIZ evolves according to the Trends of Engineering System Evolution (TESE). Causes, indicators and recommendations for each stage of the system evolution on the S-curve have been formulated and they are taught at L2 and L3 training classes. The stage of TRIZ development has been also identified, “since it is not on the market everywhere, TRIZ as a method is probably at the transitional stage” [8]. The way to the success seems clear, the only thing to do is to follow the recommendations and the system will reach the next level of development. There are following recommendations for the transitional stage:

- The Engineering System must be launched into the market as quickly as possible.
- All parameters must be acceptable; at least one must be an A+ (champion) parameter.
- Develop the Engineering System in a field where the champion parameter is most important (the best ratio of advantages to disadvantages).
- The Engineering System should continue to be adapted to the existing infrastructure and resources.
- Big changes can still be made to the Engineering System, but not to the principle of action [9].

4. Are the Recommendations Followed?

Not all of them. No doubts that TRIZ has not been widely spread around the globe yet. Although it has been definitely launched into the market, it is present in some market niches only.

Unfortunately, there is a surprising issue with TRIZ at the second recommendation: the champion parameter of the methodology has not been clearly identified. The question about it had been asked to several experienced TRIZ specialists, but every single answer pointed out something different. One of the TRIZ Masters even said that the issue the champion parameter of TRIZ would be worth a separate conference. Thus, the first suggestion is: let us define the champion parameter and promote it as quickly as possible to open the door to the second stage of TRIZ development.

However, there is another important question, that must be answered before pointing out the champion parameter: what is TRIZ? According to the *TRIZ Body of Knowledge* [10], “contemporary TRIZ is both a theory of technology evolution and a methodology for the effective development of new technological systems”. Looking for the champion parameter for the *theory* or *methodology* can be difficult as the notions are too general, too fuzzy. Does it mean TRIZ specialists are not able to use their own tools to solve their own problems and achieve the next step of system evolution? No. We could reach for one of the classical TRIZ models of solution and follow the recommendation of the Inventive Principle No.1, “Segmentation: divide an object into independent parts”. The model suggests to analyse each component separately, instead of looking for champion parameter for TRIZ as a whole. *TRIZ Body of Knowledge* includes a list of contemporary tools, so pointing out a champion parameter for each of them, or for small toolkits, should require less effort. Once the champion parameter is identified, the areas where it is most important would be easier to spot.

The recommendation in terms of adaptation to the existing infrastructure and resources has been already followed: TRIZ is being introduced to some companies along with other methods [11], TRIZ is being taught at many universities, but also in kindergartens [12].

5. Changes in TRIZ

The last recommendation allows changing the system, provided the principle of action is preserved. What can be changed in TRIZ? *TRIZ Body of Knowledge*, published in 2008, emphasizes that this is a starting point to develop a comprehensive body of knowledge comprising the contemporary TRIZ and specifies the criteria of recognizing a concept, component or tool:

- It has to be used by the majority of TRIZ schools in the world (not surprisingly, most of these elements of TRIZ were either authored and co-authored by or were developed in close collaboration with Genrikh Altshuller).
- It has to be used in the majority of non-commercial publications on TRIZ authored by TRIZ Masters
- It has to be used in the majority of TRIZ courses presently offered in the world [13].

These criteria immediately rise a question about the way from the completely new idea to the concept, component or tool recognized and used by the majority of TRIZ schools.

6. Introducing Changes

Things were simpler in Altshuller’s time: as a creator of the methodology, he had the right to decide about the introducing new tools. After his death in 1998, the TRIZ community had to face the problem of updating the methodology. There is a body called TRIZ Research and Development Council in the “old” MATRIZ, but in spite of the regulations [14] no piece of information about their work can be found on the website at the moment. There is a website entry called *TRIZ R&D Council Coordination Group on TRIZ Developments Regulations* [15], and the only one document available is *TRIZ Assumptions Revision*, published in 2014, which “represents the collective/collaborative vision of several major TRIZ schools that are participating in TRDC” [16]. *TRIZ Body of Knowledge*, despite of expectations (“In preparing this document, we not only intend to lay the foundation for defining the boundaries and content of modern TRIZ, but also hope to open a discussion on these topics among the people for whom TRIZ has become a profession. We believe that such a discussion is necessary for the healthy development of TRIZ”) [17] has not been updated for a long time.

The number of TRIZ certificates is growing worldwide, not to mention TRIZ users off certification systems. Do all the people know *TRIZ Body of Knowledge? Glossary of TRIZ and TRIZ-related terms* [18]? If so, are they aware that these documents may be a subject of change? Who can change it and how? Perhaps disadvantages of information flow within the TRIZ community are the problem here? Fortunately, there is the flow analysis among TRIZ tools, and such disadvantages should be easy to identify and to deal with, but there is one important thing missing here: a procedure of updating the methodology [19].

New concepts do appear in books [20], conference papers [21], TRIZ Master dissertations [22], but not being discussed, supported and promoted, they gain a limited popularity or go forgotten soon after being published. A person initiating a new concept, or a change in an existing one, must be aware that a path from an idea to a popular tool comprised in *TRIZ Body of Knowledge* is long, however it is based on certain rules, which are transparent and easily available. There should be a procedure that guarantees unbiased experts opinions, but also opens discussion on a wide forum, thus supporting the promotion of the novelty within the TRIZ community. On the other hand, such procedure would assure high-quality results, by eliminating attempts to reinvent a wheel. The reasons of rejection should be always explained by experts. The justification could have an important educational function, especially because “the modifications to ARIZ and other tools became the favourite pursuit of TRIZ novices” [23]. At the moment it is unclear how to update methodology and who can do it. The criteria alone are not sufficient, there must be a procedure of introducing changes and modifications, otherwise everybody can create anything and call it TRIZ.

7 TRIZ Associations in XXI Century

In Altshuller’s time the information flow among any association members was much slower than today. Nowadays there are many opportunities to contact immediately, to exchange ideas and opinions with no in person meetings: there are websites, newsletters, Internet discussion forums, chats, instant messaging applications, webinars and online meetings available for everybody around the globe. New technologies of information exchange and new channels of communication can keep members active throughout the year, not just during conferences. The only goal to achieve is to make the information flow as efficient as possible, because it takes more than a message and a channel to communicate [24]. The flow analysis can be helpful to improve the communication among TRIZ specialists.

The first step towards the better communication within TRIZ community has been already made: some TRIZ associations, contrary to the “old” MATRIZ, which is an association of regional organizations only, provide an individual, paid membership and there are sets of benefits available exclusively for members [25] [26]. MATRIZ Official, The International TRIZ Official Association, offers a discussion forum among their benefits. It seems to be the good place where new ideas could be presented, discussed and – in case of a formal acceptance – promoted among the community. The idea of paid membership and a forum available exclusively for members, is a way to prevent problems like spam or off topic content, however an active moderation, based on certain rules, is an absolute condition for such forum to be a vivid and friendly place to share thoughts for experienced professionals and for beginners as well.

The promotion of new concepts and tools is essential, otherwise there is no chance for them to be spread within TRIZ community and used by majority of schools and presented in majority of courses. This is the key role of associations: to enhance the effective information flow among their members.

8 Conclusions

Although G.S. Altshuller decided to stop working on problem solving tools at some moment, and focused his attention on the issues of development of creative personality [27], it does not mean the toolkit has already reached its ultimate version. Almost 25 years have passed since Altshuller's death, and during this time many changes have taken place in the world. In new circumstances new challenges emerged, thus the necessity to refine tools as well as introduction of novelties are natural consequences. The stage of TRIZ evolution is identified, the recommendations for the stage are known. Lack of clearly defined champion parameter of TRIZ prevents following all the recommendations and may be the factor that slows down the evolution of the system. TRIZ community needs a transparent procedure of introducing new things and modifications to the methodology. Such procedure, similarly to TRIZ Body of knowledge, should be common for major TRIZ organizations. The main goal of associations in XXI century is to enhance the information flow by application of new communication technologies. Effective information exchange among TRIZ specialists is the fundamental of further development of the methodology.

Changes are inevitable and we must deal with them, because “during the transitional stage, the product's reputation is essential” [28]. The best way to build the reputation of TRIZ is to prove its efficiency and reliability, i.e., to solve problems with TRIZ using TRIZ tools – the best problem-solving toolkit developed so far.

References

1. CERTIFIED TRIZ PRACTITIONERS, SPECIALISTS AND MASTERS <http://www.matriz-official.net/index.php/certification/2-uncategorised/17-certified-triz-practitioners> . Last accessed 10 May 2023
2. List of certified TRIZ specialists <https://matriz.org/matriz-offices/council-on-expertise-and-methodology-cem/certification/lists-of-certified-triz-specialists/> . Last accessed 10 May 2023.
3. Publications related to “TRIZ” <https://www.researchgate.net/topic/TRIZ/publications> . Last accessed 10 May 2023
4. Google search results for “TRIZ events 2023” <https://www.google.com/search?q=triz+events+2023&oq=TRIZ+&aqs=chrome.69i59j69i60j69i61j69i60j69i6513j69i60.3587j0j7&sourceid=chrome&ie=UTF-8> Last accessed 10 May 2023
5. Amazon search results for “TRIZ”, in category “books” https://www.amazon.com/s?k=TRIZ&rh=n%3A283155&dc&ds=v1%3A4IkKkBkTzIPE2WjQG5wFpUIx5rwoosi%2Fsqc%2BmYW08Ew&crd=2NVQWAF85ZAKD&qid=1684435655&rmid=2941120011&srefix=triz%2Caps%2C189&ref=sr_nr_n_1 Last accessed 10 May 2023
6. Альтшуллер Г.С, *ИСТОРИЯ РАЗВИТИЯ АРИЗ*, 1986 <https://altshuller.ru/triz/ariz-about1.asp> . Last accessed 10 May 2023
7. Markov S., 40 Inventive Principles in classical and modern TRIZ, <https://geniusrevive.com/en/40-inventive-principles-in-classical-and-modern-triz/> . Last accessed 10 May 2023
8. Lyubomirskiy A., Litvin S., Ikovenko S., Thurnes Ch., Adunka R. *Trends of Engineering System Evolution (TESE)*, TRIZ Consulting Group GmbH, Sulzbach-Rosenberg, 2018, p.20
9. GEN3 Partners Inc., Ikovenko S., L3 training materials, 2007-2017

10. Fey V., Litvin S., Rubin M., *TRIZ Body of Knowledge*, 2008
https://www.researchgate.net/publication/315611273_TRIZ_Body_of_Knowledge . Last accessed 10 May 2023
11. Shaughnessy H., *What Makes Samsung Such An Innovative Company?*, “Forbes”, 07 March 2013, <https://www.forbes.com/sites/haydnshaughnessy/2013/03/07/why-is-samsung-such-an-innovative-company/> . Last accessed 18 May 2023
12. TRIZ methods in kindergarten.
<https://minikar.ru/en/tests/metody-triz-v-detskom-sadu-ispolzovanie-metodov/> . Last accessed 10 May 2023
13. Fey V., Litvin S., Rubin M., Op. cit. p.2
14. TRIZ Research and Development Council Regulations <https://matriz.org/trdc-regulations/> . Last accessed 10 May 2023
15. TRIZ R&D Council Coordination Group on TRIZ Developments Regulations
<https://matriz.org/wp-content/uploads/2012/09/TRDC-TRIZ-Coordination-Group-Regulations.pdf> . Last accessed 10 May 2023
16. Barkan M, TRIZ Assumption Revision, 24 January 2014, <https://matriz.org/triz-assumption-revision/> . Last accessed 10 May 2023
17. Fey V., Litvin S., Rubin M., Op. cit. p.1
18. Souchkov V., *Glossary of TRIZ and TRIZ-Related Terms*, MATRIZ, 2018
https://matriz.org/wp-content/uploads/2016/11/TRIZGlossaryVersion1_2.pdf . Last accessed 10 May 2023
19. Pay attention that the document *Goals, Functions and Regulations for Expertise Group on TRIZ Publications* says about correlation to the Body of Knowledge, not about introducing updates. <https://matriz.org/wp-content/uploads/2012/09/TRDC-TRIZ-Expertise-Group-Regulations.pdf> . Last accessed 10 May 2023
20. For example: Petrov V., Voronov G, *A New Approach to Su-Field Analysis*, 2013, ISBN: 9781696203678
21. For example: Mann, D., *Matrix 2022: Re-imagining the Contradiction Matrix*,
https://link.springer.com/chapter/10.1007/978-3-030-86614-3_16 . Last accessed 10 May 2023
22. For example: Mayer O., *Increased Addressing of Human Senses as a Trend*,
<https://matriz.org/wp-content/uploads/2017/09/O.Mayer-TRIZ-Master-dissertation.pdf> . Last accessed 10 May 2023
23. Zlotin B., Zusman A., *ARIZ on the Move*, 1998, <https://www.metodolog.ru/triz-journal/archives/1999/03/e/index.htm> . Last accessed 10 May 2023
24. The six factors of an effective verbal communication,
https://en.wikipedia.org/wiki/Jakobson%27s_functions_of_language Last accessed 10 May 2023
25. Membership regulations of MATRIZ Official, 11.03.2023, <http://www.matriz-official.net/index.php/membership/2-uncategorised/32-membership-regulations-of-matriz-official> . Last accessed 10 May 2023
26. Membership in Altshuller Institute (AI), <https://www.aitriz.org/membership> . Last accessed 10 May 2023

27. Souchkov V., *A Brief History of TRIZ*, 2009 - 2016
https://www.researchgate.net/publication/332935983_A_Brief_History_of_TRIZ Last
accessed on 10.May 2023
28. Lyubomirskiy A. et al., Op. cit. p.18

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PIONEERING BORNEO TRIZ AND FURTHER PROLIFERATE KNOWLEDGE WITH REMOTE LOCATIONS

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Abstract

TRIZ knowledge has made its way from Russia to many places around the world. It arrived in South East Asia in early 2000 and made great proliferation led by the Malaysia TRIZ community from 2010. With a focused effort to share knowledge, more than 15,000 practitioners were certified in the region over 10 years. Many achievements enjoyed “city” advantage and lacked “rural” comparative support. This paper describes how TRIZ finds its way to Borneo-island. It will document the journey and relate how less-populated locations with limited infrastructure and resources embrace the innovation culture while preserving the traditional tribal way of life. This paper will cover the multifaceted knowledge proliferation and development effort through the pioneering and formation of the Borneo TRIZ community. It showcases the creativity of the community equipped with TRIZ to solve unique local problems and develop solutions that address challenges of constrained resources.

1. Inventive problem

The discovery of 40 Inventive Principles by Genrich Altshuller has not only benefitted many inventors around the world but has inspired an adaptation of the knowledge into the development of an ecosystem for promoting a knowledge-based society. Building on the core set of 40 Inventive Triggers, a community-centred approach was undertaken in Sarawak. The set of triggers as cards was initially intended to assist school students in learning about inventions, turned to be a tool to motivate a native community to document their tribal knowledge. Further sharing of the TRIZ methodology and tools with remote indigenous communities of Borneo Island has led to the use of the inventive knowledge to connect to their implicitly held traditional knowledge.

Sarawak, the largest state of Malaysia, has stepped up its focus on innovation and talent development as it strives to transform toward a developed state target by 2030. The state houses a population of 2.9 million consisting of more than 40 ethnic groups, majority from indigenous communities spread across a vast 48,000 sq. miles of one of the oldest and most biodiverse

rainforests in the world. The state aspires to address the challenges of driving sustainable innovation development while preserving its living indigenous heritage. In a quest to address the digital divide, it is important to ensure that all communities, especially those in remote locations, are included and not excluded in the development efforts. Furthermore, efforts in modernization and catching up with the development agenda, in spite of noble intentions, often lead to conflicts by overlooking cultural preservation, causing a steady erosion of the local living cultures.

Universiti Malaysia Sarawak (UNIMAS), a leading university in Sarawak, undertook the challenge to ignite a strategic change for its institution and state. In the UNIMAS Strategic Plan 2021-2025, it has committed to play an active role in fulfilling the state and country’s aspirations to deliver highly skilled and competent innovative workforce while preserving the traditions within the boundary of advancing infrastructure by 2030. A pioneering undertaking of leveraging inventive problem solving as a way forward was explored. The graphic representation of the inventive problem and solution generation approach is summarized in Figure 1. The Theory of Inventive Problem Solving (TRIZ) methodology was adopted to tackle contradictory needs of balancing development needs without comprising inherent cultures and traditions. The methodology complemented the Strategic Change Management framework and refined the thinking in strategy development and implementation.

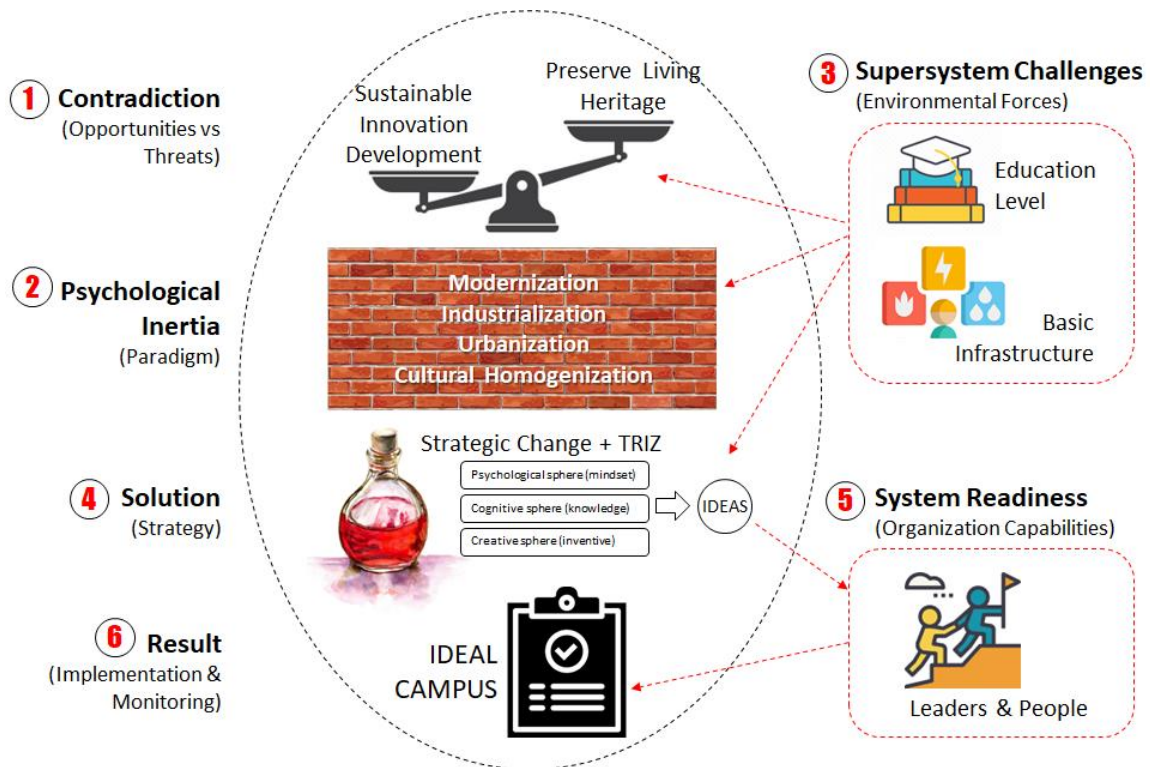


Figure 1: Inventive problem statement and solution generation approach

2. Research methodology

With the rapid adoption of digital technology, the modern world is experiencing an unprecedented pace of changes that require constant monitoring of the changes and building a system that is flexible to respond to these changes. The UNIMAS Leadership has benefitted from the adoption of the Strategic Leadership and Change Management Framework with consideration

of environmental changes. The model was documented and published by P. Schoemaker, S. Heaton, D. Teece in 2018.

The Strategic Change Management Framework, as shown in Figure 2, encouraged strategic leaders to closely monitor environmental changes in 4 key conditions; V-volatility, U-uncertainty, C-complexity, and A-ambiguity. Leaders are encouraged to use their leadership skills to sense (anticipate the future and challenge the status quo), seize (interpret the trends and decide the strategic change), and transform (align the workforce and encourage continuous learning) to look ahead, plan in advance, and move the organization forward.

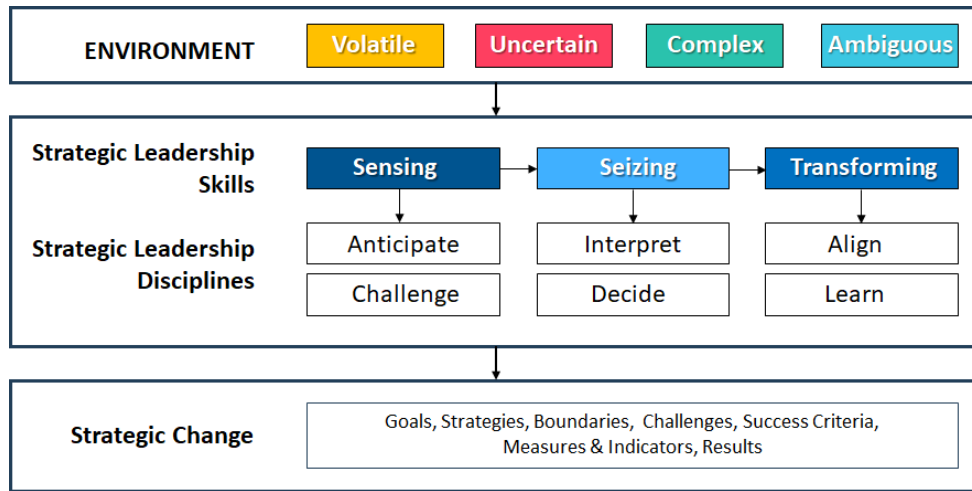


Figure 2: Dynamic capabilities, strategic leadership, and change framework

Through the collaboration of UNIMAS’s Leadership Centre and the Institute of Social Informatics and Technological Innovation, the awareness of contradiction analysis as part of the strategic change initiative has taken serious consideration. The Strategic Change Management framework and TRIZ methodology were used to resolve the identified contradictions, develop a change strategy, analyze organizational capabilities, and refine the implementation plan.

The work of Silverstein, DeCarlo, and Slocum, shared in 2007, guided the usage of TRIZ into the strategic change initiative to achieve the competitive advantage. Figure 3 shows the inclusion of TRIZ elements. TRIZ concepts enhance operational excellence with its inclusion in both strategic and operational leadership aspects. It enhances innovation velocity with the adoption of TRIZ tools in process management and quality assurance drives. Third, the TRIZ elements must take a top- to-bottom role in people functions.



Figure 3: TRIZ and Strategic Change Initiatives

The TRIZ ideality concept was used to think of the ideal system. It derives the concept of the Ideal Campus. This idea excited senior management and was used to guide the majority of its strategic change plans.

Several inventive principles, such as no. 1-segmentation, no. 3-local quality, no. 15-dynamicity, and no. 22-blessing in disguise, contributed significantly in shaping the solutions to the changes. The Su-Field model was also used to map a Transformation roadmap for individuals in the system.

When the strategy was mapped with the strategic change management and implementation factors, as shown in Figure 4, it highlighted two major needs. One need is to establish an innovation ecosystem (externally to university), not just about making changes within the university (internally). The second need is formalized as a cross-organization coordination body to ensure coherent of alignment, monitoring, and implementation: this mooted the idea of Borneo TRIZ formation.

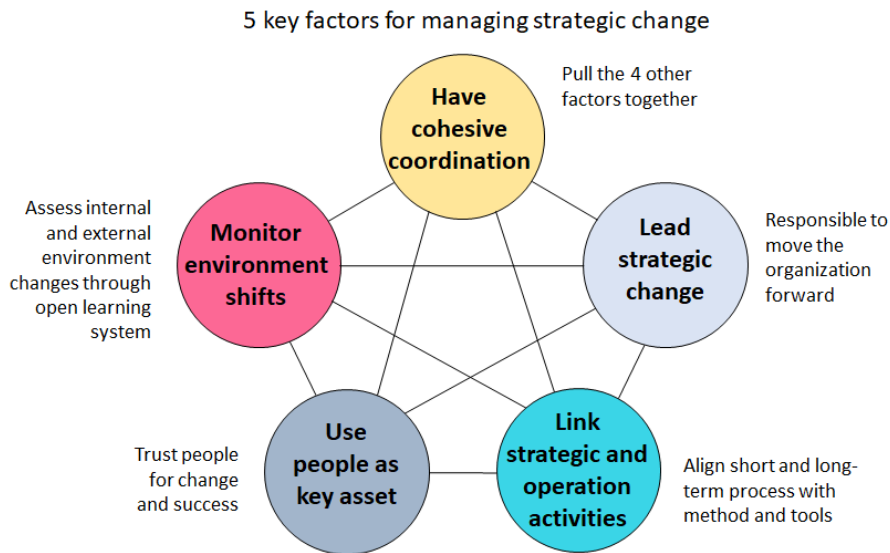


Figure 4: Manage and implement strategic change factors

The main strategic goal was to develop a highly skilled and competent innovative workforce (people) while preserving local traditions (culture) and strengthening community inclusion (people). The second strategic goal is to conserve resources and minimize waste to protect the environment (environment), while advancing the modern infrastructure (infrastructure) by 2030.

This research paper will focus on the main strategic goals of leaders, people, and culture.

3. Key Results

3.1 Ideal Campus

During the UNIMAS strategic change management retreat at the end of 2018, with a selected number of senior leaders exposed to some knowledge of TRIZ, the Ideality concept was referred to begin the strategic thinking process with the end in mind. The picture of an ideal system delivering all its benefits but not of its cost or harm, led to the idea of the UNIMAS Ideal Campus. The objectives were to develop UNIMAS toward a self-driven, self-sustained, and

innovatively nurtured institution. Its functionalities were identified and summarized in Figure 5.

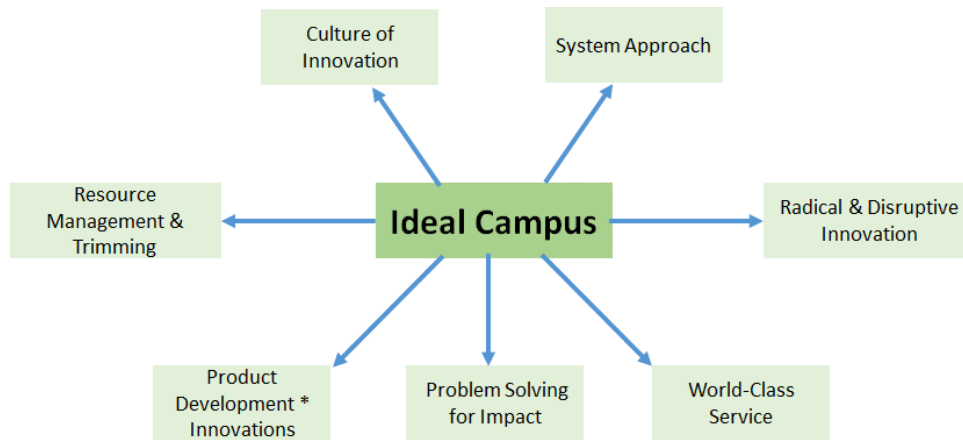


Figure 5: Ideal Campus and its functionalities

It is critical to involve all human resources directly or indirectly affected by the strategic change to be part of the effort. With this understanding, the UNIMAS senior leaders made a landmark decision to train all middle managers of the university with TRIZ. The decision marked a first for a university to proliferate TRIZ organization-wide in Malaysia and South East Asia. More than 200 university administrators were TRIZ trained in 2019 and 2020. Before the decision, 118 TRIZ Level 1 practitioners consisted of academicians and postgraduate students from 2011 to 2018 were trained. A trajectory climbs of TRIZ trained practitioners from 15 pax per year for 8 years (2011 to 2018) to 100 pax per year in 2 years (2019 and 2020). The momentum also propelled sharing with undergraduates, where more than 1,200 students from 4 faculties were trained since 2019.

3.2 Indigenous community outreach

The Ideal Campus also launched Collaborative Engagements between different faculties in the university. The collaboration engagement framework is shown in Figure 6 below.

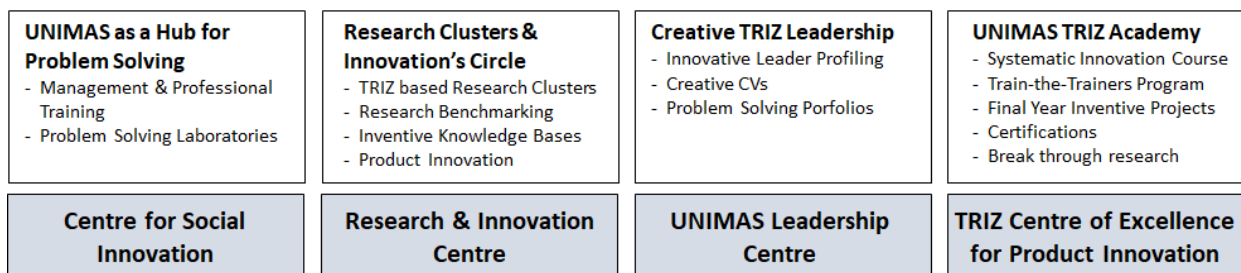


Figure 6: UNIMAS Collaboration Engagement Framework

Two research clusters emerged from this idea. The first cluster works on Bio-medical Technology with TRIZ from a collaboration with the Faculty of Health and Medical Sciences (FHMS) and the Faculty of Computer Science and Information Technology (FCSIT). The second cluster works on the study of an indigenous innovation spearheaded by the Institute of Social Informatics and Technological Innovation (ISITI).

The work by ISITI resulted in the adaptation of the TRIZ 40 Inventive Principles using local examples. The adaptation idea came from the Local Quality inventive principle and the initiative to share advanced knowledge with the indigenous community. The adapted inventive principles were presented in the form of Inventive Trigger Cards. It is a set of 40 cards with the knowledge and made available in two languages, namely English and Bahasa Malaysia.

The indigenous communities living in far-in land could relate to the inventive principles as documented in the Trigger Cards. The use of the 40 inventive cards has become the intermediary between the communities to bridge the gaps in terms of articulating and connecting their past innovation expressions in a contemporary context.

3.3 Strategic Transformation Pathway

The adoption of TRIZ has contributed to the university’s strategic change process. It consolidated the distributed and isolated innovation efforts into a coordinated and sustainable innovation agenda. Using the Su-Field model concept, the organization transformation process is summarized in Figure 7a.

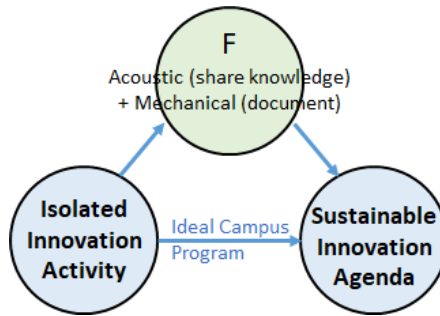


Figure 7a. Organization-level Transformation Strategy

Further usage of the Su-Field model concept was adapted into a people scenario and focused on the individual level, the changes at the strategic level led to a clearer transformation stage career pathway description. Four main transformation stages are documented to guide and direct middle and working levels through the changes. The transformation stage is demonstrated in Figure 7b. These pathways helped clarify the change initiative and process, and are useful for performance management, career and succession planning processes.

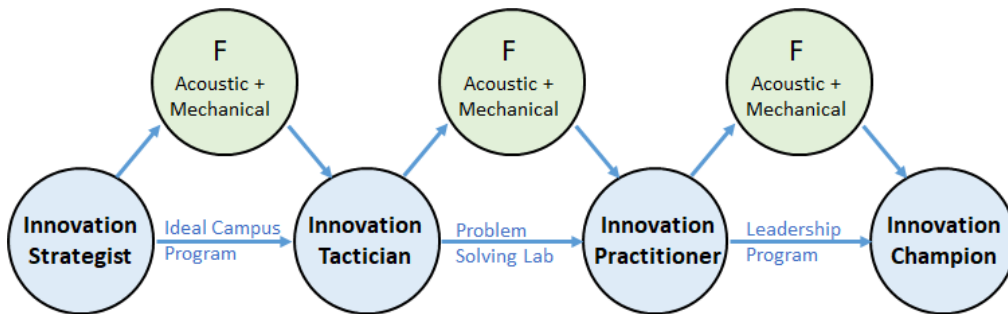


Figure 7b: Individual-level Transformation Strategy

3.4 TRIZ@Industry

Proliferating TRIZ to local state-level industry is a key part of the proliferation plan. When a senior leader of the university was charged after attending the International TRIZ Level 3 Professional course, the secret of the TRIZ methodology was communicated with a key energy company named Sarawak Energy. The state-government-linked company was supportive and training started in 2018 and 2019.

A total of 34 TRIZ Level 1 Practitioners from the company were trained in 2018, followed by 26 TRIZ Level 2 Practitioners and 20 TRIZ Level 3 Practitioners equipped with advanced TRIZ tools in 2019. The seed was sown, but the rotation of leaders within and a restructuring process deprioritized the learning and stalled proliferation and adoption. It may take longer incubation period but we are sure the momentum will be reignited.

3.5 TRIZ Olympiad

The TRIZ momentum has not only inspired people within the university but also reached the Sarawak Youth Economic Development Foundation (TEGAS). Through the leadership and partnership of TEGAS, UNIMAS, and MyTRIZ, the TRIZ Olympiad program was initiated. The objective was to equip students with advanced problem solving skills, develop their cognitive skills, and build a network of stakeholders.

The Olympiad TRIZ program took on a three-prong implementation strategy. Strategy one involved training the school teachers. With the support of the State-Level Education Department, teachers with a Science, Technology, Engineering, and Mathematics (STEM) background were identified and trained.

Strategy two focused on encouraging the application of TRIZ knowledge by school teachers through a platform called TRIZATHON. The teachers applied their knowledge and were guided by local TRIZ experts. Interestingly, during the teacher training session, the teachers achieved several wonderful ideas such as innovative pens and enhanced face masks, which competed at the national level TRIZ competition held at the end of 2020.

Strategy three involved extensive coordination of the Olympiad through the state schools. School teachers, students, subject domain experts, and TRIZ experts with volunteers contributed their time and effort to organize and participate in the Olympiad.

Several supporting items such as TRIZ Inventive Trigger Cards, Competition Website based on a TRIZ Knowledge Management System were developed by UNIMAS for the event. Quiz and Discussion sessions were included to accelerate knowledge proliferation and creation. Figure 8 illustrates the interaction model of the TRIZ Olympiad key components.

The Covid-19 pandemic put the program at a sudden stop in 2020-2022. But beginning 2023, the momentum has restarted and hopefully more schools from about 1,500 schools, 40,000+ teachers and 480,000+ students will be part of the platform.

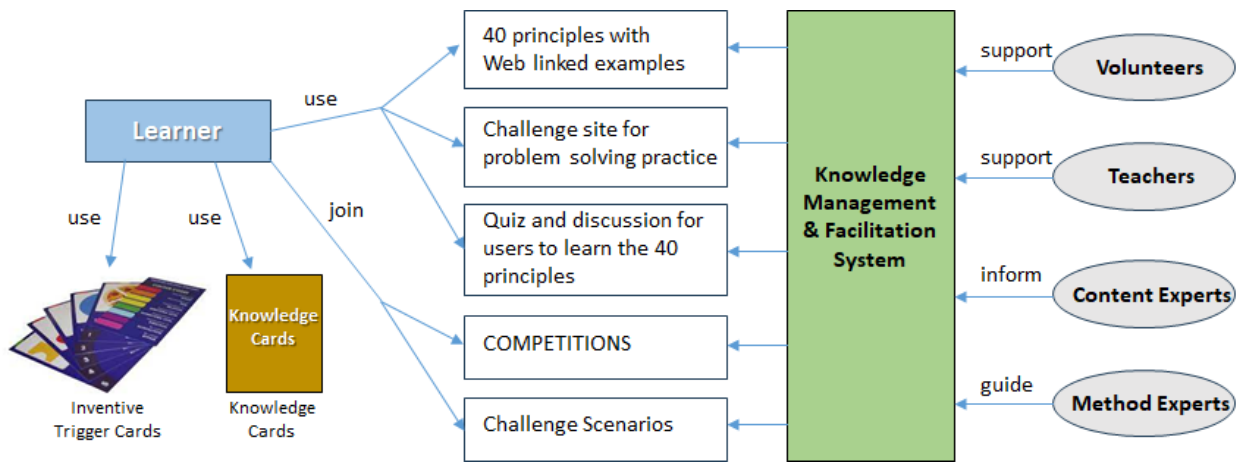


Figure 8: TRIZ Olympiad Component Interaction Model

3.6 Borneo TRIZ

With Ideal Campus encouraging TRIZ learning amongst the university lecturers, under- and postgraduates, and administrators, the Research Clusters reaching out to indigenous communities, and TRIZ Olympiad supporting problem solving learning with the school teachers and students, and TRIZ@Industry seeding the knowledge into industry, it looks like Sarawak is set to harvest the fruits of its investment.

UNIMAS and TEGAS have spearheaded much of the initial efforts, there is no doubt that every single stakeholder has put in their efforts and played their roles, but the various organizations are responsible for working together and driving the culture into their respective systems. To achieve real strength, the idea of Borneo TRIZ was floated by MyTRIZ. Taking the system thinking approach, a combined effort in a single local cohesive unit will deliver more than the sum of its part. Borneo TRIZ formalization was embraced by the Sarawak TRIZ communities and launched on 19 October 2022. The historical moments are shown in Figure 9.

Borneo TRIZ Association aims to generate awareness of TRIZ, share common goals among stakeholders, stimulate localized participation to upskill on advance problem solving and innovation skills, represent unique issues of threatening tribal heritage and ensure no one is left behind. Ultimately, it is to drive teamwork and achieve synergy to resolve the contradictions.



Figure 9: Promoting TRIZ in the Region

4. Conclusion

TRIZ arrived into Borneo Island through Sarawak at the end of the first decade of double zeros (Year2000). Through the initiative led by UNIMAS, TEGAS, and MyTRIZ, TRIZ has proliferated into all levels of societies in Sarawak.

Several breakthrough projects have been deployed, ranging from the concept of Ideal Campus, training of university administrators, sharing and adapting modern innovation tools while documenting tribal knowledge of indigenous communities, encouraging problem solving skills for school teachers and students via TRIZ Olympiad, and creating a career pathway for local innovators.

The Borneo TRIZ initiative was initiated in 2022 and is expected to accelerate the preparation for future skills that also allows indigenous communities to be able to connect and benchmark with scientific inventions by linking to the inventive principles that came from patent analysis. It is important to refine the strategy, implement the solutions, obtain the results and not forgetting to connect the communities and achieve synergy in the effort.

With the leaders, people, and culture being worked out, we are enthusiastic about the ChatGPT era developments with TRIZ to fully empower all underserved people.

References

1. Sawaguchi, Manabu. (2016). How does Japanese “Kaizen activities” collaborate with “Jugaad innovation”?. 1074-1085. 10.1109/PICMET.2016.7806683.
2. MATRIZ Level 1 Training Manual, 2019. <https://matriz.org/wp-content/uploads/2019/01/Level-1-Manual-Word.pdf> . Last accessed: March 22, 2020
3. Kaloshin, N.G., A brief overview of TRIZ (In Russian) <https://www.trizland.ru/trizba/articles/3033/> Last accessed: March 22, 2020
4. Silverstein, D., DeCarlo, N., Slocum, M., *Insourcing Innovation: How to Achieve Competitive Excellence Using TRIZ*, Auerbach Publications, 2007
5. Schoemaker, P.J.H., Heaton, S., and Teece, D. (2018). Innovation, Dynamic Capabilities, and
6. Leadership. *California Management Review*, Vol. 61(1) 15–42.
7. Altshuller G., “Creativity As An Exact Science”, Gordon & Breach Science Publishing House, New York, 1984, ISBN 978-0677212302.
8. Belski,I,(2005). The Role Of Practice In Mastering TRIZ, *Proceedings of TRIZFest*, St. Petersburg, Russia, June.
9. Belski,I, (2007). TRIZ Course Enhances Thinking and Problem Solving Skills of Engineering Students, *Proceedings of the TRIZ-future conference*, Frankfurt, Germany, 6-8 Nov., pp 9-14.

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WHO NEEDS TRIZ CONSULTANTS: A CASE STUDY

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Abstract

This article presents a case study of a TRIZ consulting company that has been in business since 2016. The authors, who are directly involved in this business, collected statistics on practical cases (project proposals and completed projects) and identified companies and industries with the most interest in TRIZ and the TRIZ services most in demand. These results can be useful both for TRIZ practitioners to help them identify new clients and make more targeted offers, as well as for TRIZ developers who want to improve or develop TRIZ tools and services for those industries not currently taking full advantage of the TRIZ methodology. At the same time, this article may also be of interest to industry specialists and managers, who can learn what technical and business problems TRIZ can help them to solve.

Keywords: TRIZ, TRIZ consulting, TRIZ project

1. Introduction

For decades, TRIZ has been used to facilitate innovations in various industries by identifying and solving difficult inventive problems. Its superior effectiveness compared to other innovation methodologies has been proven by numerous practical projects [1].

TRIZ can be easily integrated into a typical Stage-Gate process of new product development [2] and combined with other popular innovation methods such as Six Sigma, Theory of Constraints (TOC), Design Thinking, etc.

The applications of modern TRIZ are numerous [3], and advanced TRIZ practitioners today innovate in areas such as high-tech electronic industry [4], chemical industry [5], software development [6,7], business model development [8], organizational and management problem solving in organizations [9], etc.

Most published case studies refer to the use of TRIZ in large companies such as Intel, General Electric, Samsung and LG, although some efforts are being made to extend TRIZ to small and medium-sized enterprises (SMEs) [10-12].

Despite the enormous potential of TRIZ, its application in the real world is still very limited, and most innovations are still created by trial and error or other methods that are less effective than TRIZ. This leaves TRIZ practitioners with many opportunities to apply their skills to help companies solve their problems.

However, to effectively offer problem-solving services using TRIZ, it is necessary to know (1) which size companies - small, medium, or large - are most interested in using TRIZ, (2) in

which industries TRIZ is currently most in demand, and (3) what types of TRIZ projects are needed most.

Unfortunately, this information is not widely available, despite the considerable number of published case studies, because

1. Most of the case studies are published by a company's own engineers and, therefore, the engineers' experience is limited to that company and its problems, and
2. Case studies usually only describe how TRIZ solved a particular company's problem, but we do not know whether TRIZ was used at the company's request or whether it was the solver's initiative.

The authors of this article, as professional TRIZ consultants, have accumulated enough statistics over many years of working with various companies in a wide variety of industries to determine, at least in part, which companies and industries are most willing to use TRIZ these days and which TRIZ services they need most.

2. Method and Data Analyzed

To obtain the necessary information, we conducted a statistical analysis of 162 requests for proposals (RFPs) that Gen TRIZ LLC received from 94 companies in India, Israel, Colombia, Russia, Kazakhstan, and the US from 2016 to 2023. As we were interested in the current demand for TRIZ, we did not include older RFPs.

Each RFP included in the analyzed pool is relevant to the objective of this paper because:

- All companies specifically requested to use modern TRIZ for solving their problems,
- Each company provided a description of the problem as well as requirements and constraints for a potential solution, which were detailed enough to develop a proposal, and
- Each company reviewed and negotiated the proposal submitted by GEN TRIZ.

While not every proposal submitted led to a project, the large amount of time and effort spent by the client in preparing the RFP, reviewing, and negotiating the proposal demonstrates the company's genuine interest in using TRIZ to solve their problem.

The analysis performed includes:

1. Calculation of the distribution of RFPs by company size. The size of a company (small, medium, or large) was determined as in the QEA-screening tool [13].
2. Calculation of RFP distribution by industry groups, which were determined in accordance with the Global Industry Classification Standard (GICS) [14].
3. Calculation of RFP distribution by the type of TRIZ project requested, which was done separately for small, medium, and large companies. The types of TRIZ projects considered in this study are those that GEN TRIZ offers:
 - New Product Development
 - Product or Process Improvement
 - Cost Reduction
 - Technology Scouting [15]
 - Adjacent Market Identification [16]
 - Patent Circumvention
 - Verification / Prototyping

- Subversion Analysis (Failure Determination and/or Anticipatory Failure Determination) [17].

RFPs related to the continuation of a previously completed project (e.g., requests to verify concepts created in a previous project) were not included in this study.

For confidentiality reasons, the specific products and technologies that companies wanted to develop or improve, as well as the names of those companies, are not disclosed in this study.

3. Results

The calculated distribution of RFPs by the size of the company is shown in Fig. 1.

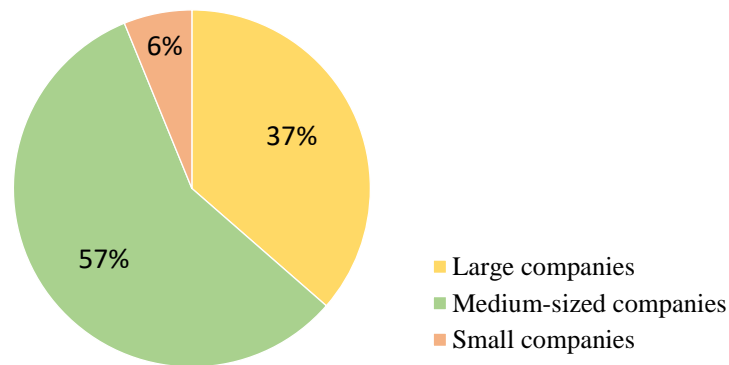


Fig. 1. Distribution of RFPs by company size

As seen from Fig. 1, over a half of RFPs was received from medium-sized companies; over a third of them – from large enterprises, and only a small fraction of RFPs was received from small startup companies.

The calculated distribution of all RFPs by industry groups are given in Fig.2. The industry groups in Fig.2 are determined as in GICS [14].

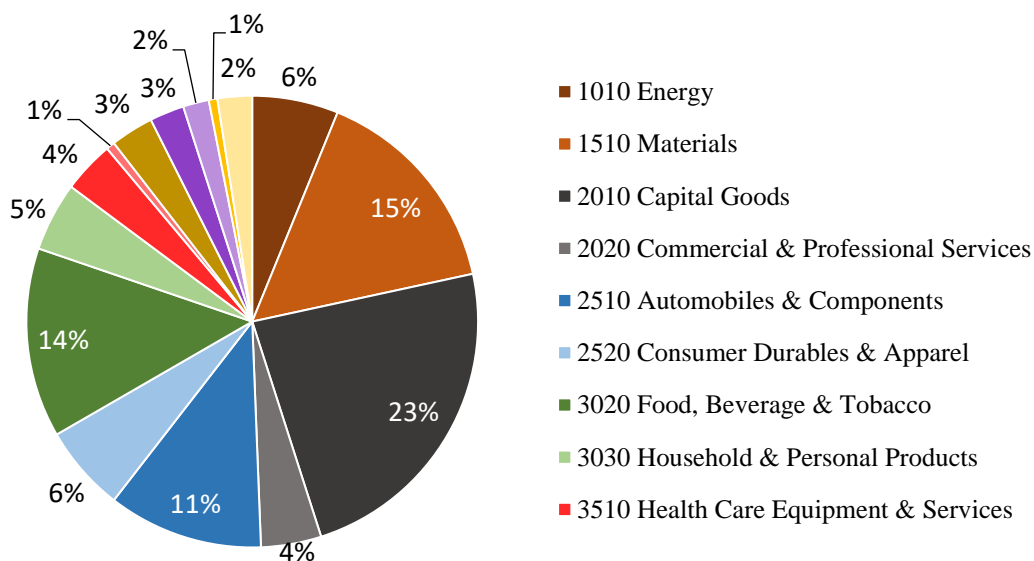


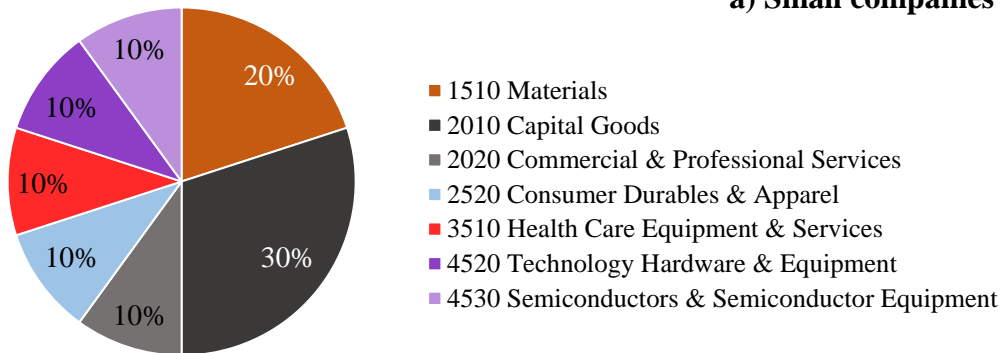
Fig. 2. Distribution of RFPs by industry groups

As shown in Fig. 2, industries where TRIZ help is needed most are:

- Capital goods
- Materials
- Food, Beverage, and Tobacco
- Automobiles and Components.

The distribution of RFPs by industry group differs for companies of different sizes, as shown in Fig. 3. For example, the large companies that are most likely to seek TRIZ assistance are in the Energy and the Automobile and Components industry groups (Fig. 3c), while the medium-sized companies that would like to engage TRIZ are mostly in the Materials, the Capital Goods and the Food, Beverage, and Tobacco industry groups (Fig. 3b).

a) Small companies



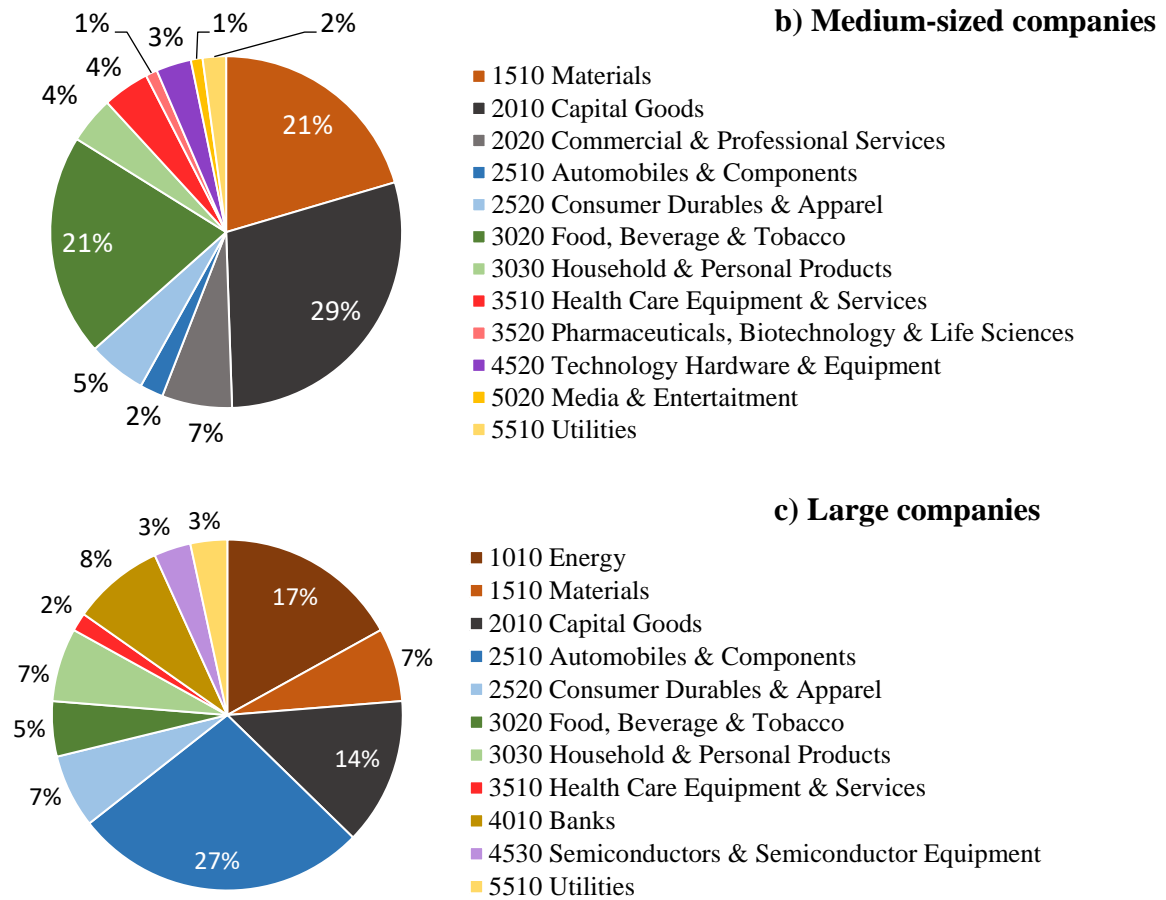


Fig. 3. Distribution of RFPs by industry groups for companies of different size

The distribution of RFPs by type of TRIZ project requested is presented in Fig. 4.

As can be seen from Fig. 4, not all TRIZ services (project types) are equally in demand and the most demanded services are Product or Process Improvement (about 35% of all RFPs received) and New Product Development (about 25% of RFPs), while the least popular services are Sub-version Analysis and Patent Circumvention, which are very rarely requested.

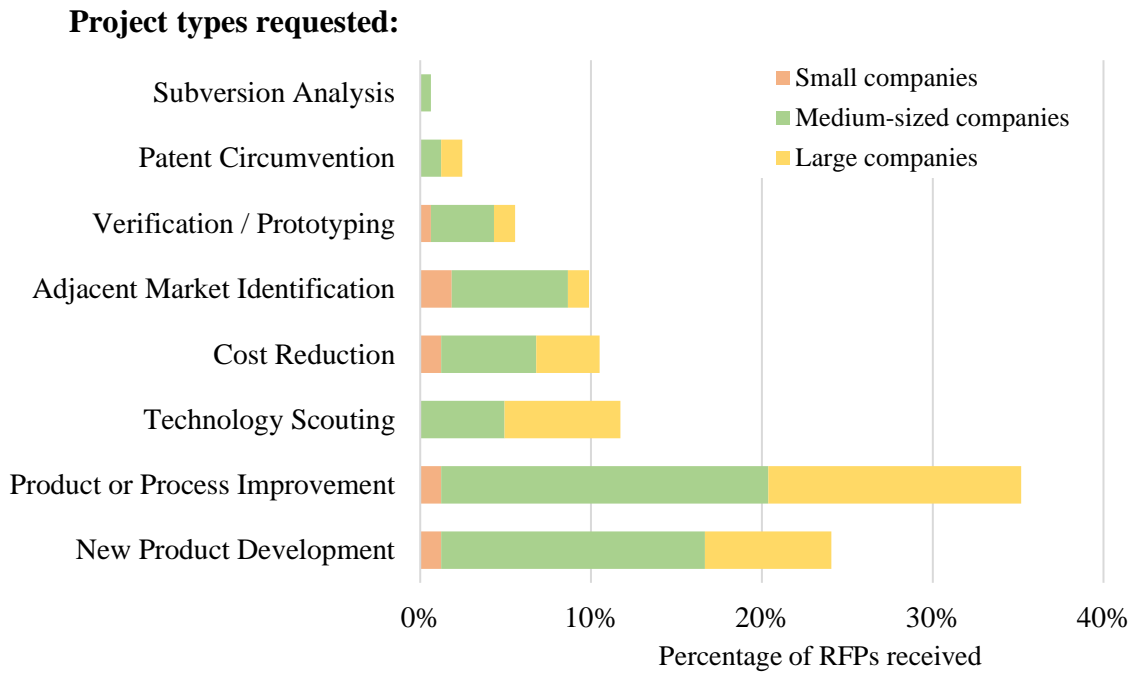


Fig. 4. Distribution of RFPs by the type of TRIZ project requested

Fig. 4 also shows that companies of different sizes usually require different types of services, for example, most RFPs on Adjacent Market Identification (AMI) and Verification / Prototyping projects were generated by medium-sized enterprises while large companies showed more interest in Technology Scouting than AMI.

The results shown in Figs. 1-4 are summarized in Table 1 below.

Table 1. Summary of the results obtained in this study

The size of the company most in need of TRIZ	Industry groups where TRIZ is most needed	The most popular TRIZ services
Medium	<ul style="list-style-type: none"> • Capital goods • Materials • Food, beverage & tobacco 	<ul style="list-style-type: none"> • Product or process improvement • NPD • AMI • Cost reduction • Technology scouting • Verification and prototyping
Large	<ul style="list-style-type: none"> • Automobiles & components • Energy • Capital goods 	<ul style="list-style-type: none"> • Product or process improvement • NPD • Technology scouting • Cost reduction

4. Discussion

It should be noted that the research presented in this paper is limited to the practice of just one TRIZ consulting company, which (1) primarily targeted Indian, Israeli, Colombian, Russian

and Kazakh companies, (2) did not actively offer its services to IT companies, and (3) did not offer to solve managerial or business model problems.

Therefore, the results presented may reflect some geographical peculiarities or omit some industries where TRIZ can be used.

Nevertheless, despite these reservations, the statistics collected are representative enough to help TRIZ practitioners more effectively identify the most promising industries and, within those industries, identify companies that could be interested in TRIZ. Then TRIZ practitioners can offer these companies the TRIZ services that they are likely to want, as shown in Table 1.

There are a few observations to be made about the results:

- The demand for TRIZ on the part of small companies is surprisingly low. In fact, these companies tend to be start-ups developing a completely new product, which usually requires solving numerous inventive problems – which is exactly what TRIZ was originally designed for. Therefore, it would be fair to expect that such companies would be interested in TRIZ services.
- The overall demand for Subversion Analysis is low, while among small companies there is almost no demand for this service. However, based on the Trends in Engineering Systems Evolution, Subversion Analysis is most effective for products and processes in the first or transitional stage of evolution [17], which is usually where start-up companies are.
- Demand for AMI services among large companies is unexpectedly low. Large companies usually have mature products that can benefit from being introduced into adjacent markets, which means that AMI is just what they need.
- In addition, for some reason, large companies use TRIZ services less often than medium-sized companies, although they usually have just as many technical problems to solve but more financial opportunities to engage TRIZ consultants.

Small companies most likely do not use TRIZ because they do not have enough money to hire TRIZ consultants and, therefore, try to solve all their inventive problems on their own.

As for large companies, unlike medium-sized ones, they often have their own large R&D and marketing departments, so they also try to address their technical and market problems themselves.

5. Conclusions

Despite certain reservations, the results reported here can be used in several ways:

- TRIZ practitioners can use them to offer TRIZ services more effectively, targeting those companies and industries that are most likely to use TRIZ, and offering the services that are most in demand.
- Industry managers and engineers can find out if there are already TRIZ services in their field that they or their competitors can use.
- TRIZ developers can improve TRIZ services and tools that are currently underutilized to make them more effective and attractive to small and large companies and suitable for use in industries where TRIZ is not currently widely used.

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References

1. Abramov O., Medvedev A., Rychagov V. "Evaluation of the Effectiveness of Modern TRIZ Based on Practical Results in New Product Development". In: Benmoussa R., De Guio R., Dubois S., Koziółek S. (eds) *New Opportunities for Innovation Breakthroughs for Developing Countries and Emerging Economies*. TFC 2019. IFIP Advances in Information and Communication Technology, vol. 572, pp. 36-44. Springer, Cham, 2019.
2. Abramov O. "TRIZ-assisted Stage-Gate Process for Developing New Products". *Journal of Finance and Economics*, vol. 2(5), 2014, pp 178-184.
3. Muñoz C. "The Application of TRIZ. An Overview". Munich, GRIN Verlag, 2017. <https://www.grin.com/document/366470> . Last accessed: May 25, 2023.
4. Krasnoslobodtsev V., Langevin R. "Applied TRIZ in High-Tech Industry". *Altshuller Institute meeting, TRIZCON2006*, Milwaukee, WI USA, April 2006. <https://www.metodolog.ru/triz-journal/archives/2006/08/01.pdf> . Last accessed: May 25, 2023.
5. Abramov O., Kogan S., Mitnik-Gankin L., Sigalovsky I., Smirnov A. "TRIZ-Based Approach for Accelerating Innovation in Chemical Engineering". *Chemical Engineering Research and Design*, vol.103, 2015, pp.25-31.
6. Kluender D. "TRIZ for Software Architecture". *Procedia Engineering*, vol. 9, 2011, pp. 708-713.
7. Brad S., Brad E., Homorodean D. "CALDET: A TRIZ-Driven Integrated Software Development Methodology". In: Benmoussa, R., De Guio, R., Dubois, S., Koziółek, S. (eds) *New Opportunities for Innovation Breakthroughs for Developing Countries and Emerging Economies*. TFC 2019. IFIP Advances in Information and Communication Technology, vol. 572, pp. 400-416. Springer, Cham, 2019.
8. Souchkov V. "TRIZ and Systematic Business Model Innovation". *xTRIZ*, 2010. http://www.xtriz.com/publications/Souchkov_TFC2010_TRIZandBusinessModels.pdf . Last accessed: May 25, 2023.
9. Sklyarova O., Musaelyan A., Bukhov N., Medvedeva L., Bidzhieva A. "Application of TRIZ Technique in the Organizations' Activity". *International Journal of Economics and Business Administration (IJEBA)*, vol. 8(4), 2020, pp. 563-571.
10. Feniser C., Burz G., Mocan M., Ivascu L., Gherhes V., Otel C.C. "The Evaluation and Application of the TRIZ Method for Increasing Eco-Innovative Levels in SMEs". *Sustainability*, vol. 9(7), 2017: 1125.
11. Russo D., Regazzoni D., Rizzi C. "A Long-Term Strategy to Spread TRIZ in SMEs. Analysis of Bergamo's Experience". In: Koziółek, S., Chechurin, L., Collan, M. (eds) *Advances and Impacts of the Theory of Inventive Problem Solving*, pp. 147-157. Springer, Cham, 2018.
12. Russo D., Carrara P. "Innovation Lab: New TRIZ Tools for Fast Idea Triggering". In: Benmoussa R., De Guio R., Dubois S., Koziółek S. (eds) *New Opportunities for Innovation Breakthroughs for Developing Countries and Emerging Economies*. TFC 2019. IFIP Advances in Information and Communication Technology, vol. 572, pp. 16-25. Springer, Cham, 2019.

13. Abramov O., Markosov S., Medvedev A. “Experimental Validation of Quantum-Economic Analysis (QEA) as a Screening Tool for New Product Development”. In: Koziółek S., Chechurin L., Collan M. (eds) *Advances and Impacts of the Theory of Inventive Problem Solving*, pp. 17-25. Springer, Cham, 2018.
14. MSCI Ink. “The Global Industry Classification Standard (GICS®)”. *MSCI*. <https://www.msci.com/our-solutions/indexes/gics> . Last accessed: May 25, 2023.
15. Fimin P., Smirnova E., Abramov O. “Technology Scouting for Solid Waste Treatment: TRIZ Approach”. *Acta Technica Napocensis - Series: Applied Mathematics, Mechanics, and Engineering*, [S.I.], vol. 63(3S), 2020. <https://atna-mam.utcluj.ro/index.php/Acta/article/view/1387>. Last accessed: May 30, 2023.
16. Abramov O., Litvin S., Medvedev A., Tomashevskaya N. “TRIZ Roadmap for Identifying Adjacent Markets”. *TRIZ Review*, vol. 2(1), 2020, pp.8-21.
17. Abramov O. “Functional Approach to Subversion Analysis in New Product Development”. (In Press): Accepted for presenting at TRIZ Future Conference 2023, Offenburg, Germany, September 12-14, 2023.

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CONSIDERING INFORMATION AS A LEGITIMATE COMPONENT IN TRIZ BASED FUNCTION ANALYSIS

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Abstract

The term "information" is widely used in the scientific domains and everyday life. There is no field of knowledge that has avoided a temptation to apply it. This is a consequence of the continuing expansion of the semantic field of this term. However, in the modern TRIZ community one can observe a lack of a common approach to deal with information.

Endless debates have been happening about application of a function analysis for creating and analyzing models of systems where information is involved. In this paper, the authors demonstrate that "information" can be treated as in the function analysis.

A combination of two approaches – "Data Knowledge Information Wisdom (DIKW) Pyramid" and "Reality Tunnels" is proposed for analysing technical systems in which information plays an important role.

Keywords: Information, Function Analysis, DIKW Pyramid, Reality Tunnel

1. Introduction

The term "information" is used extensively and has different interpretations. In our opinion, the existing function approach known in TRIZ focus on function formulation processes when dealing with substances and energy flows in relation to the evolution of engineering (technical) systems. This is somewhat of a paradox, since the main activity in TRIZ Function Analysis, Trimming, Function-Oriented Search is precisely in working with information.

It can be noticed that the main part of TRIZ activity historically and evolutionarily is related exactly to receiving and processing information. First of all, G. Altshuller, at initial stages of TRIZ development, worked with information extracted from the patent databases. G. Altshuller's earlier attempts to use philosophical approaches and observations of success stories of productive inventors gave very limited insights. Working with information is not equivalent to direct work to change technical systems. In other words, one does not have to drill holes, as-

semble and adjust specific parts of technical systems, etc. The results of this work with information about technical systems was the emergence of new information and new framework such as 40 Inventive Principles, 76 Standard Solutions, Patterns and Trends of Developing Engineering Systems. Second, when teaching TRIZ to different categories of learners, both training materials and illustrative cases studies are very important as well as the way of presenting. Third, the process and results of TRIZ projects always have specifics of searching, selecting and processing information. E.g., application of Function-Oriented Search may lead to different results depending on the qualification and experience of a TRIZ practitioner.

Thus, the importance of considering specifics of handling information in TRIZ activity is beyond doubt.

The purpose of this paper is to establish the main features of practical work in collecting, studying, transferring and reconfiguring information for improving and developing engineering systems with TRIZ.

1.1 Introductory Examples

Let's take a look at an example that is widely used to explain how the concept of "function" is defined [3].



Fig. 1. What is a function relation between kids and a school bus?

Since there is no interaction (direct physical contact) between the kids and the bus, it is assumed that there is no function relation between them.

Let us consider this example in some detail.

The children have already performed an action - they moved to this bus stop. They have used information about the bus schedule and route to do so. Moreover, this action is necessary to perform the next actions - that is, to get on the bus and travel. The bus has also performed the action (moving) as the driver knew the same information about schedule and route.

Thus, the absence of function connection in the canonical definition [2,3] is quite understandable and acceptable, but does not fully and only fragmentarily characterize this simple situation. For a more complete understanding of the occurring (or not occurring) specific events, it is necessary to introduce an information component. This information component is extremely important for describing the system "transport system of children delivery" and understanding the mechanisms of combining individual components into the system. In this example, the consideration of informational interactions leads to the fact that the absence of "canonical" functions at some interval of the lifecycle is not always a reason to exclude these intervals from the function analysis of the system as a whole. Moreover, as we have shown with this simple case study, accounting for information interactions in the absence of "classical" functions is a quite

meaningful and important indicator of system activity. Depending on the specific context, we can identify this lack of active action as a deficiency or a resource.

1.2 Analytics marathons

Now, let us consider another example, which is more complicated. It is about analytics marathons [4].

According to [4], preparation is important for analytics marathons too. The pre-race preparation is a kind of data strategy work that must happen before collecting, visualizing, and analyzing data. Unfortunately, this step is frequently overlooked or ignored.

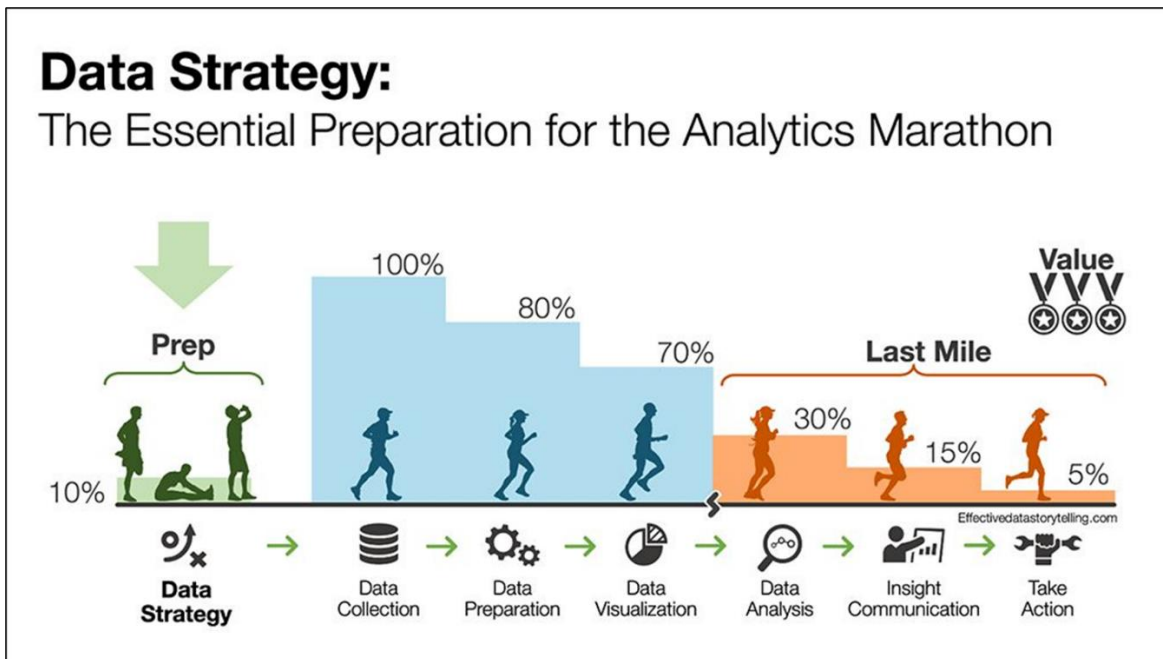


Fig. 2. Illustration of the importance and effectiveness of information activities [4]

This metaphor (see Fig. 2) clearly shows that data/information processing issues are not always conducted efficiently in terms of the resulting value and impact on the subsequent actions.

2. What We Mean by Information in This Research

There is no precise, generally accepted definition of "information". This is typical for many fundamental scientific concepts.

For example, Britannica Dictionary definition of information: knowledge that you get about someone or something: facts or details about a subject [5].

A review of the various approaches to classifying information [1] shows an extremely large variety of them. The most of such classifications ad hoc

In this research, we have considered only those aspects of information that seem to be important in TRIZ in general and in Function Analysis specifically.

Nowadays, the popular direction of TRIZ development is applying Function Analysis in information technology [6,9,10]. However, it remains outside the scope of this paper. In our opinion,

formulating the main useful function (as proposed in the publications mentioned above) “to process data” or “to inform operator” is of limited use due to its excessively high generality. It is suitable for high-level analysis. However, in practical cases it is not enough.

For example - process data is produced using very different algorithms. Correspondingly, the information extracted from data is different and requires at least a comparison. The results of executing function “to inform operator” can also be different - the information provided can be simply missed, not completely understood or perceived differently. In this case, the operator's subsequent actions may also vary quite significantly.

3. Data Information Knowledge Wisdom (DIKW) Pyramid for Practical Application in Function Analysis

In order to meet research objectives, it is necessary to apply the approach known in TRIZ - that is, the separation of levels of working with information. We used the so-called "Data Information Knowledge Wisdom" (DIKW) Pyramid as a separator of levels for widening context/ contextualization (see Fig. 3).

First, this classification is quite widely used in many knowledge areas [11,12,13,14,16,17,18]. Second, this hierarchy is quite easily adaptable for a variety of applications [15].

According to [17]:

"The DIKW hierarchy is based on a set of four axioms:

- (a) Data, information, knowledge, and wisdom represent distinct levels of knowing characterized by different complex content.
- (b) The content of each level is obtained by processing the content of the lower level.
- (c) Complexity increases in a bottom-up fashion.
- (d) Transitions from one level to another one are nonlinear and non-programmable processes”.

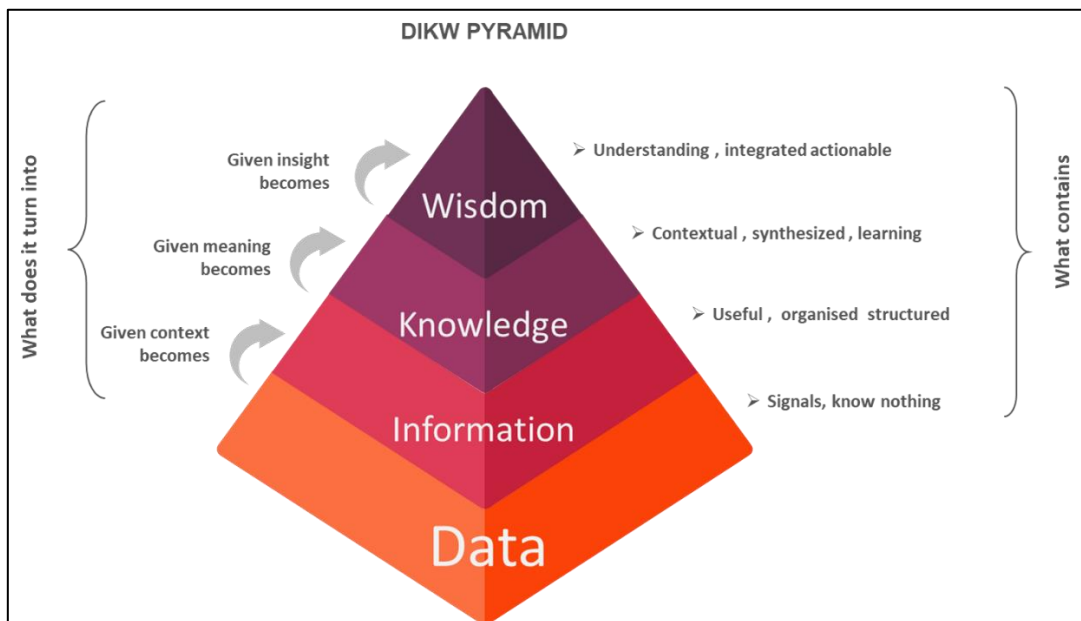


Fig. 3. Data Information Knowledge Wisdom (DIKW) Pyramid [adopted from 11,14,16]

An important addition to DIKW for our applications is to characterize and describe in function language the sources and ways of obtaining data. However, applying a function description as

"to inform operator" is too general and not always a fruitful description. For example, the temperature of the human body can be measured with a thermometer or a non-contact pyrometer. Even more advanced system can be used [21]. Measures from the temporal artery, considered an ideal place to detect temperature changes, as the blood that circulates there comes from the core of the body. Sixteen infrared sensors take over 4,000 measurements, which is a revolutionary advancement of HotSpot Sensor Technology [21].

Thus, depending on the specific measurement technology/procedure, different accuracy is achieved, different noise factors must be taken into account and the quality of the data is consequently affected.

Table 1 represents specifications of different levels of DIKW pyramid in relation to Function Analysis

Table 1. Characteristics of the DIKW Pyramid in relation to TRIZ based Function Analyses

Level of DIKW Pyramid	Specifications	Notes
Wisdom	Ability to formulate judgments, identify an interpretation and a set of values of the objectives	New emerged Trends identification, Ideal Final Result
Knowledge	Answers to <i>how-to</i> questions Laws of nature, instructions, know how	TESE, Function model
Information	Answers to questions that begin with such words as <i>who, what, when, where, how many</i>	Component analysis, structural, parametric analysis with AFA [7,8]
Data	Symbols: Quantitative data (i.e., numbers, signals), and/or Qualitative data (i.e., color, flavor). Usually obtained from sensors and/or observations	Raw data from all available sources

DIKW fits naturally into the concept of poly-modeling typical for the modern TRIZ and all postmodern science.

The completeness of data/information/knowledge analysis for each “level” is difficult to define theoretically. Practically, however, the boundaries of frame are determined by two simple considerations:

- (1) continuing to deepen the analysis does not bring new meaningful results. For example, quantum-mechanical representations do not bring usability in studying macro-processes.
- (2) if more detailed understanding is needed, the levels and horizons of analysis can be recursively reconsidered. Thus, it is recommended to proceed similarly to the analysis of technical systems [2,3]

A complete picture of information understanding is formed by non-linear/non-additive summation of the contributions of different DIKW levels. The distribution by levels - how much is needed for understanding - is determined specifically in each situation based on project goals.

First of all, it is important to check the information completeness at different levels. It is also possible to compliment the approach described with "tunnels of reality" (see the next chapter).

The best possible scenario is when the user on his/her own goes to a higher level. Perhaps - it is necessary to interact from the upper and lower levels with appropriate content. For example, some people have their own specific perception of metaphors, analogies, abstract truths. Then the wisdom of quotations from Buddha, Confucius, and dialectics unexpectedly significantly helps the completeness of understanding of the situation. From time to time, it is a surprisingly sufficient factor of mutual understanding.

4. Strategy of instantiation “Reality Tunnel“

Timothy Leary and Robert Anton Wilson coined the term of “Reality Tunnel“ [22,23]. It refers to a theory that, with a subconscious set of mental filters formed from beliefs and experiences, every individual interprets the same world differently, hence "Truth is in the eye of the beholder" [24].

If we clear the concept of "Reality Tunnel" from an esoteric interpretation, then it can be used as a convenient format of representations of various *Points of View*. In this case, it is possible to productively combine the approaches of the DIKW pyramid and “Reality Tunnels“ of each individual/team. This is schematically shown on Fig. 4.

Then, the priority task of understanding the information is becoming a visual task - the “Reality Tunnels“ recognize borders within DIKW levels. As soon as the borders are identified, the tunnels can be brought together and guide to common sense.

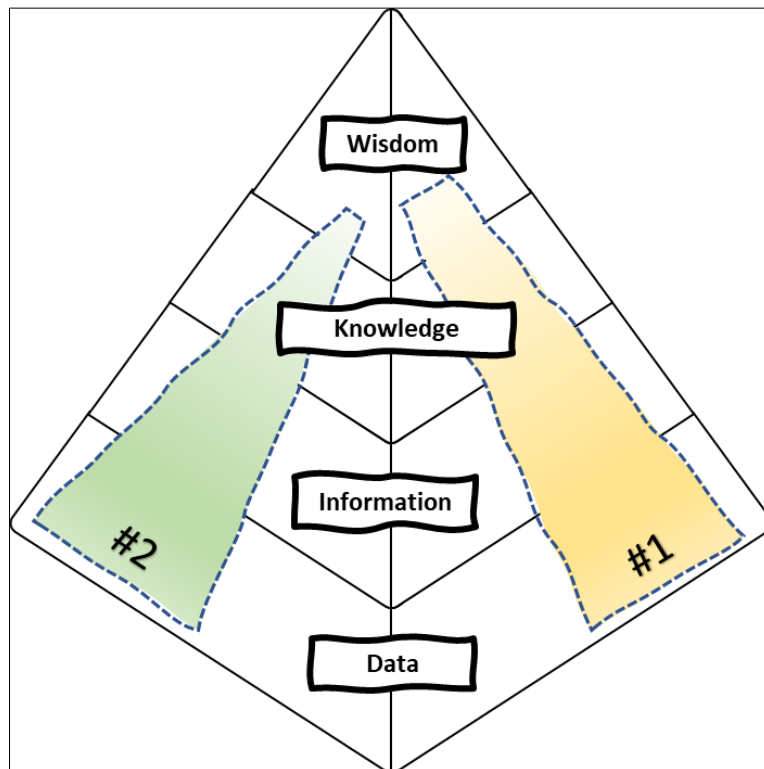


Fig. 4. Combination of DIKW Pyramid and Reality Tunnels (#1; #2)

5. Concluding remarks

Function Analysis is one of the most effective analytical tools of the modern TRIZ. However, its application is still limited to the system that contain information as an important part.

Based on combination of the adapted approaches of DIKW Pyramid and "Reality Tunnels", a holistic framework is proposed to explain the work with information in Function Analysis. The framework is designed for Function Analysis of technical systems, but is not limited to such applications.

It confirms a necessity of introduction of Function Analysis for measurement processes in order to understand specifics of obtaining data. An existing generalized approach where measurement functions are formulated as «to inform operator, to inform sensor, etc.» turns out to be insufficient.

For processing information, "Reality Tunnels" serve as a tool for navigating between different levels of DIKW pyramid and for establishing common understanding of the system by members of the project team. In fact, when working with information, the purpose of mutual understanding always exists, even if not defined specifically.

The next steps include development of specific procedures and algorithms of modeling information system with TRIZ based Function Analysis.

References

1. Krzanowski, Roman. (2023). Information: What We Do and Do Not Know-A Review. https://www.researchgate.net/publication/370105722_Information_What_We_Do_and_Do_Not_Know-A_Review
2. Basic Provisions of the Methodology of Function Cost Analysis: Methodological Recommendations. - Moscow: Inform-FSA, 1991. - 40 c. <https://triz-summit.ru/triz/metod/fsa/1991/> (in Russian)
3. GEN TRIZ Level 1 training manual
4. Brent Dykes https://www.linkedin.com/posts/brentdykes_analytics-bostonmarathon-datastrategy-activity-7052371257316560898-483W?utm_source=share&utm_medium=member_desktop
5. <https://www.britannica.com/dictionary/information#:~:text=Britannica%20Dictionary%20definition%20of%20INFORMATION,or%20details%20about%20a%20subject>
6. Govindarajan U.H., Sheu D., Mann D. Review of Systematic Software Innovation Using TRIZ/Int. J. Systematic Innovation, 5(3), 72-90 (2019) https://www.researchgate.net/publication/332407108_Review_of_Systematic_Software_Innovation_Using_TRIZ
7. Litvin S., Feygenson N., Feygenson O. "Advanced Function Approach". Proceedings of the 10th ETRIA World TRIZ Future Conference 2010, 3-5 November, Bergamo, Italy. pp. 79-85.
8. Feygenson, O., Feygenson, N. (2016). Advanced Function Approach in Modern TRIZ. In: Chechurin, L. (eds) Research and Practice on the Theory of Inventive Problem Solving (TRIZ). Springer, Cham. https://doi.org/10.1007/978-3-319-31782-3_12
9. Nähler, H.T., Gronauer, B. (2016). Using Enhanced Nested Function Models for Strategic Product Development. In: Chechurin, L. (eds) Research and Practice on the Theory of Inventive Problem Solving (TRIZ). Springer, Cham. https://doi.org/10.1007/978-3-319-31782-3_4

10. Nähler, Horst & Gronauer, Barbara & Bertoncelli, Tiziana & Beckmann, Hartmut & Chrząszcz, Jerzy & Mayer, Oliver. (2023). Modelling of Software and IT systems in TRIZ. 10.1007/978-3-662-66201-4_1.
11. Ackoff, R.L. (1989), "From data to wisdom", Journal of applied systems analysis, Vol. 16 No. 1, pp. 3-9. <https://softwarezen.me/wp-content/uploads/2018/01/datawisdom.pdf>
12. Turning Learning Right Side Up: Putting Education Back on Track, 1st edition Published by FT Press (June 3rd 2008) - Copyright © 2008 Russell L. Ackoff Daniel Greenberg
13. J. Bigelow, Developing managerial wisdom, Journal of Management Inquiry 1(2) (1992) 143–53.
14. Rowley, J.E. (2007). The wisdom hierarchy: representations of the DIKW hierarchy. Journal of Information Science, 33, 163 - 180. <https://www.semanticscholar.org/paper/The-wisdom-hierarchy%3A-representations-of-the-DIKW-Rowley/bdf94027d5410b211411157ad7aacfca05aea53d>
15. Aukett, J. The DIKW pathway: a route to effective oral health promotion? Br Dent J 226, 897–901 (2019). <https://doi.org/10.1038/s41415-019-0357-9> <https://www.nature.com/articles/s41415-019-0357-9>
16. Van Meter, H.J. Revising the DIKW Pyramid and the Real Relationship between Data, Information, Knowledge and Wisdom. Law Technol. Hum. 2020, 2, 69–80 https://www.researchgate.net/publication/347145057_Revising_the_DIKW_Pyramid_and_the_Real_Relationship_Between_Data_Information_Knowledge_and_Wisdom/citations
17. Bratianu, C., & Bejinaru, R. (2023). From Knowledge to Wisdom: Looking beyond the Knowledge Hierarchy. Knowledge, 3(2), 196-214. https://mdpi-res.com/d_attachment/knowledge/knowledge-03-00014/article_deploy/knowledge-03-00014-v2.pdf?version=1683177715
18. Bratianu, C., & Bejinaru, R. (2023). Wisdom Management: A Semantic Analysis. https://www.researchgate.net/profile/Constantin-Bratianu/publication/369594493_Doi_Text_Copyright_Wisdom_Management_A_Semantic_Analysis/links/6423dde292cfd54f84388f8a/DOI-Text-copyright-Wisdom-Management-A-Semantic-Analysis.pdf
19. Frické, M. (2019). The knowledge pyramid: the DIKW hierarchy. Ko Knowledge organization, 46(1), 33-46.
20. Frické, M. (2009). The knowledge pyramid: a critique of the DIKW hierarchy. Journal of information science, 35(2), 131-142.
21. The hottest thermometer. The coolest technology. <https://www.withings.com/eu/en/thermo>
22. Reality-Tunnel: How Beliefs and Expectations Create What you Experience in Life <http://ultrafeel.tv/reality-tunnel-how-beliefs-and-expectations-create-what-you-experience-in-life/>
23. Bilokonsky M. Introduction to Reality Tunnels: A Tool for Understanding the Postmodern World (2017) <https://medium.com/reality-tunnels/introduction-to-reality-tunnels-a-tool-for-understanding-the-postmodern-world-72cdd98af9d0>
24. Reality tunnel https://en.wikipedia.org/wiki/Reality_tunnel#cite_ref-1

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USING SUSTAINABILITY MODELLING WITH TRIZ IN PRODUCT DEVELOPMENT PROJECTS TO EMBED SUSTAINABLE GOALS

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Abstract

Following sustainability guidelines in the product development is in general accepted but how to consider it on the engineering side when the main target is not sustainability is difficult. To overcome this at the start of a project a procedure is proposed which combine functional modeling from TRIZ with sustainability targets. This approach was applied in several projects and the recommended use of the functional analysis from TRIZ, the PESTLE model and 5 R's adapted to make it more usable. Out of the projects an example was derived to show the experiences and potential of the procedure.

Keywords: Sustainability, PESTLE, TRIZ, Use case

1. Motivation

Development projects to achieve new functions, more customer convenience, cost reductions or manufacturing optimization often miss the perspective of sustainability. The variety of stakeholders with different interests makes it difficult to define sustainability criteria in the normal everyday development especially due to the increasing requirements around sustainability (1).

Concrete tools for the implementation of Circular Economy (CE) or Ecodesign goals are known, what is missing is a support tool how to define sustainability from the start. To be able to incorporate sustainability with a holistic view it is important to be able to derive a direction for sustainability parallel to main given project goals even if there are single sustainable targets given.

To solve these challenge O. Mayer published a procedure (1) which was applied in several projects to gather experiences which create confidence in the approach and revealed minimal changes to make it more operative.

Sustainable modelling with TRIZ defined by O. Mayer

O. Mayer described a procedure with the help of function and process analysis from TRIZ to support the finding of tasks which are primarily aimed to eliminate harmful function or improve functions with an non-normal degree of fulfilment based on sustainable targets (1). This tasks are recommended to be solved by the 5 R's and with the help of TRIZ tools (2).

The procedure referred to is described in seven steps. Some adaptations for step 5 and 6 emerged with the practice (in bold) and will be discussed later (1):

- 1: Define a situation and the associated system components and super system components;
- 2: Create a functional analysis for the system and derive tasks for incremental improvement according to main tasks;
- 3: Creating the processes necessary to create and dismantle the situation. A cradle to grave analysis;
- 4: For the functional analysis (FA), the PESTLE elements are introduced as super system components or fields;
- 5: For each element, a functional analysis is performed and the tasks for improvement are defined. That is, to each PESTLE element exists a connection from each component whereas the PESTLE content is transferred to a function description based on the FA from step 4 for new , harmful or insufficient function or the content is linked to the Trends of Engineering System Evolution (TESE);
- 6: Solving the tasks for harmful functions or for functions that do not have the degree of fulfillment normal with the selected 5 R's. Of course, the contradiction matrix can be used for this or if it is about social aspects Design Thinking methods can be used to determine how people react
 - 6.1: Separate functions related to social issues:
Clarify if other tools can be used or a combination with TRIZ
 - 6.2: Separate functions related to technical issues:
Select one of the 5 R's rule or other Ecodesign rules and apply TRIZ tools for supporting the solution process where applicable.
Depending on the defined target iterations are possible related to the selected 5 R's;
- 7: Evaluate the solution ideas with a tool such as SWOT analysis or the Priority Matrix

The main learning from the usage of the procedure refers to step 5 which will be described separately because it affects the operational work and the solving process in step 6.

Experiences and adaption of the procedure

Using the procedure on a specific project the expectation was to find development direction more easily due to the focus. This is not true which was realized in different projects using existing knowledge base on sustainability.

Figure 1 show a more generic view which is also applicable for components e.g., a valve actuator. Even with such a narrower view the proposed way to use PESTLE as a field of the super-system in the FA was challenging which led to a small adaption (Fig. 2).

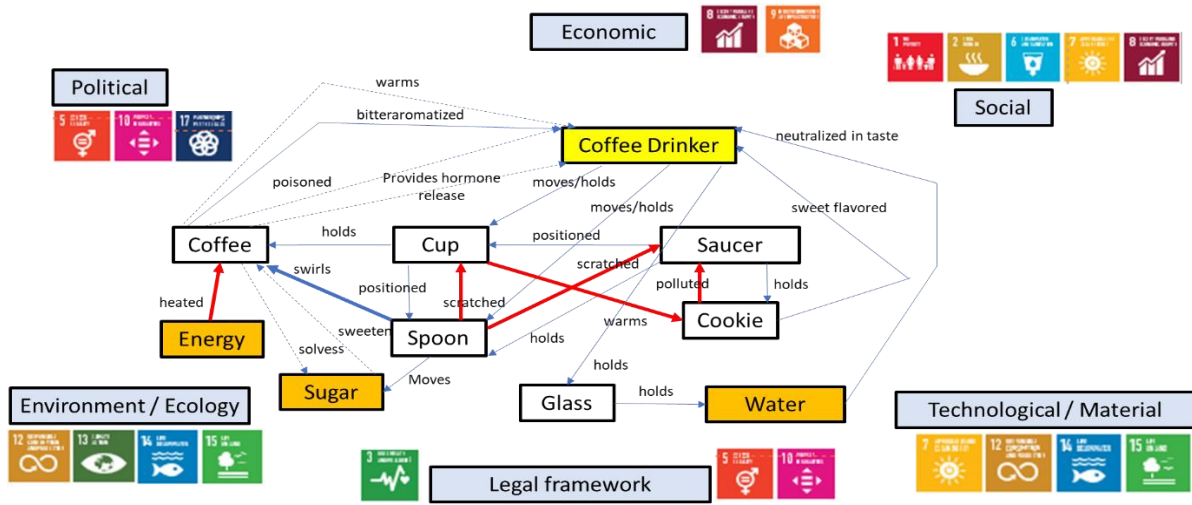


Fig. 1. PESTLE elements adding to the FA (no claim to completeness) (1)

Insights derived from papers, experts view... were summarized as shown in Fig. 2 so sustainable topics are conscious after the PESTLE Analysis (Fig 2 No. 1). Based on the target system these insights were transferred to related existing functions or new were defined (Fig. 2 No. 2). If no function could be found the link to TESE was used to get a future development direction (Fig. 2 No. 3).

Current discussions in the context of sustainability emphasis the role of the user, so that other tools are used in addition to the TRIZ tools mentioned (1,3,4). This is not explored further in this paper, but the technical and social perspectives are therefore separated in the solution finding phase in step 6. It is important to decide which of the 5 R's is selected to reduce the initial workload, which may also entail iterations, which is acceptable.

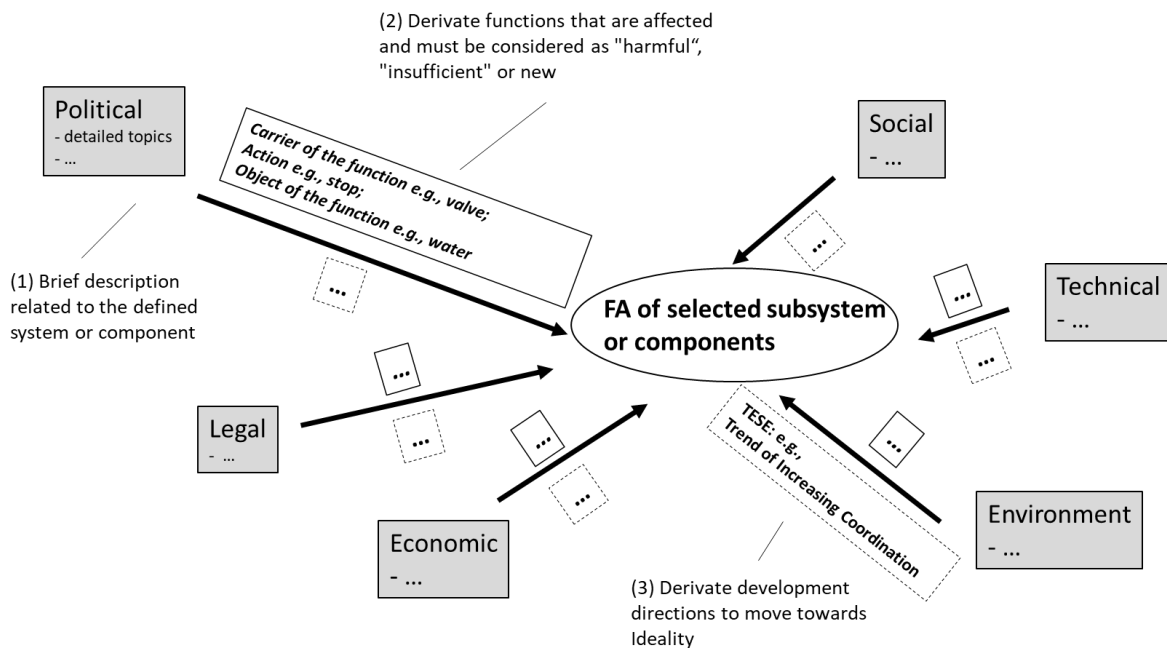


Fig. 2. PESTLE elements adapted to the FA of selected subsystem or component

2. Example / Use case

To explore the proposed procedure a technical system was selected which is mature and for which e.g., energy efficiency rules exist. Thus, a European domestic appliance was selected. Most efforts are aimed at cost savings and user convenience beside sustainability, part from sustainability issues required by legislation. A compact dishwasher was selected with the aim to reduce the part numbers to safe costs and gain more space for the cleaning cavity. For the paper, a simplification was done to explain the experience with the procedure but still based on a wider content. In general, iteration from the complete system to subsystems or components was a key to manage the insights gathered by this procedure. The recommended seven steps are now explained in detail:

2.1 System Definition / Super System

A dishwasher for kitchens or caravans (Fig. 3 left) should be technically optimized at the third component level (Fig. 3 right). The impact from business models was excluded.

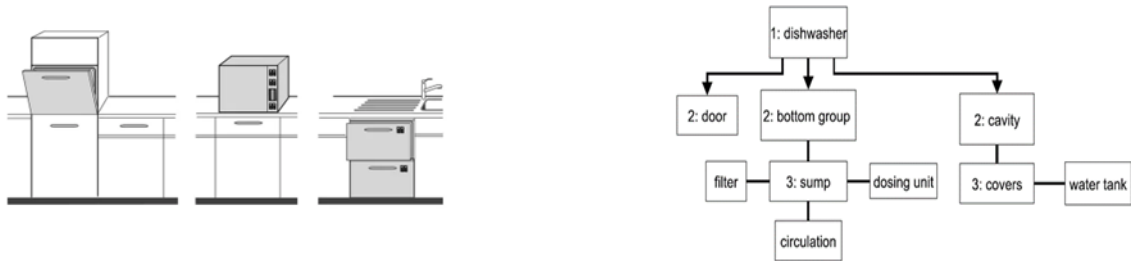


Fig. 3. Compact dishwasher (high built-in, upright, integrated, drawer) and related component level (5)

2.2 Functional Analysis (FA) of the present system

Following Fig. 3 an upright type with a tank and/ or water supply was selected with the focus on resource efficiency for water usage and the main function to move stain from the dishes for the function analysis (Fig 4).

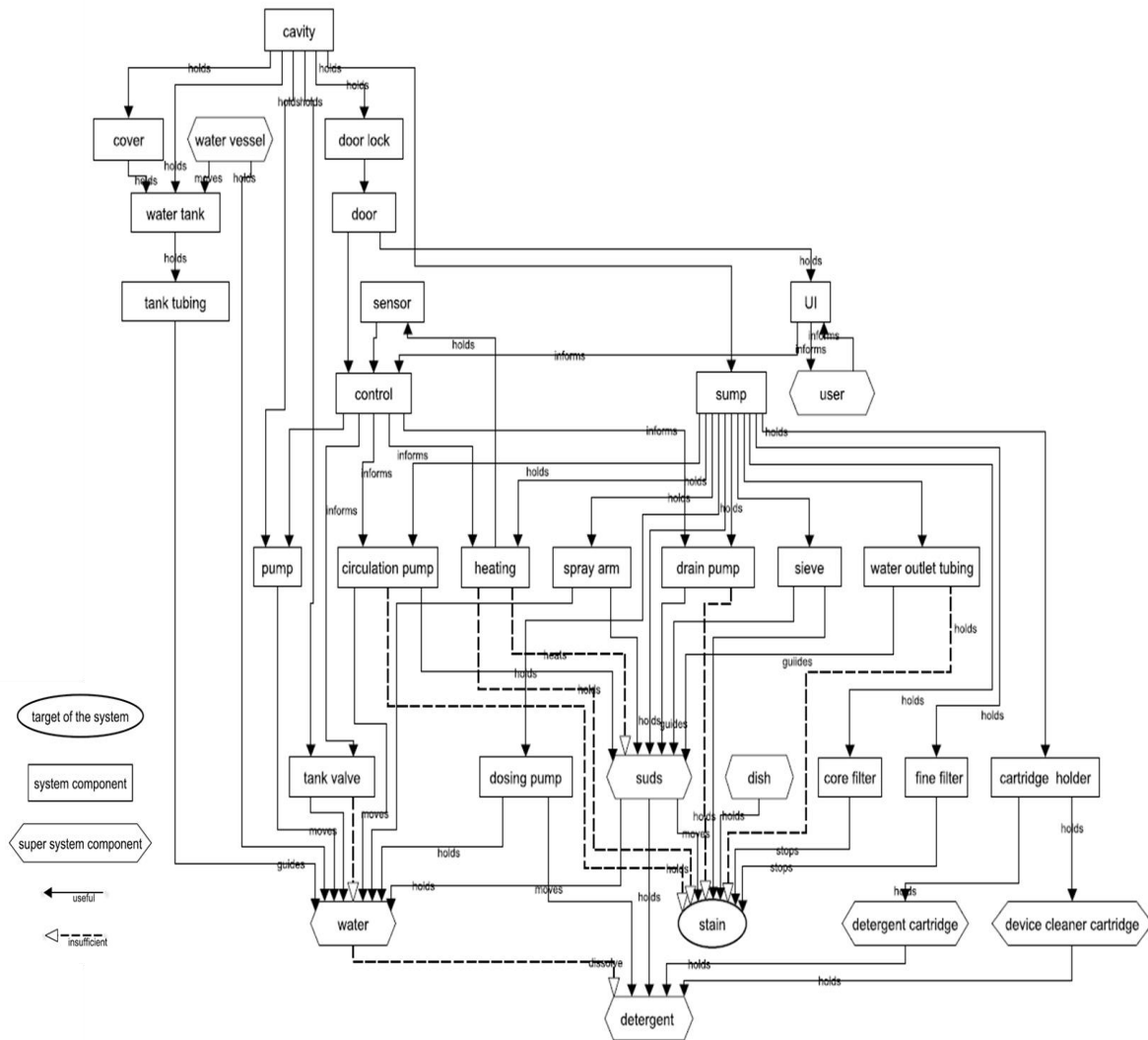


Fig. 4. FA of the selected dishwasher

Based on the FA first tasks could be described (Tab. 1). Obvious tasks related to sustainability can be addressed as well but were not followed at this stage.

Table 1. Examples from the task list based on the FA

<p>How can the number of fluid actuators be reduced to save costs?</p> <p>How can the access to the water tank be realized to clean it?</p> <p>How can the dissolution of detergents be improved to get a better distribution?</p> <p>How can the inlet valve be used as an aqua stop?</p> <p>...</p>

To improve the overview for the next step the system was broken down in subsystems e.g., water supply or detergent module. To solve the tasks TRIZ tools were used at this stage - see 4.6.

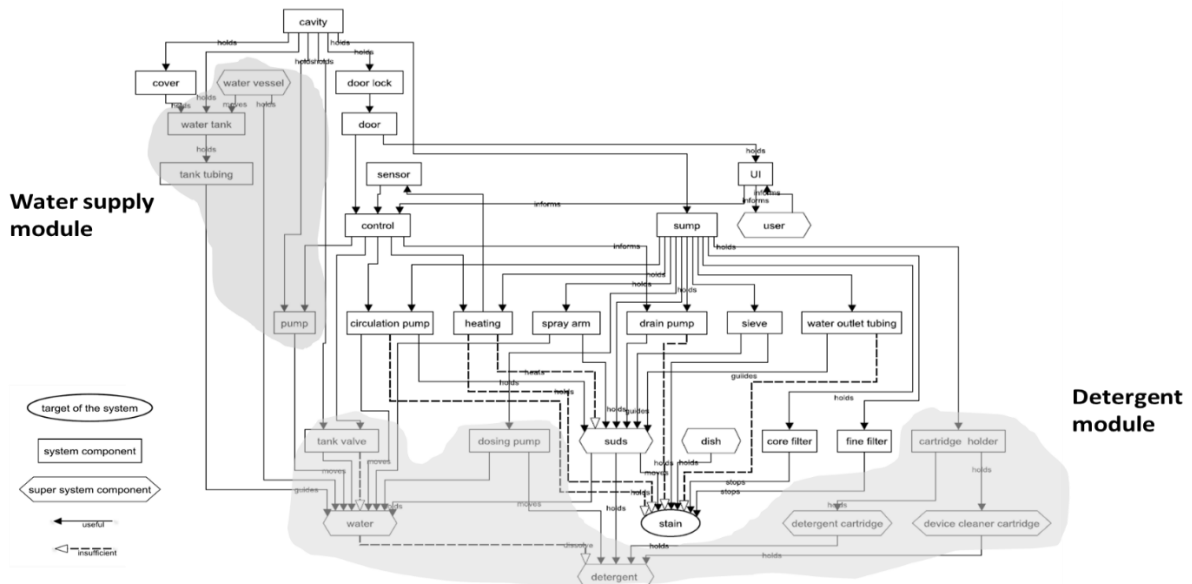


Fig. 5. Definition of subsystems

2.3 Process Analysis

The overall process of the cradle-to-cradle process (Fig. 6) was reduced on the use phase (Fig. 7). For simplification, a part of the use phase was selected: How can the cleaning of the dishwasher be improved at the end of the process? This phase is often forgotten because it can be defined as an auxiliary process which is not linked to the main function but through FA and process analysis the impact become transparent (Fig. 7 and 8).

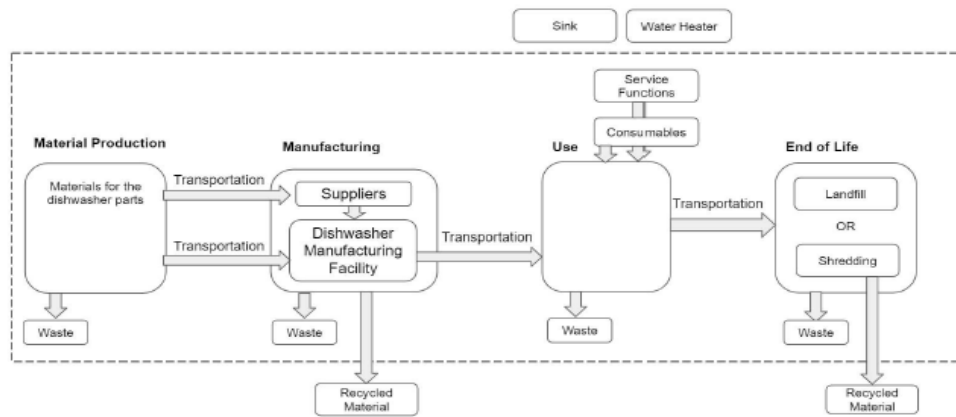


Fig. 6. Life Cycle of a Machine Dishwasher according to Willskytt (6)

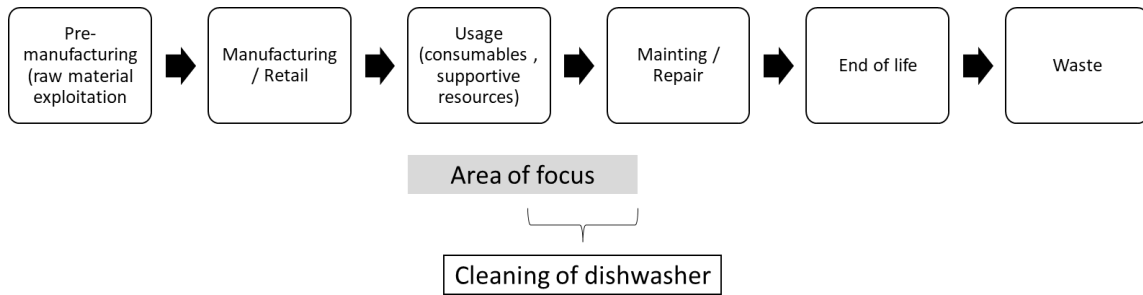


Fig. 7. Selected process for the dishwasher

Cleaning of the dishwasher can be divided into three steps: prepare, apply, and move (dirt) suds. Figure 8 shows a simplified process where the insufficient functions are indicated by dotted lines.

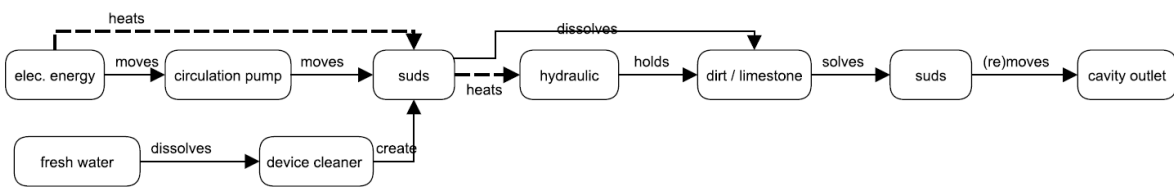


Fig. 8. Process of cleaning the dishwasher

Based on the process analysis first tasks could be found. Obvious tasks related to sustainability can be addressed as well but were not followed at this stage

Table 2. Examples from the task list based on the Process Analysis

How can the device cleaner be replaced?
How can the heating be reduced?
How can the fresh water usage be reduced?
...

2.4 PESTLE Analysis

Based on literature and market requirements, an overview for the dishwasher was created in order to describe the targets for the water-related system parts in a further step.

Table 3. PESTLE for the dishwasher and water related subsystems – some examples (2,3,4,6-12)

.Compact dishwasher					
Technology / Material	Economic	Environment / Ecology	Political	Social	Legal
Microgrids	Sharing Economy	Water shortage	Change of energy mix	Multi-use (home- carvan)	Right-to-Repair
Cyber-Physical System	E-Commerce	CE (EN 4555X...)/ EU regulations	Sharing Economy	Rebtdeffect	REACH / EU regulation
Closed-loop-control	„Everything as a service“	Waste water treatment	Reduction of plastic waste	Shift of food preparation	

Dishwasher hydraulic					
Digital Sinner Circle	Water expenses	Water shortage	Extend product lifetime	Hygenic awareness	Right to Repair
New detergents	Supply chain	LCA impact on consumables (2)	Reduction of packaging (2)	Misunderstandin of the process	REACH / EU regulation
Adaptive control	Waste disposal cost reduction	CE (EN 4555X,...) / EU regulation		No interest to do maintenance	

For the next steps, selected parts of the water supply and detergent dosing module (Fig. 4 and 5) were used for an additional FA model to get a better overview (Fig. 9).

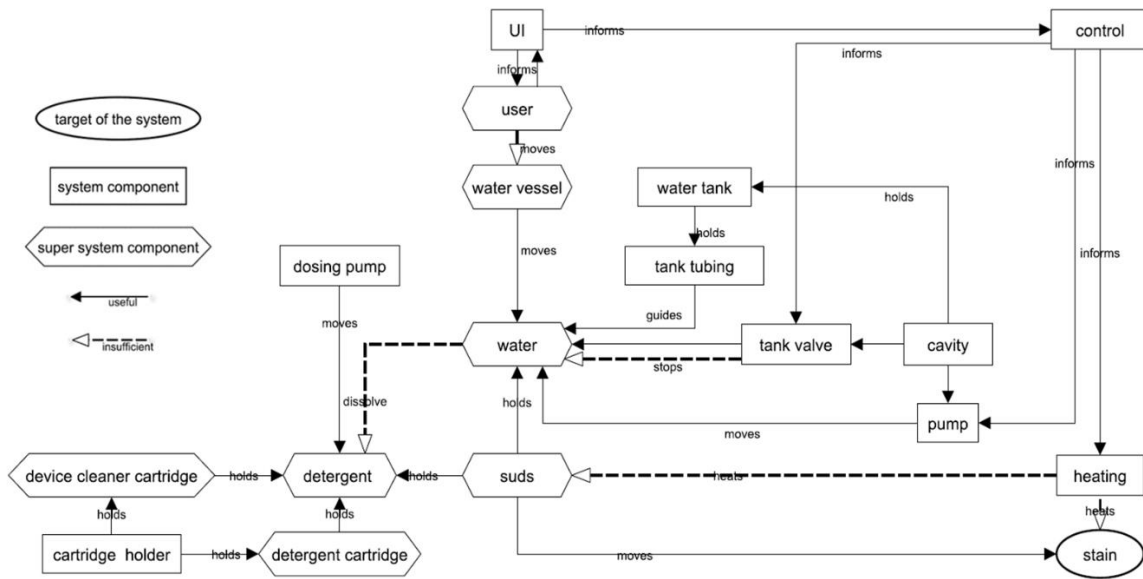


Fig. 9. FA subsystem -water supply and detergent module

2.5 Use the insights from PESTLE as supersystem component

With selected topics based on design guidelines (6,7,8,9,10) from Table 3 a function analysis was done according to the procedure where the PESTLE as supersystem elements is transferred to a function description and tasks described (Fig. 10).

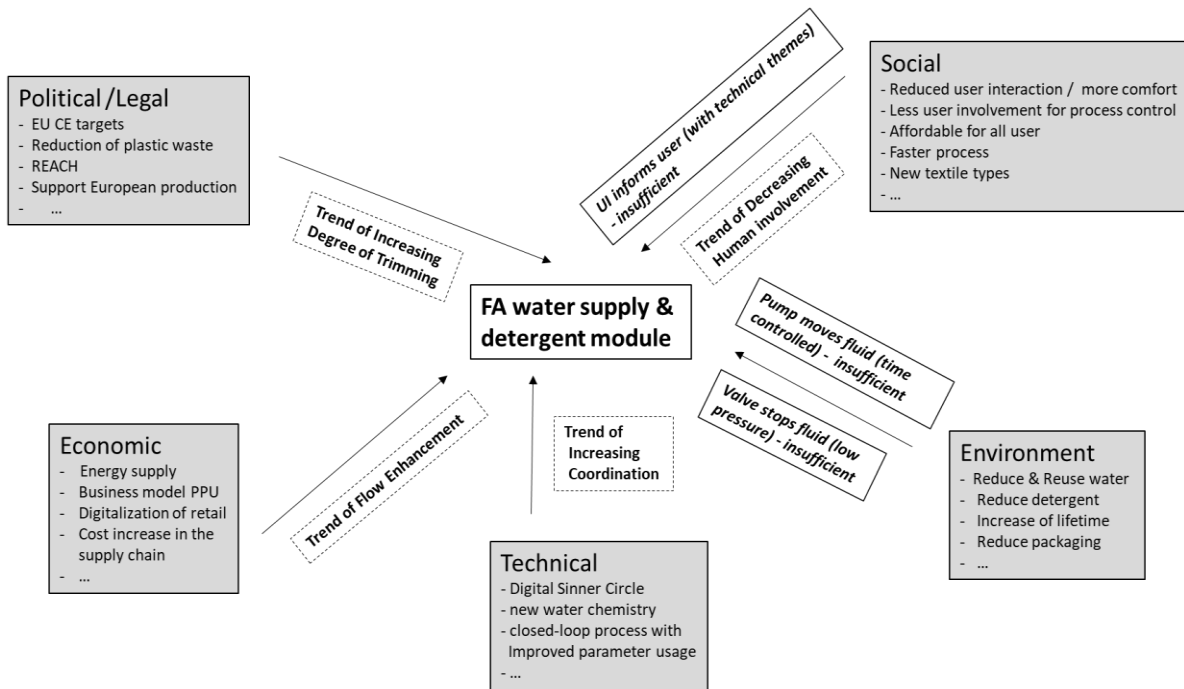


Fig. 10. PESTLE elements that complement the FA

With Figure 10 e.g., the water tank, cartridge and user involvement were selected for improvement which leads to Table 4. The upper part of Table 4 refers to the usage of TESE and the bottom part to “new” function description.

Table 4. Development directions and tasks

Development directions	Tasks
Packing for detergents needs to be reduced (Trend or Transition to the Supersystem)	How can we avoid separate cartridges for the cleaning? How can consumables be designed out?
The water tank for energy or water efficiency purposes is not used (Trend of Increasing System Completeness)	How can we change the control to satisfy the test process for energy efficiency without harming the system by contaminate water?
The water temperature can be reduced due to new detergent systems. (Trend or Transition to the Supersystem)	How can we avoid the heating?
The user is not aware of the benefit and function of Eco-programs (Trend of Decreasing human interaction)	How can we inform the user to use the ECO program in such a way to maximize the sustainability of the system?
Function	Tasks
The tank valve stops the freshwater (harmful)	How can the existing valve be used to stop the water for emergency cases?
The pump/ tubing guides the liquid cleaner (insufficient)	How can a pre-mixing be achieved?
The liquid cleaner holds non-biodegradable substances (harmful)	How can we eliminate the liquid cleaner?

With the tasks from Table 4, there is a deeper view of sustainable issues that justifies not describing or already solving them in Step 4.2 and 4.3.

2.5 Solution finding / examples

The mentioned importance of social aspects besides technical solutions leads to separate path which has only been superficially worked on. The social aspects can be addressed by informing the user e.g., by the user interface. To improve this other tool are recommended (see step 6) (1). The TRIZ Trends “Reduction of human interaction” shows a technical development direction to offer more “self-functions” like the self-cleaning of the tank to reduce the user involvement.

Following the procedure, Eco-design rules and the 5 Rs were selected. For "Cleaning the dishwasher", the theme Lifetime extension and Repair was chosen, which also covers the user's desire for less interaction.

Two steps were used to solve the tasks based on the different FAs performed:
I: Using Trimming and Physical Contradictions to address the original project targets
II: Using Eco-design rules / 5R's and combine the solutions from I in parallel with the recommendation based on the TESE to address sustainability

Examples for step I:

A FA TRIM model was established (not shown) to reduce the component number e.g., to only one pump which is combined with the external inlet water pressure or gravity from the tank.

To improve the water tank size a Physical Contradictions (PC) was used e.g.: More water volume in the tank should be used to run the cleaning cycles more reliable and less water volume in the tank should be used to reduce the space for the tank

Solving the PC with separation in space lead to the design of two associated tank on the top and bottom. Following the separation in time with dynamization the cavity and tank are connected to move the fluid during the rinsing to store water for the dishwasher cleaning.

Examples for step 2:

To solve the tasks from table 4 (e.g., bolded items) the solutions from the first iteration I are combined with Eco-Design guidelines and Evolutionary Trends (7,9,10). For example, the task to avoid the cartridges can be combined with the separated tanks by adding a detergent storage area in the tank. In parallel with the dosing unit the separate device cleaner can be replaced by a coordination of the volume and time dosage of a standard detergent. In parallel the fluid control can be extended to use the water in the process several times by storing a pre-filtered water beside the final dishwasher cleaning.

At the end, the target to gain more cleaning space (cavity) and a cost reduction was achieved. The elimination of two pumps and a higher controllability of the fluid together with the separation of the tank to use existing empty spaces is promising. Adding development directions derived from the FA with the PESTLE as supersystems the first solutions related to the core

projects can be improved to address sustainable topic as well with minor changes.

2.6 Evaluation

To judge the solutions in respect of cost or market needs standard tools were used. For the sustainability it is more complex, so the use of a life-cycle assessment (LCA) is recommended but for the described use case the detailed insights from the PESTLE analysis allows a qualitative judgment.

Working on a specific actuator for the selected subsystems confirms this simplification because the input to select the “right” solution out of a morphological box or SWOT was possible. Nevertheless, a LCA is in progress.

3. Conclusion

The application of the approach in everyday development for projects without sustainability goals showed the applicability. Using the described adaptation as an "instruction manual" facilitates the usage of the TRIZ tools. The proposed procedure helps to get a point where “standard” guidelines can be used or different directions are extracted for further iterations

The deliberate restriction of not considering sustainability in steps 2 and 3 has no negative impact as the main task is solvable. In steps 4 and 5, the understanding of sustainability increases, which expands the existing solution and lead to a less incremental solution in step 6.

The general difficulty of determining the system boundaries can be solved by iteration, as different 5 R's can be used in step 6 without extending the original goal.

The search for functions as defined by TRIZ in step 6 is not always possible but facilitate the usage of TRIZ. The derivation to select TESE also gives a guideline together with established Ecodesign rules.

With the experiences the concept of resources defined by TRIZ seems to be promising in step 6 even it is not new (7). If the resources are used in the meaning of evolutionary resources which take future development e.g. in this context for the detergents, water treatment into account the usage makes sense (13).

In the next step this will be evaluated for components because the described procedure creates a basement which supports the exploitation of resources in the sense of TRIZ.

References

1. Mayer, Oliver. "TRIZfest-2022." TRIZfest-2022 (2022): 170.
2. Reike, Denise, Walter JV Vermeulen, and Sjors Witjes. "The circular economy: new or refurbished as CE 3.0? exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options." Resources, conservation, and recycling 135 (2018): 246-264.
3. Alt, Thomas, et al. "How many resources can be saved by changing consumers' automatic dishwashing behaviour?" Tenside Surfactants Detergents 60.3 (2023): 191-202.
4. Alt, Thomas, et al. "Exploring consumer behaviour in automatic dishwashing: a quantitative investigation of appliance usage in six European countries." Tenside Surfactants Detergents 60.2 (2023): 106-116.
5. <https://www.hea.de/fachwissen/geschirrspueler/aufbau-und-funktion>, downloaded 2023.06.01

6. Willskytt, S. I. R. I. Resource efficient products in a circular economy—The case of consumables. Diss. Chalmers University of Technology, 2020.
7. Russo, Davide, Daniele Regazzoni, and Tiziano Montecchi. "Eco-design with TRIZ laws of evolution." *Procedia engineering* 9 (2011): 311-322.
8. Willskytt, Siri, and Sergio A. Brambila-Macias. "Design guidelines developed from environmental assessments: A design tool for resource-efficient products." *Sustainability* 12.12 (2020): 4953.
9. Spreafico, Christian. "An analysis of design strategies for circular economy through life cycle assessment." *Environmental Monitoring and Assessment* 194.3 (2022): 180.
10. Abeliotis, Konstadinos, et al. "Trends in laundry by 2030." *HPC Today* 10 (2015): 22-28
11. Ina Hook, et all. "Anti-Circumvention of Standards for better market Surveillance, Test reports – Part 5: Domestic dishwashers", 2020 -https://www.anti-circumvention.eu/storage/app/media/ANTICSS_Test-reports_Part5_DISH_draft-final.pdf, downloaded 2023.06.01
12. Bertoldi, Paolo. "Proceeding of the 11th International Conference on Energy Efficiency in Domestic Appliances and Lighting (EEDAL'21)." (2023).
13. Ikoenko, Sergei, M. Raymusiala, and S. Yatsunenko. "State-of-the-Art TRIZ, Theory of Inventive Problem Solving." *Novismo Ltd* (2019).

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TRIZ IDEAS IN A SYSTEMATIC PRESENTATION

P.N. Shimukovich

Abstract

Genrikh Altshuller started working on the theory of inventive problem solving (TRIZ) almost 70 years ago. The whole subsequent period is a continuous development of TRIZ, both by the founder himself and by his associates, students, and followers. I developed my own version of TRIZ by combining modern achievements of systems theory and classical TRIZ. At first I called my author's approach the PN-method (P.N. are my initials), then the Recommendations on Systemic Problem Solving. At present I think that the most acceptable variant of the title is "TRIZ Ideas in a Systemic Presentation". The content of my approach is stated in 8 written and published books and many articles. The following material outlines the structure of the approach and then compares it with classical TRIZ to show the significant differences. The amount of information provided is determined by the allowable size of the article. Particular questions of the approach, its detailing, and analysis of examples of application - all this is in my books. I would also like to note that the demonstration of the differences between my approach and classical TRIZ is done by comparison. That is, the classical TRIZ and my approach are compared, but it is not a criticism of TRIZ! I was and am in awe of and deeply respect the results obtained within the framework of classical TRIZ - without them there would be no basis, including for my research. At the same time, I believe that there are no restrictions on presenting an approach that differs significantly from the classical one at a TRIZ conference: I inform my colleagues about what I have done and assert - it works! And it works effectively!

Keywords: New TRIZ Approach, PN-method, Innovation, Technical Creativity, Invention, Problem-Solving, Inventiveness.

The approach I have developed is obtained by combining classical TRIZ and modern achievements of systems theory. In this connection, when starting to solve any problem, one should rely on the basic concepts of systems theory and identify the system that generates this very problem. Such a system can be represented as follows (Fig. 1).

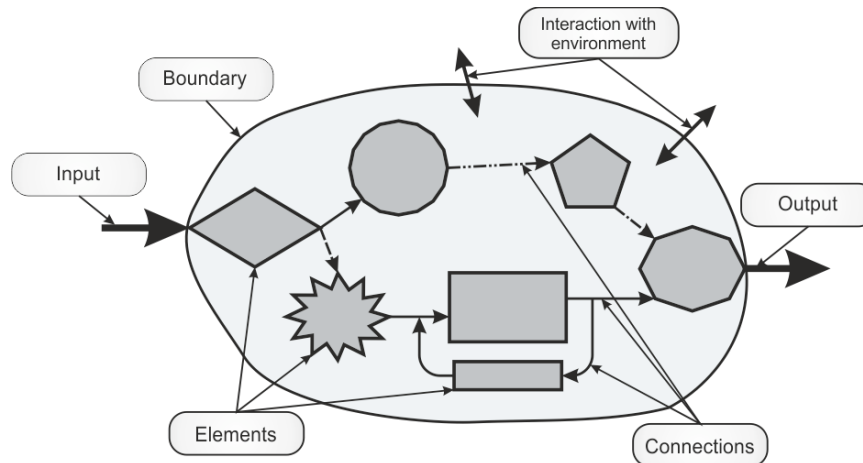


Fig.1. Graphical representation of the system.

In the presented system the elements, connections, boundary separating it from the environment, input, output and interaction with the environment are highlighted. It should be noted, distinguishing the system from the structure of the problem is an independent creative work. It is simple to define a system when, for example, you hold a pen in your hands: here is the body of the pen, here is the cap, and here is the ink reservoir... What if it is a wireless computer network? What if it is a failure of a complex technical device and the root cause is not obvious? What if it is a clandestine terrorist organization? It is clear a priori that in the latter cases, even taking into account all the elements of the system is a difficult task. It is even more difficult to accurately determine the connections between them. Right now, for example, the media only informs us that no terrorist organization has claimed responsibility for a terrorist act. But a terrorist act is, from the point of view of the theory of systems, the output of such an organization. And it takes a lot of work for the competent authorities to establish whether this act belongs to the organization in question or to some other organization. I hope I have succeeded in outlining the complexity and, at the same time, the creative nature of such a task.

Then the selected system should be considered in 12 system aspects, that is, 12 times to change the point of view of the essence of the problem (Fig. 2), the names of aspects are given in the same figure.

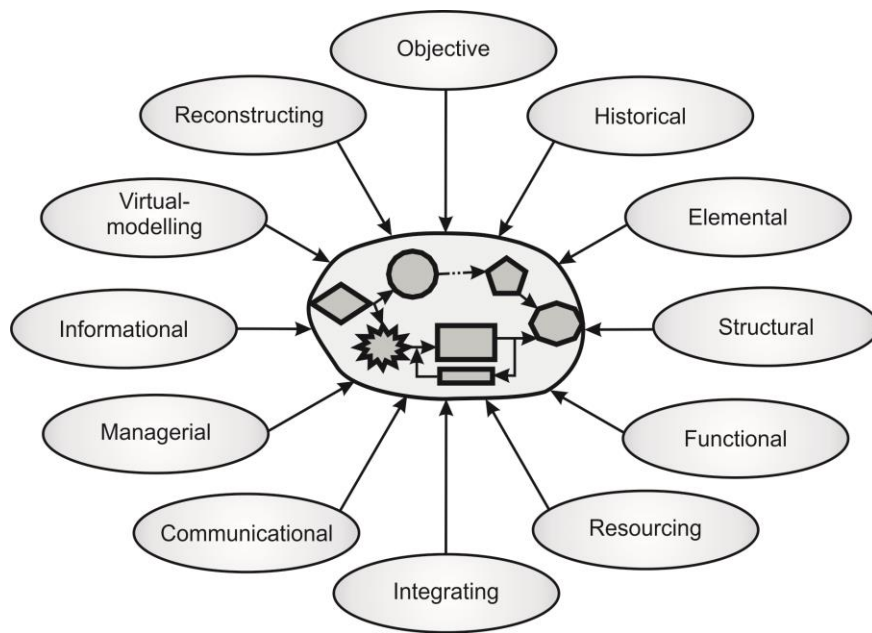


Fig.2. Systematic consideration of the object of analysis.

The ten systemic aspects are well known; I have borrowed them from systems theory. Two aspects, virtual-modelling and reconstructing, are suggested by me; their names are the subject of discussion and, possibly, clarification. The most general idea of the direction of aspects is given by their names, full information can be found in my books [1], [2], [3], as well as in my video [4] and other videos posted on the same channel.

The inclusion of virtual-modelling and reconstructing aspects in my approach is predetermined by the high intensity of technology development associated with artificial intelligence and global digitalization

Each of the selected aspects includes a certain set of system actions, the performance of which allows obtaining the desired solution of the problem. For example, the element aspect contains the following actions: change, take into consideration new properties of an element or its parts; change property parameters (dimensions, shape, mass, symmetry, homogeneity, color, temperature, etc.); change the position of an element, etc. A total of 86 system actions are contained in all aspects; I have compiled a list of them on the basis of generalization of TRIZ tools and provisions of the theory of systems.

A solution obtained by performing one or a set of system actions can be strengthened by formulating and solving a TRIZ-contradiction. TRIZ-contradiction is known in the TRIZ community as a physical contradiction. The main difference of my proposed term "TRIZ-contraction" is that, using system concepts, it can be called supersystemic in relation to the term "physical contradiction". Among other things, I believe that the use of my proposed term contributes to popularization of TRIZ, because even an outsider, having mastered this tool, will subconsciously understand that there is some TRIZ, even if not known to him, and he could solve an important problem for himself with its help.

I emphasize that, based on system preconditions, I formulated TRIZ-contradiction in a modified form in comparison with known in TRIZ formulations of physical contradiction: "TRIZ-contradiction is a situation in which conditions of a problem impose contradictory requirements to one of components of the following list:

- the analyzed system as a whole;
- element of this system;
- the connection between the elements;
- resource consumed by the system;
- function performed by the system;
- the interaction of the analyzed system with its environment.

This definition is more complete than the known ones, and takes into account all the components shown in Fig. 1 and characteristic of any system. Accordingly, this definition is systemic.

One of the main concepts in TRIZ is that of ideality, including the concept of an ideal system: there is no system, but the function is fulfilled. It is clear a priori that an ideal system defined in this way is some theoretical abstraction, just like "an absolutely black body", "an ideal gas" in physics, "a point", "infinity" in mathematics, etc. This unattainable limit, nevertheless, has an enormous heuristic power and determines the gradient of the researcher's aspirations when dealing with a problem.

My approach allows to concretize the notion of ideality by means of twelve system aspects: the transformations proposed within each aspect, if they are the best, in fact - locally ideal, in the aggregate should also lead to the final ideal solution. Thus, the concept of ideality introduced in TRIZ is decomposed in my approach into twelve smaller components, each of which can be evaluated by its own criterion. Taking the above into account, a system can be called ideal for specific conditions of application if it has:

- each object (element, connection) in its composition has an independent value, functionality and is there and when it is really needed;
- structure is optimized according to some criterion and usually has a hierarchical or network structure;
- the potential of each object is fully spent on the quality performance of its main function and additional/supporting functions;
- mass, dimensions and material, energy and information resources consumed by it during the life cycle are of minimal importance;
- a new systemic quality that does not belong to any of its constituent objects manifests itself;
- optimal interaction with the environment is ensured;
- the required variety of control actions is realized or mastered;
- the required informational diversity manifests itself;
- there is a prospect of development;
- models or fragments of virtual reality in a reasonable amount are included in the analyzed system;
- the proportion between the humans participating in the system and the devices built on the basis of artificial intelligence is optimized;
- the purpose of creating the system and its actual functioning correspond to each other.

Note that the presented criteria can be measured quantitatively and allow evaluating the creative work both during its performance and after its completion. The final index of ideality can be determined by a procedure equivalent to multi-criteria optimization with an assessment of the contribution of each particular aspect to the final index of ideality.

Next, I will focus on the significant differences between my approach and classical TRIZ, directly related to the process of creative work.

In the theory of systems it is accepted that the input of the system can be: the substance (materials), energy and information. People paid attention to the necessity of inclusion of the above components in the composition of systems not at once, but according to the periods of development of civilization, among which technosphere, energy sphere and infosphere are distinguished. Each of these periods corresponded to the predominant development of one of them. It is considered that the first period comes from the depth of millennia and ends in the XX century. This is the mastering of the material nature of the world, the creation of material production and the formation of an understanding of the material nature of the world. The second period begins in the 18th century with the steam engine and probably ends in the 20th century with the development of thermonuclear energy. This is the development of the energy resources of the solar system, the creation of energy abundance, the understanding of the unified nature of energy and its relationship to matter. The third period is associated with the stage of mastering information. This is the period in which we are currently living.

Now let's see how these three periods relate to my approach and classical TRIZ. I will consider this problem on the example of the process of improvement of percussion devices.

At the stage of technosphere, attention was paid to the material used for making percussion devices. Since primitive times, people used wood and stone. As soon as they learned how to smelt metal - percussion devices began to be made of this material. Similarly, new percussion devices were created as they mastered the manufacturing of rubber, various plastics, etc. The approach realized here is obvious: a new material appears and specialists in the field of percussion devices creation immediately "try on" its suitability for manufacturing of percussion parts, variants with obvious benefit from application of the new material get a ticket to life.

An alternative branch of improvement of percussion devices at the stage of technosphere can be considered a change of contact conditions of impacting surfaces. Fig. 3 - 7 show some variants of contact of impacting surfaces.

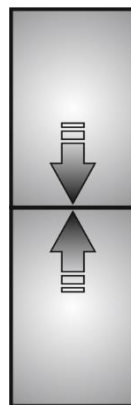


Fig. 3. Contact of flat surfaces of impact devices.

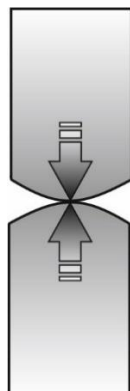


Fig. 4. Contact of spherical impactor surfaces.

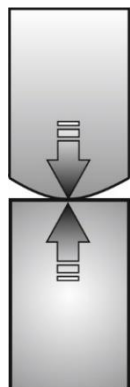


Fig. 5. Contact of sphere and plane.



Fig. 6. Contact of sphere and concave surface.



Fig. 7. Multipoint contact of impact surface with a plane.

The purpose of such transformations of impacting surfaces can be very different, but in our case it can be characterized by regulating the magnitude of contact stresses in the impact zone. Since the devices of the presented schematic executions really exist, it means that they are in demand in different fields of application.

One more and relatively young variant of improvement of impact devices may be called a cavity (Fig. 8) inside the striking part 1 and put in it an additional mass 2, which has the possibility of longitudinal movement in relation to the part 1. The initial setting of the value of the end gap Δ provides a solution to a dual problem:

- At one calculated value of the end gap Δ the mass 2 collides with the surface of part 1 when this part 1 after the collision already performs the reverse motion from the colliding surface. Such an impact results in a significant reduction of the impactor's recoil. This is especially important, for example, in space, when working with a hammer in conditions of weightlessness;
- At other calculated value of the end gap Δ , the mass 2 strikes the inner surface of the part 1 up to the moment of its rebound from the striking surface. Due to this, the time of impact impulse action on the striking surface increases and the effect of the impact increases.

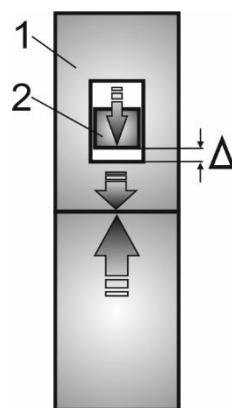


Fig. 8. Impact device with an additional striker.

Let me pose a question: what happens if the colliding surfaces of parts 1 and 2 (Fig. 8) are subjected to transformations similar to those depicted in Figs. 3 - 7? Of course, if this question

is answered correctly, conditions will be created to form a new list of impactors with specific performance properties.

The given examples do not exhaust the variety of possible changes of percussion devices, but they demonstrate the abundance of variants.

I will now put the energy sphere at the top of the list. The first source of energy to actuate an impact device was the human muscular force. Then the force of the earth's gravity was used. Then, again as it was discovered, electricity, compressed air energy, and the energy of pressurized fluid were taken into account. Today we are not surprised by electric breakers, pneumatic breakers, hydraulic breakers, but at one time they were revolutionary innovations.

Now we live in the information age. What is the impact of information on the improvement of percussion devices? Unfortunately, almost nothing. Only in some samples we can find indication of impact force, impact velocity... This means that this field is still waiting for its researchers.

It is possible to put a question: are such variants of combination of impact devices with information necessary? The answer is unambiguous - we need them! I will confirm it with examples.

In smartphones we are used to a variety of indications: visualization of smartphone charging process, battery level, network signal; confirmation of message delivery to the addressee; confirmation that the signal reached the addressee, but he does not pick up, etc.

I can be reproached that a smartphone is a device designed to handle information, and for that reason it has so many information components. But it isn't.

As another example, I'll take an ordinary umbrella. And in this device, which is not an information device, we find: pressure sensors built into the umbrella and warning light signals to the owner of the umbrella about the approach of rain (drop in atmospheric pressure); sensors that assess the degree of contamination of raindrops; reflective elements informing in the dark time of day the drivers of approaching cars about the presence of the umbrella owner on their route; on the peripheral ends of the frame guides are mounted speakers, which allows you to get in the underdome space quality stereo sound, the dome of the umbrella equipped with one or more indicators of UV radiation to determine whether the permissible level of UV radiation, etc.

The above examples of percussion device, smartphone, and umbrella are placed here with one purpose - to show that the established approaches in classical TRIZ need to be changed.

Classical TRIZ recommends: having obtained a problem, for example, in the contact of bodies in a point, one should apply other variants - contact along a line, along a surface, along a volume. The examples I have presented show that this problem applies only to one sphere of transformations - to the technosphere. Within the energy sphere, TRIZ suggests using the abbreviation MATCEM, i.e. to consider successively the variants of using mechanical, acoustic, thermal, chemical, electric and magnetic energy while searching for a solution. As for the infosphere, i.e. working with information, there are no TRIZ recommendations at all: at the turn of the 1960s, information was not as important as it is now, so there are no recommendations. My approach, on the other hand, has an informational aspect that is directly aimed at working with information. The virtual-model and reconstructive aspects are also informational. I believe that if we take the position of active supporters of classical TRIZ, the abbreviation MATCEM should be changed, for example, to MITCEM or MATCEMI, thus adding an informational component to the energy sphere. In the latter case, the letter "A" will retain the acoustic impact, meaning it is the energy component, not the information component. However, I think it is more correct to transform MATCEM into TEI, where technosphere, energy sphere, and infosphere

are united respectively, each with its own set of subordinate influences. In particular, information in any analyzed task can participate in the most different kinds, having the possibility to influence all human senses, or be fixed by special devices.

Limited by the size of the article, other differences between my approach and classical TRIZ cannot be described in as much detail as in the case of MATCEM, so I will simply list them:

- TRIZ has a large number of tools for creative problem solving: 40 methods of solving technical contradictions, 11 principles of solving physical contradictions and 76 standards for inventive problem solving. All of them are in a row, which predetermines a lot of work to choose the right tool. In my approach, system actions - analogues of classical TRIZ tools - are hierarchically ordered in the form of tree branches. By choosing one of the branches as a solution variant, all other branches are excluded from consideration, which reduces the amount of work by times;
- In TRIZ it is suggested to solve physical contradictions with the help of 11 principles. I have reduced the number of variants to two - the contradiction is solved in time or in space, while the quality of obtained solutions and the number of possible variants of solutions are not reduced. This fact is confirmed by long practice of application of the approach;
- Based on systems theory, I formulated a proposal to change the graphical representation of the vepole from triangular to the generally accepted in graph theory and in systems theory - two elements are connected by one line. The change I propose increases visibility of the scheme and corresponds to the implementation of the convolution line known in TRIZ for the improvement of TRIZ itself. In addition, depicting the vepole in the form corresponding to the accepted in the theory of systems, allows applying mathematical methods to optimize the structure of the analyzed system;
- My approach uses system terminology, which simplifies its adaptation to various tasks - technical, organizational, managerial, and domestic. In classical TRIZ, as it is known, the terms typical for technical problems prevail, which forms certain difficulties in solving, for example, organizational and managerial problems;
- The developed approach is well adapted not only to creative problem solving, but also to performing a number of operations of related processes - analysis of initial situation, formulation of goal, forecasting of future results, writing of invention formulas, work on practical implementation of obtained creative result into materialized sample.

In addition to the presented material I can note that in my books there are also reflected questions of stimulation of an ordinary person to creativity, realization of search - "what to invent?", determination of reasonable correlation of logical and intuitive in the process of creative problem solving, choice of the preferable variant of the solution from the set of possible and a number of others. Taken together, all the issues discussed in my books allow organizing practical innovation work in any interested company, as well as to form a corresponding educational course in educational institutions. The practice I have developed allows me to assert that in both cases the results will be high, corresponding to the modern level.

The next step in the development of my approach will be the development of its computer version, based on the latest achievements in digital technology and artificial intelligence. Certain actions in this direction have already been taken.

References

1. Shimukovich, P.N.: TRIZ-controversies in innovative solutions: a PN-method. Ed. 4. Moscow: LENAND (2018).
2. Shimukovich, P.N. Problems have solutions! TRIZ-ideas in a systematic presentation. Ed. 2, revised. Moscow: LENAND (2017). (English translation available: Shimukovich P.N. Solutions Do Exist for Every Problem! A systematic presentation of TRIZ-ideas. Moscow: URSS (2019)).
3. Shimukovich, P.N.: TRIZ-ideas in a systematic presentation: key issues of creative application. Moscow: LENAND (2023).
4. Shimukovich, P.N. Presentation of the author's books. <https://youtu.be/Y8nU5xRrr64>, last accessed 2023/04/02.
5. Shimukovich, P.N.: Information Method of Creativity. Information, language, semiotics, TRIZ at the service of innovations. Izd.2, stereot. Moscow: LENAND (2017).
6. Shimukovich, P.N.: Incitement to Creativity. The origins of successful innovation. Moscow: LENAND (2018).
7. Shimukovich, P.N.: TRIZ-ideas in a system statement: patenting and embodiment of a creative result. Moscow: LENAND (2023).
8. Shimukovich, P.N.: TRIZ-ideas in a systematic presentation: Practice. Moscow: LENAND (2019).
9. Shimukovich, P.N.: TRIZ-ideas in a systematic presentation: The path to a creative result: a holistic presentation and step-by-step analysis. Moscow: LENAND (2021).

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APPLYING THE THEORY OF INVENTIVE PROBLEM SOLVING (TRIZ) TO POLICY MAKING: IDENTIFYING COMPLEX POLICY PROBLEMS AND GENERATING INNOVATIVE SOLUTIONS

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Abstract

This study paper's goal is to examine how the Theory of Inventive Problem Solving (TRIZ) and its guiding principles might be used to the formulation of public policy. The purpose of the study is to investigate how TRIZ can be used to innovate policymaking and address complicated policy issues. The purpose of this study article is to evaluate the effectiveness of TRIZ in policymaking and to pinpoint the potential advantages that may result from its application. The study specifically aims to investigate how TRIZ may be used to discover and resolve policy issues in a systematic and efficient manner, as well as how it can be utilised to provide creative policy solutions that satisfy the interests of stakeholders. A review of the body of research on TRIZ and its use in policy making is part of the qualitative research methodology employed in this work. A theoretical framework for comprehending the TRIZ principles and its possible applications in policy making is provided by the literature review. The conversations with policymakers provide useful insights into the application of TRIZ in actual policy contexts.

The results of this study demonstrate that TRIZ can be a useful tool for policymakers in recognising and resolving difficult policy issues. Policymakers can develop creative and efficient policy solutions that satisfy the needs of stakeholders by applying TRIZ principles like contradiction analysis and ideality, TESE. The study also indicates how TRIZ can be used to stimulate innovation in the policy-making process by enticing decision-makers to approach problems with creativity and method.

The importance of this study rests in its contribution to the understanding of how TRIZ might be used in the formulation of policy. This study offers insightful information for policymakers, researchers, and practitioners by highlighting the possible advantages of TRIZ in policymaking. To fully grasp TRIZ's potential and constraints in various policy situations, it also emphasises the need for additional study and experimentation. In the end, the study adds to the overarching objective of encouraging creativity and efficiency in policymaking and enhancing citizens' lives through better policies. The paper primarily uses examples from Indian Law.

Keywords: policy making, TRIZ in LAW, Legal Innovation.

How TRIZ can be used in policy making to solve complex, contradictory and novel problems quickly.

1. Introduction

The problem that the research paper is trying to solve is that policymaking needs new approaches and methods. Traditional methods may not be able to solve complex policy problems and come up with new ideas. The goal of this paper is to look at how the Theory of Inventive Problem Solving (TRIZ) and its guiding principles can be used in policymaking. The goal is to improve how policies are made and carried out. The goal of the paper is to find out how well TRIZ helps find and solve policy problems, to list the possible benefits of using it, and to encourage creativity and efficiency in policymaking. By using TRIZ and its ideas, the paper hopes to help come up with policies that are more creative, thorough, and ready for the future. The paper primarily uses examples from Indian Law.

2. Research methodology.

This research paper represents an effort in qualitative research of Theory of Inventive Problem Solving (TRIZ) to the domain of policymaking and law. The study embarked on a solo research journey, where the author's undertook extensive literature review, self-guided exploration, and innovative thinking to formulate the 39 parameters, 40 Inventive Principles, and Trends of Engineering System Evolution (TESE) specifically tailored for policymaking. The author's in-depth understanding of TRIZ principles, combined with their expertise in law and policy, enabled the development of a unique methodology that had not been previously explored or documented. The author's independently carried out a systematic analysis of case studies, policy frameworks, and legal contexts to identify potential applications and challenges of TRIZ in policymaking. This comprehensive research process involved critical thinking, creative problem-solving, and a deep dive into the intricacies of policy formulation and implementation. The insights gained through this solitary research endeavor laid the foundation for a groundbreaking methodology that has the potential to revolutionize the field of policymaking. The author's independent exploration and novel contributions to TRIZ in the context of law and policy demonstrate their innovative and self-directed research approach, setting a precedent for future studies in this emerging field.

3. Significance of this Research

The significance of this research lies in its contribution to the field of policy making. To the best of the author's knowledge, this study represents a unique endeavor as it maps the major principles of TRIZ in the context of policy making. By exploring the applicability of TRIZ in the policy domain, this research fills a gap in the existing literature and offers a novel perspective on problem-solving and innovation in policy formulation. While it is important to acknowledge the limitations of individual knowledge and the possibility of other related studies, this research represents an original contribution to the field and opens avenues for further exploration and application of TRIZ in policy making.

4. Policy Making Process.

4.1 Agenda Building

A problem must be recognised and brought to the government's attention before a policy can be developed. For instance, corruption has been a problem in India for a long time, but it wasn't until the high-profile corruption scandals and the ensuing protests in the 2010s that the issue was brought to light and stronger official action was demanded. Another example is air pollution. Indian society tolerates a certain level of pollution; however, when the air quality index in cities like Delhi spikes drastically during the winter months or is perceived to be consistently poor, it becomes a matter for policymakers to address.

Specific incidents can underscore a problem and place it on the agenda. The flooding of cities like Chennai, Bengaluru or Mumbai prompts questions about urban planning, drainage systems, and whether construction should be permitted in certain flood-prone zones. New policies on counter-terrorism (the Unlawful Activities Prevention Act amendments, for example) were responses to the terror attacks like the one in Mumbai in 2008.

Agenda building is a critical first step in the policy-making process. It is the stage at which problems are recognized, defined, and prioritized for political and bureaucratic attention. A problem becomes an issue on the policy agenda when it is publicly acknowledged and political leaders decide it warrants action at the policy level.

Recognizing and Defining Problems: In a world with infinite needs and finite resources, not all problems can be addressed at once. Agenda building is necessary to determine which problems are significant enough to warrant attention and action. This often requires a process of problem definition where the nature, causes, and impacts of the problem are explored. This aids in creating a shared understanding of the problem among stakeholders and policymakers. For instance, the pollution in Indian cities was identified and defined as not just an environmental problem, but also a public health crisis, thus warranting urgent policy attention.

Prioritizing Problems: Once problems have been recognized and defined, they need to be prioritized. Agenda building is necessary for this process of prioritization. It entails taking into account variables like the severity of the issue, the population impacted, the accessibility of resources for solving the issue, and the level of political and popular support for action. The severity of the air pollution challenge, its effects on public health, and growing public concern have all contributed to this issue moving up the legislative agenda in India.

Mobilizing Support: Agenda building is also necessary for mobilizing political and public support for action. By highlighting the urgency and importance of a problem, agenda building can create the political will for action and the public demand for policy change. An illustration of this is the anti-corruption campaign in India, which contributed to the development of the reform agenda.

Guiding Policy Development: Once a problem is on the policy agenda, it guides the subsequent policy development process. The problem definition and the priorities set during the agenda building stage shape the objectives of the policy, the strategies for achieving them, and the measures for evaluating policy success.

Thus, agenda building is crucial in policy making as it sets the direction for policy action. Without a well-defined and prioritized agenda, policy making can be haphazard, reactive, and less effective in addressing societal needs.

TRIZ talks about "The Ideal Final Result, representing the best possible solution, serves as the goal or target state of the project." Hence without deciding the agenda of the what the policy wishes to achieve, it is not possible to the goal of the policy.

4.2 Policy formulation and adoption

Text Policy formulation involves devising an approach to address a problem. This process can involve various stakeholders such as the Parliament, the executive branch, the judiciary, and interest groups. Often, differing proposals are put forth. For instance, the Prime Minister may have one strategy to address farmer distress and agrarian crisis, and the opposition party members of Parliament may have a different viewpoint. Policy formulation results in a concrete outcome: A bill is introduced in the Parliament or a regulatory body drafts proposed guidelines.

The process then progresses to adoption. A policy is adopted in India when Parliament passes legislation, the guidelines become final, or the Supreme Court delivers a verdict on a case.

Policy formulation and adoption in India can face several challenges. Here are two examples:

1. Problem: Divergent Interests and Stakeholder Conflicts

Managing the differing interests and potential conflicts between many stakeholders is one of the biggest issues involved in the creation and acceptance of policy. For instance, the government had to strike a compromise between the needs of companies, which required land for development projects, and farmers, who were worried about losing their way of life, when creating the Land Acquisition, Rehabilitation, and Resettlement Act in 2013.

TRIZ Solution: TRIZ offers tools like contradiction analysis to help identify and resolve these contradictions. The principle of "Prior Action" (Principle 10), for instance, can be used to ensure proper rehabilitation and job opportunities for the farmers before land is acquired. Principle 4, "Asymmetry", could suggest changing the proportion of industrial to agricultural land in different areas to maintain a balance.

2. Problem: Complexity and Uncertainty of Policy Outcomes

The complexity and unpredictability of policy results present another difficulty in developing and implementing policies. For instance, India introduced the Goods and Services Tax (GST) to streamline the tax code and expand the economy. Due to the complexity of India's economy and the diversity of its states, it was difficult to forecast how the GST would affect the country.

TRIZ Solution: The concept of 'Ideal Final Result' (IFR) in TRIZ can provide a guiding vision to navigate this complexity. The IFR for GST, for instance, could be a simplified, unified tax structure that promotes economic growth without imposing undue burdens on any state or sector. TRIZ principles like "Nested Doll" (Principle 7), suggesting tiered implementation for different sectors or states, and "Dynamics" (Principle 15), suggesting flexible and adaptable tax rates, could then be used to guide the formulation and implementation of GST towards this IFR.

Through such approaches, TRIZ can offer innovative strategies for addressing the challenges in policy formulation and adoption.

4.3 Implementation

The implementation or execution of policy is typically performed by institutions different from those that devised and sanctioned it. A law usually only provides a general structure of a policy. For example, the Indian Parliament may pass an act for better air quality standards, but it's the Central Pollution Control Board (CPCB) that provides the details on these standards and

the processes for assessing adherence through regulations. As previously noted, the Supreme Court has no mechanism to enforce its rulings; other branches of government must implement its determinations. Successful implementation depends on the complexity of the policy, coordination between those putting the policy into practice, and compliance.

An appropriate illustration is the Right to Education Act ruling by the Supreme Court. The court acknowledged the complexity of the issue surrounding the implementation of free and required education for kids between the ages of 6 and 14. However, they did not offer clear instructions on how to put it into practice. Here, the implementation was mainly reliant on the vigilant oversight of district and state education officials, as well as local and state school boards, who frequently balked at spearheading such a big shift.

In whole of world, especially in the developing countries, when policies are made and implemented without the desired impact, the blame is often placed at the implementation end.

Implementation of policies in India can encounter several roadblocks. Here are two examples:

1. Problem: Coordination Among Multiple Agencies

For implementing policies, coordination among multiple government agencies is a common challenge. For instance, in the case of the Smart Cities Mission, multiple government departments like urban development, transport, energy, environment, etc., have to work together. This often leads to delays and sub-optimal implementation.

TRIZ Solution: TRIZ can help address this through its "System Approach" which emphasizes viewing a problem as part of a larger system and optimizing the whole system instead of individual components. The "Nested doll" principle (Principle 7) could be applied here to ensure different departments operate as nested subsystems within the overall Smart Cities Mission. Each department could have its roles and responsibilities clearly defined, yet all should function in harmony with the overall mission.

2. Problem: Resistance to Change

Another challenge is resistance to change from stakeholders, which often hampers the implementation process. For instance, the implementation of the Right to Education Act was hindered due to resistance from private schools and certain sections of society.

TRIZ Solution: TRIZ could help in managing this resistance through its principle of "Preliminary Action" (Principle 10). This principle suggests undertaking necessary preparatory actions before implementing the change. In this context, it could mean initiating awareness campaigns and dialogues with stakeholders, and addressing their concerns before the full-scale implementation of the policy.

4.4. Evaluation and termination

Evaluation involves assessing the effectiveness of a policy, and it is not a straightforward task. Cost-benefit analysis is frequently used by both inside and outside of government to try to answer this question. To put it another way, if the government invests a certain number of crores on a policy, are the gains made from it worth the investment? Data used in cost-benefit analyses are frequently hard to come by and are vulnerable to several, sometimes conflicting, interpretations.

History indicates that once implemented, policies are hard to terminate. They are usually terminated because the policy has become outdated, has clearly failed, or has lost its backing among the interest groups and elected officials that pushed it onto the agenda initially. For

instance, the Indian government launched a programme of river interlinking in the middle of the 1990s to address the issue of flooding and water scarcity in various regions of the nation. This programme was successful in some ways, but it also had negative effects on the environment, society, and the economy, as well as caused tensions between the states. This policy has been reviewed throughout time in light of complaints from environmental organisations, worries from impacted towns, and interstate disputes. In certain cases, plans for river interlinking have even been shelved or abandoned.

The more recent instance is when India implemented its Demonetisation programme in 2016 to combat dark money, lessen corruption, and foster the digital economy. Some of its goals were accomplished, such as expanding digital transactions, but it also caused short-term economic instability and hardship for the populace. The policy has generated a great deal of discussion, and its full effects are still being assessed.

Similarly, the controversial Farm Bills of 2020 in India designed to liberalize the agriculture sector faced massive resistance from farmers leading to protests. The bills intended to provide more freedom to farmers to sell their produce outside the government-controlled agricultural produce market committees (APMCs) and encourage intra-state trade. However, the farmers worried about the lack of minimum support price (MSP) guarantee and the rising influence of corporate houses. This resistance led the government to reconsider and finally, in 2021, repeal these laws. This serves as an example of how strong public opposition can force the re-evaluation and even termination of a policy.

5. 39 parameters and 40 Inventive Principles and TESE in policy making.

In TRIZ, 39 parameters are utilized to frame contradictions. The challenge with using these parameters in a policymaking context lies in the fact that these parameters were initially engineered for mechanical and technical systems. However, they can still be creatively interpreted and applied to policy contexts. Here are examples of some of these parameters.

Note that not all parameters can be as easily or sensibly translated into a policy-making context. For instance, parameters like "Thermal conductivity," "Strength," or "Wavelength of a used EM field," are rather technical and may not fit well with policy-making themes. However, they could be metaphorically used to describe the intensity, the power, or the spread of a certain policy effect. In conclusion, the list of 39 parameters can provide a useful starting point, but their use in policy-making would require a careful and creative interpretation.

5.1 - 39 Parameters with policy examples:

1. Weight of moving object: Consider the movement of goods and services across states. The implementation of GST in India has lightened the "weight" of moving goods across state boundaries by reducing tax-related complications.
2. Speed: The speed of policy implementation can be critical. For instance, the speed at which the Jan Dhan Yojana was implemented resulted in the rapid creation of bank accounts for millions of Indians.
3. Length of moving object: This could refer to the extent or reach of a policy, such as the geographical coverage of the National Rural Health Mission across rural India.

4. Shape: The form a policy takes can significantly impact its outcomes. For instance, the shape of the Pradhan Mantri Awas Yojana, which involves public-private partnerships, has shaped affordable housing availability.
5. Reliability: Referring to the consistency and trustworthiness of a policy. The Reserve Bank's monetary policy, for instance, aims to maintain reliability to stabilize the financial market.
6. Temperature: This might indicate the 'hotness' or urgency of a policy issue, like the immediate and high-priority response to setting up oxygen cylinders COVID-19
7. Stress: The pressure on resources due to policy can be considered. For example, the stress on public healthcare facilities during the pandemic.
8. Power: The power or authority of a policy-making body can be important. For example, the power vested in the National Green Tribunal to enforce environmental laws.
9. Area of moving object: This could refer to the scope of policy application. For instance, the scope of the Right to Education Act which covers all of India.
10. Force: This could be interpreted as the influence or power behind a policy. The force behind the Swachh Bharat Abhiyan helped drive a nationwide cleanliness campaign.
11. Tension, pressure: Refers to the pressure exerted by a policy. For instance, the pressure created by environmental regulations on industries to reduce pollution.
12. Stability of the object's composition: This could refer to the stability of a policy over time. The stability of India's foreign policy, despite changing administrations, is an example.
13. Strength: Can be interpreted as the robustness of a policy or its resistance to change. The strength of India's nuclear non-proliferation policy, despite international pressures, could be an example.
14. Durability, life time: Refers to the longevity of a policy. The continued existence of the Public Distribution System in India, since the time of independence, is an example.
15. Temperature stability: This could be metaphorically interpreted as a policy's resilience to 'heated' political or social environments. For instance, the implementation of Goods and Services Tax (GST) remained stable despite political opposition.
16. Brightness: Can be viewed as the visibility of a policy to the public. Policies with high public awareness, like the Aadhaar program, exemplify this.
17. Waste of energy: Policies that require significant resources but yield low results could be examples. Critiques of the Smart Cities Mission often point to wastage of resources with minimal on-ground impact.
18. Waste of substance: Could refer to inefficient policies that lead to resource wastage. For example, the inefficiencies in water management policies leading to wastage of water.
19. Loss of substance: Could refer to policies that inadvertently lead to depletion of resources, like certain mining policies leading to loss of biodiversity.
20. Loss of information: The Right to Information Act aims to counter this parameter by promoting transparency and accountability.
21. Energy spent by a stationary object: Could be metaphorically used to represent the efforts required to maintain a policy, like maintaining the universal PDS requires significant resources.

22. Power spent by a moving object: Could refer to policies that need significant effort to implement. For example, India's National Health Mission requires significant resources for its implementation across the country.
23. Loss of energy: Similar to 'Waste of energy', inefficient policies may result in loss of resources. The issues of transmission and distribution losses in the electricity sector exemplify this.
24. Loss of time: Policies that take a long time to implement or show results, like long-term climate change policies.
25. Amount of substance: This could refer to the volume or extent of a policy. For instance, the extent of the Pradhan Mantri Gram Sadak Yojana, covering numerous villages across the country.
26. Reliability: The trustworthiness or dependability of a policy, like the continued provision of subsidized foodgrains through the PDS.
27. Accuracy of measurement: This could refer to the precision of policy monitoring and evaluation. For example, accurately measuring the impact of the Mid-Day Meal scheme on child nutrition.
28. Accuracy of manufacturing: Refers to the precision in policy implementation. For example, the precision required in implementing the National Rural Employment Guarantee Act to ensure that benefits reach intended beneficiaries.
29. Harmful factors acting on the object: This could refer to the threats to policy implementation.
30. Harmful side effects: This parameter could be seen as unintended negative consequences of a policy. An example is the displacement of local communities due to the construction of large dams under hydropower policies.
31. Sufficiency of action: This parameter speaks to whether a policy goes far enough to address the problem at hand. The question of whether India's climate change commitments are sufficient to meet the challenges posed by global warming exemplifies this.
32. Ease of operation, convenience of use: This could refer to how accessible and user-friendly government services are. Initiatives like the 'Passport Seva Kendras', which aim to simplify the process of obtaining a passport, are examples of this.
33. Device complexity: Can refer to how complicated a policy or system is. For instance, the complexity of the tax system in India has often been a point of contention.
34. Device instability: This might refer to the volatility or uncertainty of a policy. The fluctuating norms and regulations around cryptocurrency in India provide an example.
35. Object-affected harmful factors: This can refer to negative impacts on the recipients of a policy. An example might be the loss of livelihoods for traditional fisherfolk due to the implementation of certain coastal tourism policies.
36. Object-generated harmful factors: This parameter could refer to the negative impacts caused by a policy action. For example, the environmental degradation caused by certain industrial policies.

37. Completeness of action: This parameter is about whether a policy addresses all aspects of a problem. The National Health Mission's comprehensive approach to improving health care services across India exemplifies this.

38. Relative availability of a substance: This parameter can refer to the availability of resources for policy implementation. For instance, the availability of vaccines in the initial stages of the COVID-19 vaccination drive was a significant issue.

39. Speed of action: This can refer to how quickly a policy is implemented. The rapid response and implementation of the Pradhan Mantri Garib Kalyan Yojana in the wake of the COVID-19 pandemic is a pertinent example.

5.2 40 Inventive solutions in policy making

1. Segmentation: The Atal Mission for Rejuvenation and Urban Transformation (AMRUT) launched by the Government of India aims to establish infrastructure that could ensure adequate robust sewage networks and water supply. It segments the larger infrastructure issue into smaller sectors like water supply, septage management, storm water drainage, etc.

2. Local Quality: The Panchayati Raj system in India is an excellent example of local quality, wherein local self-governance bodies create and implement policies considering local contexts and needs.

3. Merging: India's Insolvency and Bankruptcy Code, 2016 consolidated the existing framework by creating a single law for insolvency and bankruptcy.

4. 'Nested Doll': The Sarva Shiksha Abhiyan (Education for All Movement) is a program aimed at the universalization of elementary education "in a time-bound manner" and includes various smaller initiatives and programs within its larger structure.

5. Anti-Weight: Implementation of Minimum Support Price (MSP) for farmers' crops to counterbalance the effects of market price fluctuations.

6. 'The Other Way Round': The Digital India initiative focuses on electronic services, digital empowerment of citizens, and improving India's digital infrastructure.

7. Spheroidality: The Make in India initiative is aimed at encouraging manufacturing in India and encompasses various industries to ensure a well-rounded economic growth.

8. Dynamics: The Startup India policy includes provisions for revisions and modifications over time to adapt to the evolving startup ecosystem.

9. Beforehand Cushioning: Establishment of the Contingency Fund of India, which is used for emergencies or unexpected outflows, providing a cushion to handle unforeseen situations.

10. Continuity of Useful Action: Policies like the Public Distribution System (PDS) ensure that foodgrains are consistently available to the people at subsidized prices.

11. Partial or Excessive Actions: Pilot implementations of certain schemes or programs in specific regions before national-level implementation, for instance, pilot implementation of the National Health Protection Scheme in select states.

12. Mechanical Vibration: Amendments in the Indian Penal Code (IPC) and Information Technology Act over time, based on evolving societal and technological contexts.

13. Skipping: Adopting contactless payment methods and digital wallets quickly during the COVID-19 pandemic, skipping or reducing the phase of contact-based card transactions.

14. 'Intermediary': Use of social workers and ASHA (Accredited Social Health Activist) workers in implementing health-related government schemes in rural areas.
15. Cheap Short-Living Objects: The use of makeshift quarantine facilities to quickly augment the health infrastructure during the COVID-19 pandemic.
16. Pneumatics and Hydraulics: Gradual introduction of the Right to Information Act across various departments and states, slowly replacing the culture of opacity with transparency.
17. Homogeneity: The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013, aims to provide a fair compensation mechanism across different states for land acquisition.
18. Phase Transitions: Drastic shifts in the policy direction towards electric vehicles with the FAME (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India) scheme.
19. Thermal Expansion: Gradual roll-out of the Real Estate (Regulation and Development) Act, 2016, to avoid systemic shocks in the real estate sector.
20. Strong Oxidants: The accelerated roll-out of digital education initiatives in response to the COVID-19 pandemic.
21. Skipping: The Digital India Land Records Modernization Programme (DILRMP) initiative focuses on computerizing all land records, including mutations, digitization of maps, and integrating them into a land information system, skipping the less effective manual system.
22. Feedback: The Mid-Day Meal Scheme in India takes regular feedback from schools and institutes to ensure proper implementation and address challenges.
23. Self-Service: The Bhoomi project in Karnataka allows landowners to download and print their land records, making the process more user-driven.
24. Copying: The use of the Forest Rights Act inspired by similar tribal and indigenous rights recognition in various countries.
25. Cheap Short-Living Objects: The use of mobile ATMs or 'ATM vans' during the demonetization phase to handle the immediate need for cash withdrawals.
26. Replacement of Mechanical System: Adoption of digital technologies in elections like Electronic Voting Machines (EVM) and Voter Verifiable Paper Audit Trail (VVPAT) machines.
27. Pneumatics and Hydraulics: Gradual introduction of demonetization in phases, from initial announcement to exchange of notes, to withdrawal limits, and finally to remonetization.
28. Flexible Shells and Thin Films: Flexible policy for e-commerce to incorporate the rapidly changing landscape of online commerce.
29. Use of Porous Materials: Implementation of local policing initiatives that involve the community, like community policing and 'beat' systems in local neighborhoods.
30. Color Changes: The use of color-coded pollution under control (PUC) certificates to indicate the pollution level of vehicles.
31. Homogeneity: The National Pension Scheme provides a standardized pension system for all citizens, including those working in the unorganized sector.
32. Discarding and Recovering: Learning from the implementation challenges of the Sarva Shiksha Abhiyan, and incorporating these lessons into the Samagra Shiksha Abhiyan.

33. **Parameter Changes:** Adjusting income tax slabs and rates in every budget based on the current economic situation.
34. **Phase Transitions:** Introduction of the lockdown in phases during the COVID-19 pandemic.
35. **Thermal Expansion:** Gradual increase in the scope of the Pradhan Mantri Ujjwala Yojana to cover more beneficiaries and provide free LPG connections.
36. **Strong Oxidants:** Rapid implementation of the Pradhan Mantri Garib Kalyan Yojana in response to the COVID-19 pandemic.
37. **Inert Atmosphere:** Ensuring the independence of the Central Bank in making key monetary policy decisions without undue political influence.
38. **Composite Materials:** In order to build a complete strategy for housing provision, the Pradhan Mantri Awas Yojana incorporates components of credit-linked subsidies, affordable housing in collaboration with public and private sectors, and slum restoration.
39. **Inert Atmosphere:** The Reserve Bank of India's (RBI's) Monetary Policy Committee (MPC) operates independently of the government. The committee sets benchmark interest rates based on the inflation target set by the government. Its aim is to ensure price stability while keeping in mind the objective of growth. This exemplifies an 'inert atmosphere', as the committee carries out its duties free of direct government intervention, hence maintaining the credibility of the monetary policy decisions.
40. **Composite Materials:** The National Education Policy (NEP) 2020 can be seen as an example of this principle. It creates a holistic policy by combining many components of the educational system, from early childhood to higher education. It attempts to reorganise and modernise the educational system, making it more adaptable and concentrated on the improvement of students' cognitive abilities. The NEP is a composite policy that covers numerous facets of education in India by drawing inspiration from different previous policies and educational philosophies. A more complex and comprehensive policy intervention that may address a variety of problems and stakeholder needs in the educational system is made possible by this composite approach.

5.3. Trends of Engineering System Evolution (TESE)

Applying the Trends of Engineering System Evolution (TESE) from TRIZ to policymaking involves translating these technological principles into the realm of policy.

1. **Increasing Degree of Idealization:** Policies should aim to provide maximum benefits to citizens with minimal cost and harm.

For instance, the Products and Services Tax (GST) reform in India attempted to streamline the tax code, lessen the tax's cascading effect on the price of goods and services, and improve the efficiency of the tax collecting process. The goal is to get the tax system as close to the "ideal" state as possible.

2. **Evolution Towards Increased Complexity, then Simplification:** Policies often start simple, become increasingly complex over time as they're modified, and should then be simplified again.

For instance, India's labour laws have historically been complex, with many different acts governing various aspects of labour rights. Recently, these laws have been consolidated into four codes, simplifying the system and making it more comprehensible and manageable.

3. Increasing Dynamism and Controllability: Policies should be adaptable to changing conditions, but also controllable and able to be enforced.

An example is the adaptation of Indian laws to deal with cybercrimes, which were not a major issue when many laws were originally written but have become increasingly important with the advent of the digital age. This shows dynamism in policy-making, responding to evolving societal and technological conditions.

4. Increasing Use of Fields: In policy terms, this could mean leveraging different fields of knowledge or different sectors of society to achieve policy objectives.

For example, India's National Education Policy 2020 leverages insights from psychology, pedagogy, technology, and social sciences to create a comprehensive policy for the future of education in India.

5. Evolution Towards Micro-level and Nano-level: Policies may initially address issues on a large scale, but over time they may become more targeted, dealing with specific groups or regions.

An example in India could be the shift from broad poverty alleviation schemes to more targeted programs like the Pradhan Mantri Jan Dhan Yojana, opening Zero account balance in banks to all the poor, which aims to increase access to financial services for the poor.

6. Conclusions

In conclusion, the applicability of the Theory of Inventive Problem Solving (TRIZ) extends beyond its initial engineering and technological focus and offers a compelling methodology for modern policymaking. TRIZ's structured problem-solving approach can provide an invaluable framework for tackling complex policy issues, fostering innovative solutions that may remain hidden within conventional methods. Its predictive capability, underpinned by the Trends of Engineering System Evolution (TESE), can enhance policy formulation, allowing for a proactive rather than reactive stance. Resource optimization, a core concept of TRIZ, can ensure maximal policy impact with minimal resource expenditure, promoting efficiency within the policy landscape. Furthermore, TRIZ's focus on conflict resolution can play a significant role in balancing competing interests, a common challenge in policymaking. TRIZ also emphasizes envisioning an 'Ideal Final Result,' encouraging outcome-based thinking that can drive effective policy development. Lastly, the interdisciplinary approach of TRIZ, facilitated by its systems thinking, can inspire the synthesis of ideas across various fields, acknowledging and leveraging the interconnected nature of today's world in policy decisions. Therefore, integrating TRIZ into policymaking has the potential to catalyze the creation of more innovative, comprehensive, and future-ready policies.

References

1. "The Application of TRIZ in Disaster Management" by Guangdong Li and Youguo Li
2. "TRIZ-Based Innovation Methodology for Improving Public Transit System" by I. V. Shevchenko, D. V. Dunaev, and E. V. Shershneva
3. "TRIZ Application in Waste Management: A Review" by W. S. Lai and M. Z. Abdullah

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CREATING A LEARNING PULL – TRIZ BUSINESS & MANAGEMENT USE CASE

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Abstract

L&D head of an information technology organization has been challenged with a problem that there is not enough pull for learning interventions being offered to employees at various levels.

L&D head was trying her best to design & offer interventions as part of her role while having to tackle plethora of challenges such as scanty learning budget, execution pressure, employees schedule challenges for nominating themselves for learning interventions, ever changing business processes, models, & technology landscape to address learning needs, unavailability of experts for designing customized learning interventions amongst others.

Her manager Chief Human Resource Officer (CHRO) of the organization asks Learning Head to survey and identify the 'good' and the 'real' reasons as to why there is no pull from employees for learning interventions planned for them. CHRO, who have attended TRIZ for Business Innovation Course suggested L&D head to attend the course to learn TRIZ innovation methods and engage a facilitator to explore, ideate & implement innovative solutions to address the problem.

L&D head acting on advise of a TRIZ facilitator, reaches out mainly to employees and their reporting managers to get their honest views on why there is not enough pull for the learning interventions. She captures all the statements, eliminate duplicate ones, combine related ones, records her own views, and briefs CHRO with an overall picture.

TRIZ facilitator then helped the L&D team glean insights from the collected information by using Perception Mapping Tool [1] & further assisted team formulate key contradictions, that are directly or indirectly responsible for not having a pull for learning interventions. Facilitator conducted the ideation sessions with select employees & reporting managers to generate ideas to improve the situation.

Team was asked to shortlist the initial list of ideas & implement them to change the situation from 'learning push' to 'learning pull'. This transformative project is one of the key management interest projects and was getting their requisite attention.

Ideas emerged out of this exercise are implemented and there is a huge reduction in the dropout rate from learning interventions, which narrowed down from 60 % to 15% in the span of 1.5 year. Thus, there is almost 400% improvement in the chosen business metric.

1. Step By Step Assignment Approach

TRIZ facilitator interacted with L&D head & her team to understand various elements of learning & development system that included various processes, internal & external stakeholders, infrastructure.

Facilitator then put all the collected information in the form of a mind map for ease of retrieval and for not losing sight of any element which could potentially be useful for finding ingenious solutions. (Figure 1)

Facilitator also engaged with employees & their managers who are the main consumers of learning interventions and understand their views & experiences as to why there is not enough pull for learning interventions. Facilitator could sense that there are lot of perceptions coming out of these interactions, so she decided to use perception mapping tool to arrive at the key contradictions.

Facilitator then advised L&D head to collect views of employees and their managers in more explicit manner. It was not possible to reach out to all the employees and their managers, so a sample of 100 employees and managers have been selected and asked to put their top 3 reasons for not having enough pull for learning interventions.

All the statements thus collected were scrutinised to eliminate the duplicate ones, combine the related ones to arrive at the final set of statements to be analysed using perception map tool.

The analysis of perception mapping was used to arrive at the key contradictions that needs to be addressed using TRIZ for Business & Management Framework.

Using TRIZ Business & Management Contradiction Matrix and Corresponding Inventive Principles team generated ideas and put out the solutions for implementation.

Solutions are prioritised for implementation using EPIC Framework (Ease, Permanence, Impact & Cost of Solutions)

Action plan with responsibility & target date was finalised and regular reviews are conducted to ensure adherence to action plan & its effectiveness.

Results of implementation are monitored & validated.

1.2 Mapping Learning & Development Eco-system (Step A& B detailed above)

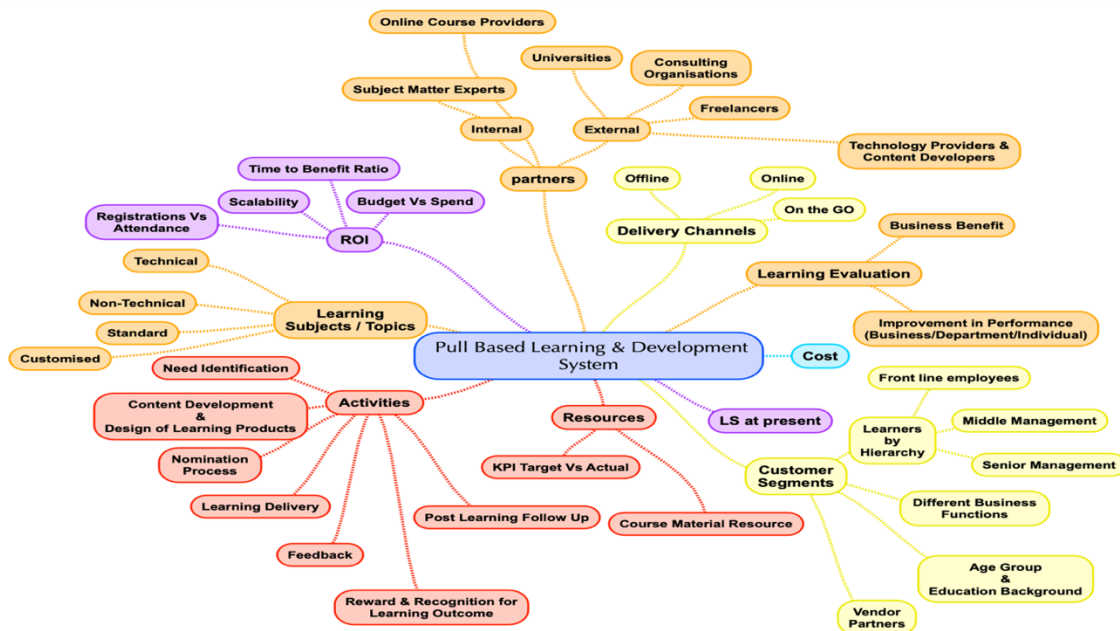


Figure 1: Holistic View of Learning & Development Eco-System

1.3 Perception Mapping: A Step By Step Process

The process of mapping perceptions involves 5 steps. Let's begin with the first step which is to collect all the perceptions from different stakeholders [1]

1.3.1 Collection of Perceptions of Different Stakeholders

When there are several stakeholders involved in a problem they have a different perception of a given reality. In this case there are many perceptions of different stakeholders as to 'Why there is no pull for learning interventions being offered?'. It therefore became apparent to reach out to those stakeholders to get those feelings & emotions out in the form of a raw statements that can be analysed using perception mapping tool basically to identify key contradictions and then using TRIZ Business Contradiction Matrix to generate solutions to address the problem.

Table 1 on the next page captures all those perceptions that are collected from employees, their reporting managers, learning head and CHRO. These statements then are finalised after deleting duplicate ones and consolidating similar ones.

The perception mapping tool is a derivation of a tool known as a 'flowscape'. A flowscape is a tool developed by Edward De Bono in 1990

1.3.2 Construction of Flow Map of Perceptions

Refer Table 1 for perception statements. The column 'Identifier' is the code given to each individual perception. The column 'Leads To' records to which other perception this identifier perception connects to. For e.g. Identifier A 'Unable to find time for learning due to work pressure' leads to another identifier in the list Y 'Long learning curve durations of interventions' so they appear in the same row.

1.2.2.1 The map is constructed by identifying each perception and asking a question where this leads to. Every perception we identified leads to one & only perception is the rule we need to follow. For e.g. 'faculties are not competent' leads (B) leads to 'not enough practical application to help do my job better' (C). Each perception feeds into one and only one other perception.

1.2.2.2 Identify a pair or pair of perceptions representing any statements that are contradictory or in conflicting with one another

1.2.2.3 The next step is to identify type of relationship between different perceptions

There are 3 types of relationships that get formed once we construct the perception mapping diagram.

The first type is known as 'LOOP' for e.g. 'No appreciation of acquired skills' (D) leads to 'No reward & recognition post learning' (F). So D leads to F and F leads to D. Since each perception leads to one & only one another, there will be at least one loop. The loop contains two perception as a minimum or there could be many forming one large loop.

The second type is known as 'COLLECTOR POINT' where several different perceptions lead to one perception. In this example perception C is a collector point which is 'no practical application of learning' so many perceptions leads to this one perception and makes it important

The third type is when several perceptions that form a 'CHAIN' between the conflict pair identified in the step 1.2.2.2.

Thus when we map the perception map we need to focus on 'LOOPS' 'CHAINS' and 'COLLECTOR POINTS' which will be more significant for us to spot issues to be addressed

Table 1: Perception Statements and Their Connections To Other Perception Statements

Identifier	Perception Statements	Leads To
A	Unable to find time for learning due to work pressure	Y
B	Faculties are not competent	C
C	Not enough practical application to help do my job better	G
D	No appreciation of acquired skills	C1
E	No connection between learning and individual's performance	S
F	No reward & recognition post learning	D
G	Absence of alignment of learning interventions with business benefits	E
H	Learning modules are not customized to my need	C
I	Module development cost is high	M
J	Module development time is high	I
K	Module coverage need to be expansive	Y
L	No flexibility of choosing learning time	A
M	Insufficient / No learning budget	G
N	Lack of competency in internal expertise for developing contents	P
O	Poor identification of learning need	P
P	Lack of learning customization	C
Q	Learning is seeing as a time waster	F
R	Learning is seen as must do thing to satisfy KRA of learning & development head	W
S	Effectiveness of learning on job performance is unknown	G
T	Inaccessibility of faculty for implementation assistance	U
U	No projects are encouraged and agreed upon before learning intervention	R
V	Doesn't aid enhancing professional value	U
W	Nomination to outside program which are not expensive doesn't address my need	G
X	Learning interventions are not able to keep pace with the changes in the work content	C
Y	Longer learning duration of interventions	A
Z	No continuous upgradation of learning module	P
A1	Learning modules need to be designed by many outside experts	J
B1	Travel is discouraged to attend learning interventions	A

Identifier	Perception Statements	Leads To
C1	Inhouse learning distracts participants as they are often called by their colleagues / bosses that comes in way of the undivided attention that they need to have and hence loss of interest of participants in learning.	L

There are 4 distinct areas of learning & development system. All perceptions that are captured fell under one of these categories

- a) Enrolment, Attendance & Engagement
- b) Meaning of learning interventions in executing one’s job
- c) Motivation for Learning
- d) Content Design & Supply Cost

The perception statements received from employees surveyed echoed all the above areas. After putting down these statements on perception map, it was evident that not all the statements had ‘lead to’ statements for connection if they belong to a distinct category listed hereabove and hence 4 separate perception maps were prepared for formulating contradictions.[2]

1.3.2.1 Perception Maps

The first set of perception statements were related to employees not enrolling or attending the learning interventions because of lack of time due to work pressure

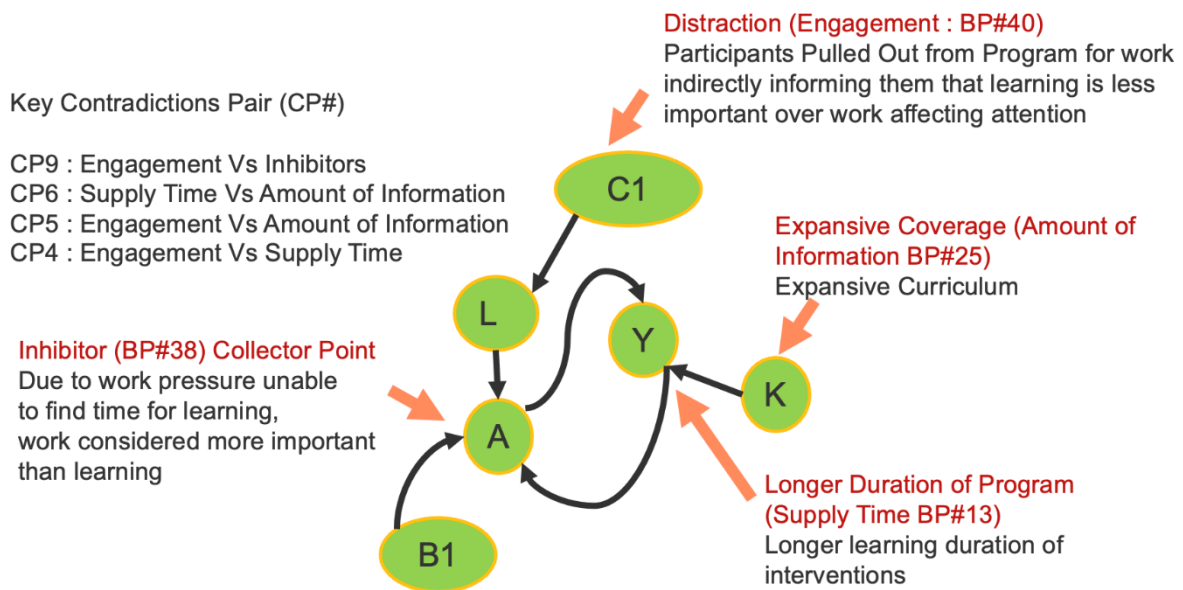


Figure 2 : Perceptions related to enrolment, attendance & engagement

The second set of perceptions were related to employees not finding meaning of learning interventions to the jobs that they do.

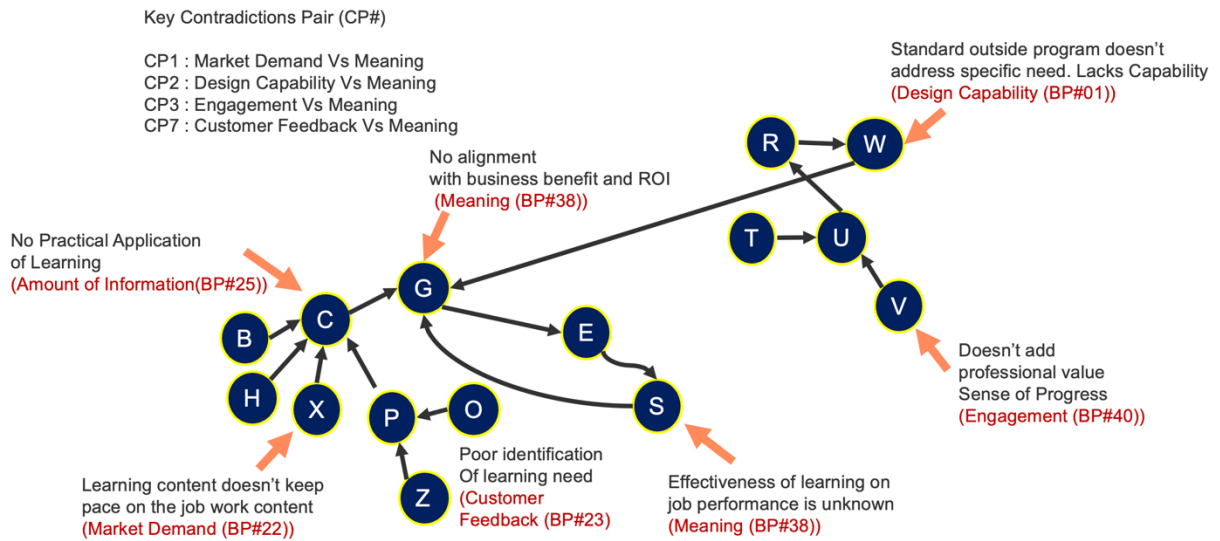


Figure 3 : Perceptions related to not finding meaning in learning interventions

The third set of perceptions were related to employee motivation for enrolment and engagement

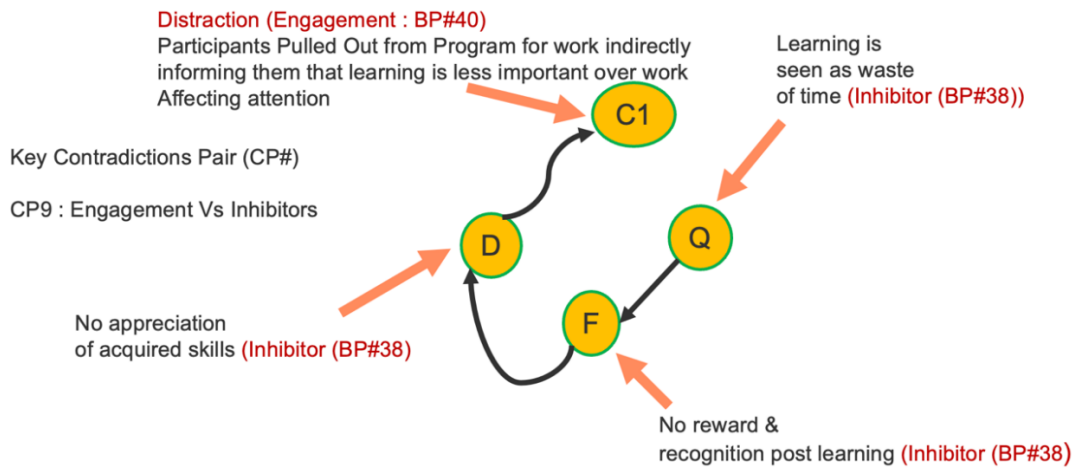


Figure 4 : Motivation for Learning

The fourth set of perceptions were related to course content design & cost

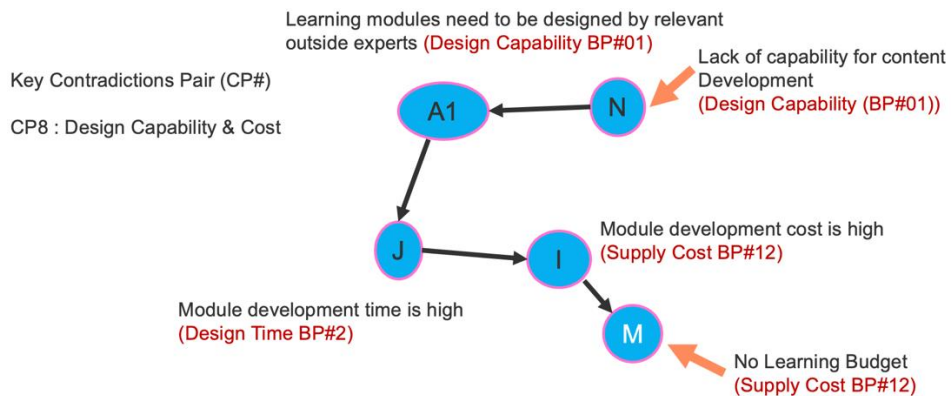
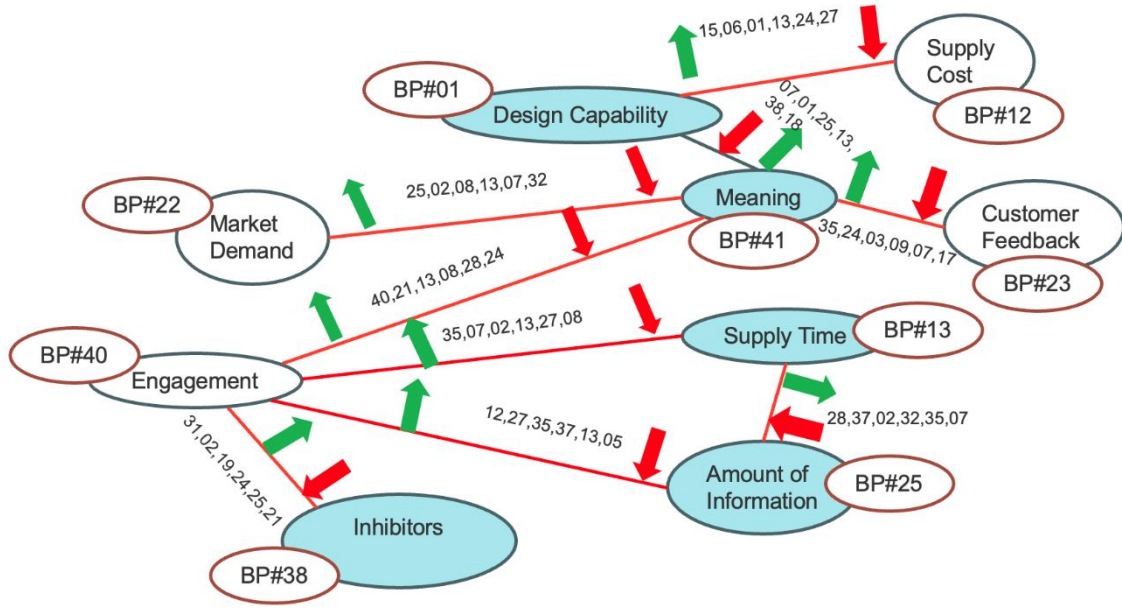


Figure 5 : Content Design & Cost

Each perception map present a chain with contradiction pair at its end or along its way. This contradiction pair is denoted by nomenclature CP followed by the contradiction pair serial number for e.g. in the figure 5, CP#8 denotes a contradiction pair “Design Capability Vs Supply Cost” number 8 is a contradiction pair serial number. As an output of perception map analysis, a holistic attribute conflict diagram was created. The attributes in the attributes conflict diagram represents TRIZ Business Parameters. (Figure 6, for more details on business parameters) [2]



Note :
Red lines indicate there is a conflict between the attributes
 BP# means TRIZ Business Contradiction Matrix Parameter
 Blue color of bubbles Indicate that these parameters are in Innovator’s direct control

Figure 6: Attribute Conflict Diagram for Learning System

Attributes are represented by a bubble and nomenclature used represents TRIZ Business Parameter, the wine red coloured circle represents the parameter number of the TRIZ Business matrix. For e.g. BP#40 “Engagement” means in contradiction matrix this is parameter number 40 and its nomenclature is ‘Engagement’. The red line is represents conflict between two attributes. For detailed definition of matrix parameters refer [2]

The green arrow in the figure 6 pointing upwards represent the parameter to be improved and red arrow pointing downwards represent parameter that worsens or stops us from improving the former. Although there are many attributes on this diagram represented in a bubble, those represented by blue colour are parameters that are in our control for effecting a change. We have given priority for ideation of those inventive principles that are connected with these blue bubbles.

The numbers written on arrow represents inventive principles which are used for ideation and coming out with solution clues. The following table gives select inventive principles their definition & solution clues. The solution clues are referenced with contradiction pair number it is supposed to address.

Table 1: Select Solution Clues based on Suggested Inventive Principles for a Pair of Contradictions

Inventive Principle	Specific Ideas, Solution Clues / Contradictions They Address (CP#)
<p>1A) Segmentation</p> <p>Divide an entity, process or system into separate parts or sections.</p>	<p>Divide the learning topic into sub-topics, sub-sub-topics and assign them to individual employees to prepare a learning module & be a faculty herself</p> <p>Divide the course into main course and refresher which is annex to the main course, refresher course focusses on changes that have happened in business practices / processes / technology landscape since the first course was designed and delivered (CP#2 & CP#8)</p>
<p>1C) Segmentation</p> <p>Increase the degree of fragmentation or segmentation.</p>	<p>Let every employee design his own content & offer to wider audience for scrutiny. Time investment for this can be budgeted in her time sheet. Take employees feedback on each of these modules to stitch together the best possible course.</p> <p>Create different versions of the training program Classroom, Video, Virtual, Audio Files as per the user's demography & need.</p> <p>Create module wise quiz, unless previous module quiz is cleared second module cannot be offered (CP#2 & CP#8)</p>
<p>2D) Taking Out</p> <p>Separate different elements of an object or system based on different condition-based requirements.</p>	<p>Employees to choose specific topics that they want to learn by providing them complete visibility of course coverage. Its like choosing a menu that they want to consume</p> <p>Take best out of modules put up by the employees on the same subject and build a new module taking the best out of all these modules to make a final course that is most enriching. Use number of likes on learning portal as a criteria for choosing a specific content</p> <p>Chose topic wise faculty instead one faculty for the entire course</p> <p>Explain the topic with an example / case study rather than giving only theoretical details (CP#1,CP#4,CP#9,CP#6)</p>
<p>5B) Merging</p> <p>Physical join or merge identical or related entities, operations, or functions</p>	<p>Peer Group Training</p> <p>Integrate learning performance into employee goal sheets</p> <p>Learning hackathon</p> <p>Merge learning with annual conference / weekly meetings (CP#5)</p>
<p>7A) & C)</p> <p>Nested Doll</p>	<p>Give a pause between course curriculum with On Job Assignment so that participants can apply their learning in practice</p>

Inventive Principle	Specific Ideas, Solution Clues / Contradictions They Address (CP#)
<p>Put one entity or system inside another.</p> <p>Allow one entity or system to pass through an appropriate gap or pause in another.</p>	<p>Identify existing available content and nest together with the new content. i.e., combination of existing content and new content</p> <p>(CP#1,CP#2,CP#4,CP#6,CP#7)</p>
<p>8B) Counterbalance</p> <p>When an entity or system deviates from a desired path, introduce protocols or forces that provide a restabilizing effect</p>	<p>Let organization allow some of the working time to be utilized for training, employees have to then commit equal personal time to balance out the total time spent on learning</p> <p>(CP#1,CP#3,CP#4)</p>
<p>13) A&B The Other Way Round Effect</p> <p>Invert the entity, process, or system.</p> <p>Invert the actions to solve the problem.</p>	<p>Let the employees, instead of external faculty prepare a small topic by researching on the subject and then creating their own modules</p> <p>Design learning modules to address causes that has resulted in performance gap instead of putting up the course and expecting that it will help in improving performance</p> <p>Let business leaders design the course, make it part of their KRA and then sell the course. The amount thus gained can be added to their department budget as a revenue from sale of the course</p> <p>Let your colleague, buddy or peer managers of your boss recommend a program for you based on their assessment what skills upgrade might help you</p> <p>(CP#1,CP#2,CP#3,CP#4,CP#5, CP#8)</p>
<p>18) B Resonance</p> <p>Make use of emotional ‘exciters’</p>	<p>Let employees write the feedback on the learning portal for others to feel excited about the program & thus enrol</p> <p>Handsomely reward employees with learners of the year award who applied learning to achieve a business result</p> <p>(CP#2)</p>
<p>19) Periodic Action</p> <p>Replace continuous actions with periodic.</p>	<p>Plan the course with different magnitudes of duration to gradually create interest.</p> <p>(CP#9)</p>
<p>25 A&B) Self Service</p> <p>25 A & B) Self Service</p> <p>Enable an entity, process, or system to organize,</p>	<p>Team identifies & designs their own learning together</p> <p>Accredited training</p> <p>Teams pick & chose the content they like to learn from the learning reservoir and make a course. They can edit the course</p>

Inventive Principle	Specific Ideas, Solution Clues / Contradictions They Address (CP#)
manage, change, or transform itself.	like WIKPEDIA whenever they feel they have a better ideas to present the content which will be useful to subsequent users (CP#1,CP#2,CP#9)
28)A Emotional Fields Introduce an emotional experience element to an entity, process, or system	Let the learning happen by simulating a business scenario and teams competing through a simulation exercise. Share the theory and / or approach afterwards for participants to learn where they could have been better in terms of their approach & thinking and finally offer facilitator's expert view to conclude the exercise. (CP#3,CP#6)
35) Parameter Change Change the form / attribute of a product or service.	Virtual learning modules Learning department is not a cost centre but a profit centre and should be run as a business so that more competitive learning products can be built Create silent rooms away from workplace where employee can go sit in a relaxed manner and either listen or see the small bits of course modules (CP#4,CP#5,CP#6,CP#7)
37) Relative Change Use the relative difference that exist in an object or system to do something useful.	Create future scenario exercises to demonstrate why the program is necessary and what it can deliver & how it can bridge the knowledge gaps Offer different types of programs according to the generation of the learner, offer different delivery means for every generation of employees (Classroom, Simulation, Virtual, Video Clips etc.) (CP#5,CP#6)
40) Composite Change from uniform to composite structures where each element is optimized to a particular functional requirement	Create module wise / topic wise nominations so that participants attend what they need to learn and may not attend the entire program if they are time stressed. (#CP3)

2. Conclusion

TRIZ is a system thinking framework that fuels innovations.

The case presented here shows application of TRIZ for non-technical problem. When there are many entities and many voices involved and problem statement is as abstract as was initially presented which was 'how to create a learning pull' it is necessary capture all the voices &

opinions to extract the real system conflicts. A perception map helps us zero down on key contradictions & attributes that we can improve to achieve the set objective in this case ‘how to create a learning pull’ After having done this we used TRIZ Business Contradiction Matrix and identified inventive principles to generate solution clues.

The mind map of the entire system helped team ideate on several elements using inventive principles. The solutions thus generated touched several elements of the system, in this case ‘learning system’ to address the original problem we started with which was ‘how do we create a learning pull’

The solutions are prioritised and action plan with responsibility was prepared for its implementation. Several communication meetings happened to start with implementation of some of the ‘out of box’ ideas like employees creating own content, putting up most liked content to form a course curriculum’ etc. This created excitement & involvement in few employees to start with and they actively participated in putting the idea into practice .

After 1.5 years into implementation employee dropout rate out of learning interventions narrowed down from 60 % to 15%. Thus, there is almost 400% improvement in this chosen business metric. Also the re-survey of select employees & managers showed that there was an improvement in on the job performance due to new way of doing things in leaning designing & executing learning interventions.

References:

1. Darrell Mann, Hands on Systematic Innovation for Business & Management, IFR Press, UK, 2007
2. Darrell Mann, Business Matrix 3.0, Solving Management, People & Process Contradictions, IFR Press, UK, 2018

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FUEL SAVING WINGLETS - TRIZ USE CASE

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Abstract

One of the major cost drivers in an airline industry is Air Turbine Fuel (ATF). The volatile input constantly keeps its margins in check, even though fuel prices have slumped considerably, it has given airline industry nightmares all through its existence.

The case presented here was when everything was not going hunky--dory for the airline industry and aircraft manufacturers have to act on SOS basis with their innovations to curb fuel consumption. There were several ways explored to improve fuel efficiency.

The case discussed here considers the problem of vortex drag reduction at the wingtips which is one of the major contributors in reduction of the lift force, adversely affecting the fuel efficiency. Following discussion explores what the problem is, where it occurs, what are the contradictions to be addressed and how TRIZ (Systematic Innovation Science) contradiction matrix & inventive principles finds its application in the proposed solution which is tested and validated for improved fuel efficiency offering several other benefits. Author doesn't claim that TRIZ is used to arrive at the final solution, which is winglet in this case but wants to show application of TRIZ in already evolved design. This case is written with a view to generate interest of engineering professionals in TRIZ and encourage them to use it in technical problem solving in their own field of work.

The case shows broader & narrower problem definition to zero down on the key problem statements & contradictions. The paper discusses several type of drag forces acting on the wingtip that affects the lift force. The ideas & eventually the engineering solution that has come up achieved a vortex drag reduction to a large extent. Finally it lists several other benefits of winglets beyond saving precious Aviation Turbine Fuel

Keywords: TRIZ, Drag Reduction, Fuel Efficiency

1. Defining Broader & Narrower Problem

Every problem statement has a broader & narrower part to it. So, airline companies must have started with an original problem statement 'how to improve profitability' which is a universal problem statement across businesses irrespective of the type of industry. To zero down on the problem statement which we eventually want to work on, we use 'WHY-WHAT's STOPPING YOU TOOL' [1]. The tool asks us to keep the main problem statement at the centre and work upwards asking the question 'why do we want to solve this problem' to identify the broader problem statements. Similarly, the tool helps us go downwards by asking a question 'what's stopping us solve this problem' this will result in getting more granular problem statements that either business and / or its partners must work on to address the original problem which in this case was 'how to improve profitability of the airline'. (Figure 1)

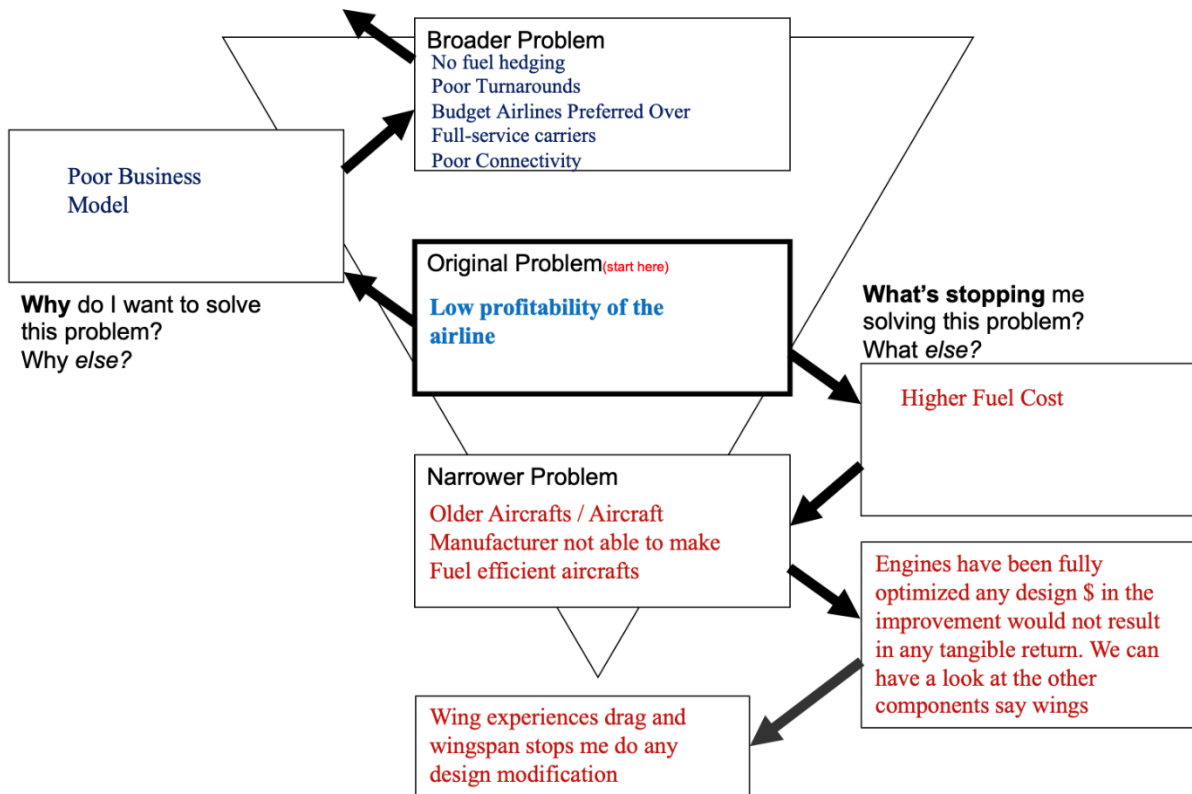


Figure 1: Why-What's Stopping Me Tool to Identify Broader and Narrower Problems

Whilst airline company's job is to work on the problems and associated factors that they have control on, which is mainly concerning their own operations & business model architecture. But when it comes to the problems that their partners need to address, they will have to take it up with them for resolution, which will benefit both airline company and aircraft manufacturers by delivering true value to their final customers, the travellers.

Our focus of discussion in this article is the narrower problem that aircraft manufacturer must define which is to improve fuel efficiency of the aircraft.

1.1 Narrower Problem

After the problem of 'making aircraft fuel efficient' landed on aircraft manufacturer's design room the first thing they must have done is to look at the system hierarchy of the product, aircraft in this case & decide where to put their efforts based on the benefit they expect to achieve as a result of their work, it may so happen that they will work on different aspects of aircraft sub-system which can potentially contribute to the improvement of 'fuel efficiency' (Figure 2) [1]

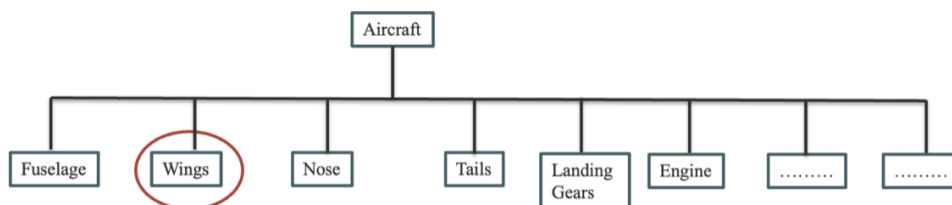


Figure 2: System Hierarchy Diagram to Shortlist Sub-System for Improvement

The engine looks to be an obvious choice as it powers the plane by consuming Air Turbine Fuel. But any investment in already optimised engine may not give manufacturer significant improvement in the fuel efficiency. There are other components to be looked at which may require minimum investment to improve and are a good candidates for fuel efficiency improvement.

Wing was chosen as a probable candidate for possible redesign for improving fuel efficiency. Let's dive into detail to look at the problems with the wing structure, air dynamics around the wing that contributes to the lower fuel efficiency.

1.2 Airfoil Components & Lift

An air foil is the shape of a wing. Subsonic flight have a characteristic shape with a rounded leading edge, followed by a sharp trailing edge, often with asymmetric camber. (Figure 3) [2]

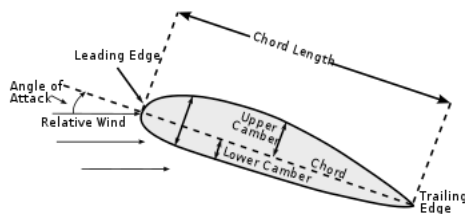


Figure 3 : Air Foil Geometry (Side View)

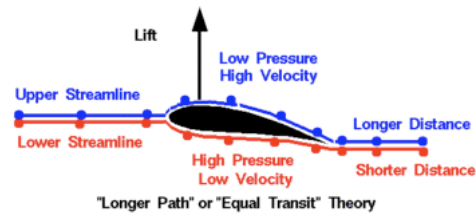


Figure 4 : Air Flow Around The Air Foil

If we recollect Bernoulli's theorem which says the total pressure of an incompressible fluid is the sum of the static pressure & the dynamic pressure. If the fluid is air and the means by which the fluid is accelerated is an air foil, the side on which the fluid travels the maximum distance will have the highest velocity and lowest static pressure and vice a versa. The difference in the velocity on each side of the air foil determines the static pressure differential. That is what generates lift. The lift on an air foil is primarily the result of its shape and its angle of attack. When either or both are positive the resulting flow field about the air foil has a higher average velocity on the upper surface than on the lower surface. The velocity difference is necessarily accompanied by a pressure difference, which in turn produces the lift force.(Figure 4) [3]

Designing a wing would have been simple if it were a two dimensional air foil. But wing has a finite length. The difference in air pressure between the lower & upper surfaces of a wing causes the air to escape around the wingtip which reduces the available lift. We will see the phenomenon in detail in the following discussion on drag.

1.3 Drag

Drag simply means the harmful forces acting on the wing which reduces the available lift. There are two types of drag the first type is lift induced drag which is 40% of total drag and the other is parasitic drag which is around 60% of total drag.

1.3.1 Lift & Induced Drag

The lift induced drag is a drag which occurs as the result of the creation of lift on a three dimensional lifting body. Induced drag primary consists of two component the vortex drag and the viscous drag.

The motion of the air rushing around the wingtip coupled with the velocity of the airflow through which the wing is flying causes a vortex to be formed near the wingtip (Figure 5) [4]. The tip vortices cause upwash and downwash air currents that alter the current of the free stream flow around the wing. They induce a decrease in the angle of attack of the average relative wind flowing around the wing. This has two undesirable by-products as shown in figure below. First the wing generates lift perpendicular to the average relative wind. This diverts the lift vector away from the desired direction which is perpendicular to the free stream. Diverting the lift vector causes a drag component to be generated that is parallel to the free stream airflow. The drag component varies as the cosine of the angle between total lift vectors (Figure 6)

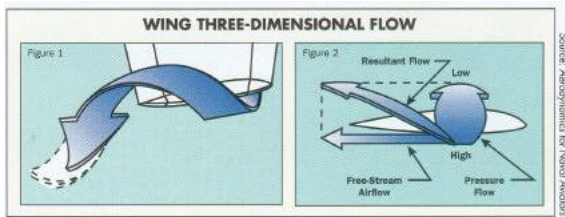


Figure 5 : Wing Three Dimensional Flow

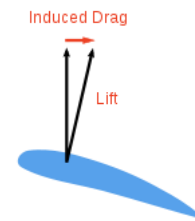


Figure 6 : Induced Drag & Lift Vectors

The up-wash / downwash effect (Figure 7) [5] of the tip vortices (Figure 8) [6] has its greatest influence of the wing section closest to the tip. The tip vortex has little effect on the average relative wind of the wing sections far inboard from the wingtip. In other words, if you push the winglets outboard, a smaller section of the wing will be effected by the tip vortices which will reduce the upwash and downwash effect. In other words if the span were infinite induced drag would be zero because there would be no wingtip.



Figure 7 : Upwash / Downwash Effect

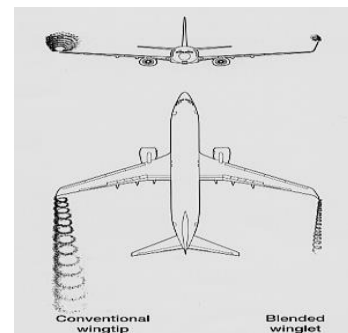


Figure 8 : Vortex at the Wingtip

1.3.2 Parasitic Drag

Parasitic drag is drag caused by moving a solid object through fluid. This is around 60% of the drag. Parasitic drag is made up of multiple components including form drag which is a result of form of the object, skin drag which occurs because of interaction between the skins of the object. As seen above a very large long wing, one with infinite span to chord ratio would have enormous parasitic drag. But with optimised wing span, chord and air foil sections the drag can be controlled. However still the vortex drag remains & affects the wingtip reducing the overall lift.

1.3.3 No further optimisation possible as system hits the fundamental limit

The vortex drag can be theoretically minimised by having an infinite span to chord ratio known as aspect ratio. Now if we optimise the aspect ratio for the improvement in lift coefficient then the result shows us that there is a marginal difference in the lift coefficient for the aspect ratio (Figure 9) [7] starting from 8 onwards to infinity, which means the system has hit the fundamental limit and cannot be improved by further optimisation (Figure 10) [8]

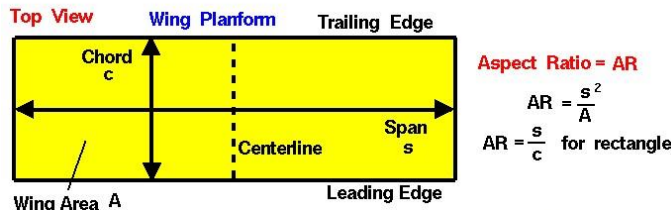


Figure 9 : Wing Geometry & Aspect Ratio

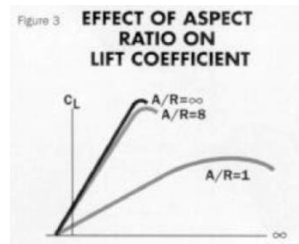


Figure 10 : Aspect Ratio & Lift Coefficient

2. TRIZ Contradictions Matrix & Applicable Inventive Principles

2.1 Contradiction Formulation

As evident from the above discussion, wingtips create a drag by the vortices it generates. This drag causes more fuel burn increasing the operational cost for airline companies. Drag can be reduced by increasing the wing-span. We can use optimisation tools to optimise aspect ratio (span to area ratio) to get the best results for lift coefficient. But there is a cost to an experimentation and beyond a point it may not be feasible to do optimisation.

Now if wing span is increased according to our wish for maximising lift coefficient, the plane may not fit the gate after landing it on the ground. At present in 747 aircraft wings are attached to fuselage nearly by 1600 bolts any increase in length will weaken the strength of this ‘fuselage & wing joint’ it will also hamper manufacturing cycle time. So increasing wing length is not easy as it looks [9]

Now on formulating contradictions for this problem. Some of the TRIZ researchers are of the opinion that physical contradiction is more important than a technical contradiction. While some other TRIZ researchers believe that both/and approach of contradiction resolution is far better than either/or approach. [10] The discussion here shares a new approach of conversion between Physical & Technical Contradiction using theory of constraints tool ‘Evaporating Clouds’ [10]

The approach goes something like this on the right hand side of the figure 11 there are two ovals ‘Parameter A’ and ‘Parameter -A’. These two, exactly as defined by evaporating cloud model, represent physical contradiction. The ‘Conflict Parameter 1’ and ‘Conflict Parameter 2’ ovals then represent our technical conflict pair. Although these two items are also in the original Evaporating model, they are not identified as being in conflict with each other. We may make this connection more explicit in the figure 11 by connecting two ovals. This represents our technical contradiction since the way in which we define the problem, we want to have two contradicting defined parameters. Finally on the left hand side of the picture is the oval labelled

‘successful outcome’ this is the aspect of our system that both the conflict parameters are required to support.

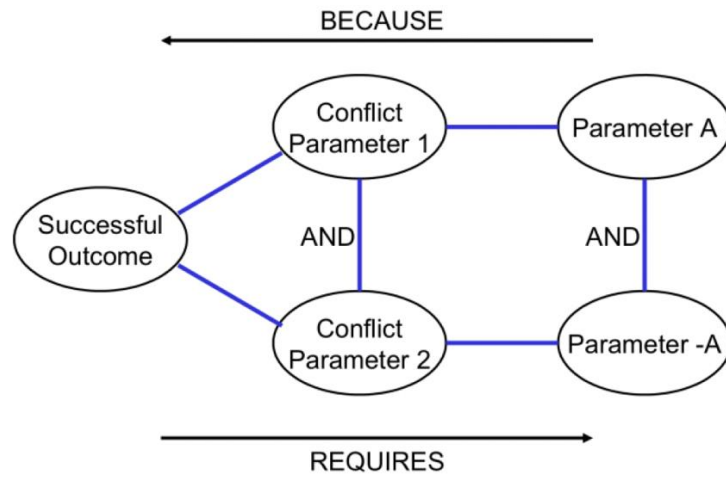


Figure 11 : Generic Scheme of Converting Between Physical & Technical Contradictions

We have applied this framework to our vortex reduction problem and the resultant scheme representing relationship between physical & technical contradiction is as under (Figure 12). The goal of this contradiction resolution framework is to find innovative ideas inspired by TRIZ inventive principles to lower vortex force without increasing the length or span.

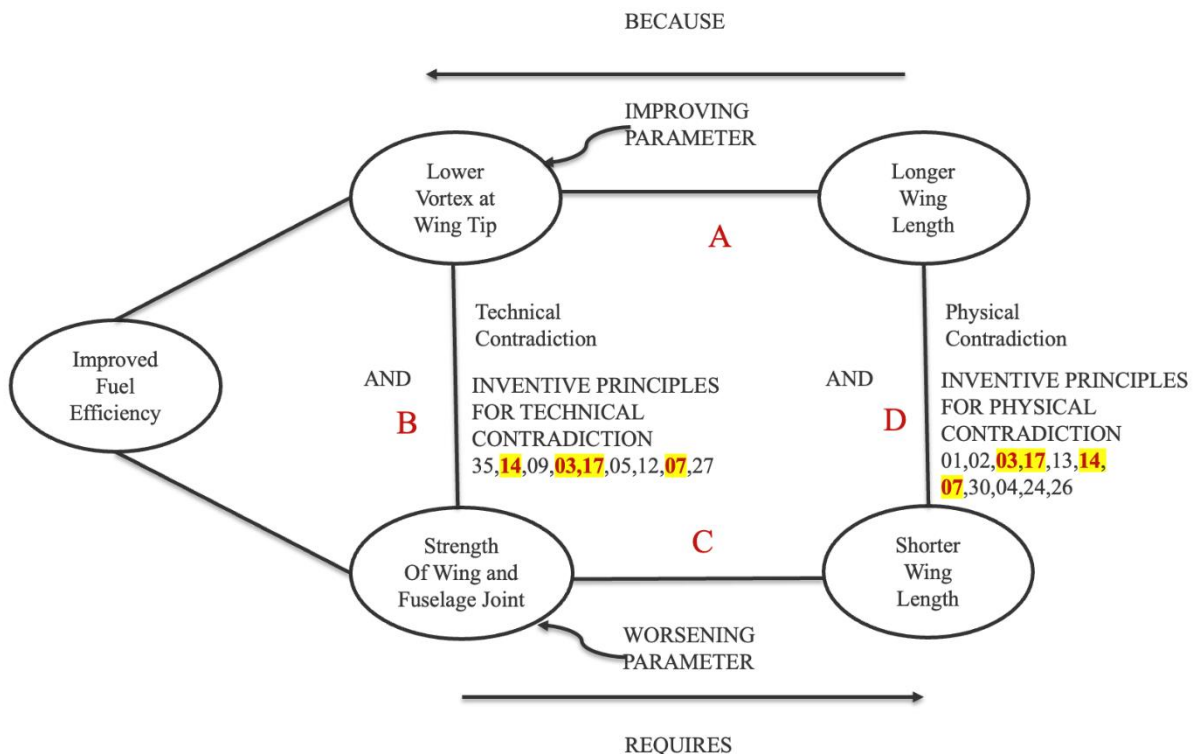


Figure 12 : Physical & Technical Contradictions Connection to VORTEX Reduction Problem

Let us discuss this framework in detail. Let’s start with connection A (Figure 12). Now tip vortex reduction is our main goal. Following the concept of Ideality (Ideal Final Result) the true value of this attribute should be zero at least theoretically which is possible if we have infinite wing length. This is how we make this connection A. The lower vortex drag (ideal value

zero) results in no loss in lift force which results in less fuel burn. The outcome of this solution is improved fuel efficiency.

Wing is connected to fuselage by 1600 bolts, now when we increase the length of the wing many folds as mentioned in connection A, obviously the existing strength of the joint will pose a challenge and will be a worsening parameter, which necessitates us to have a shorter wing length. Refer Connection C of Figure 12.

2.2 Contradiction Matrix and Applicable Inventive Principles

Thus, now we have a technical contradiction represented by connection B where improving parameter is vortex force (TRIZ Contradiction Matrix Technical Parameter #15 Force) and worsening parameter, the parameter that stops us from achieving this (TRIZ Contradiction Matrix Technical Parameter #20 Strength)

The inventive principles applicable to resolve such type of contradiction are represented on connection B they are 35 – Parameter Changes, 14 – Curvature, 09 – Preliminary Anti-Action, 03 – Local Quality, 17 – Another Dimension, 05- Merging, 12-Equipotentiality, 07- Nested Doll, 27 – Cheap Short Living Object [10]

Now let’s examine connection D which represents a physical contradiction with attribute as length. The physical contradiction in space here is ‘Longer Wing Length’ and ‘Shorter Wing Length’, where we want two opposite properties in the same object.

The brilliance of TRIZ, 70+ years old researched innovation science is that it leads innovation teams to an ingenious solution to the problem, that at first, looks difficult or crazy enough to solve.

The inventive principles suggested to solve this type of physical contradictions are. [1]

01-Segmentation, 02- Taking Out, 03- Local Quality, 17- Another Dimension, 13- The Other Way Round, 14- Curvature, 07- Nested Doll, 30- Flexible Shells and Thin Films, 04- Asymmetry, 24- Intermediary, 26- Copying

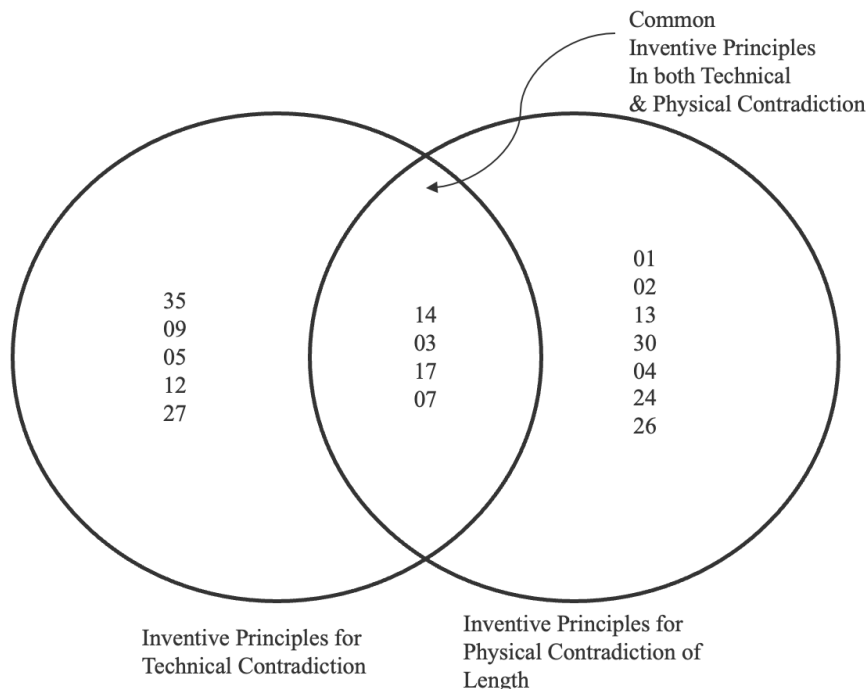


Figure 13 : Common Inventive Principles in Both Technical & Physical Contradiction

2.3 Inventive Principles Application & Solution

Aircraft engineers would have made us believe that aerodynamics is a mature science until NASA’s Richard T Whitcomb invented vertical winglets which could reduce the drag by nearly 20%. As we have seen above that stretching wingspan or increasing aspect ratio certainly reduces induced drag. But designers though must balance the benefits of less induced drag against the cost of structural weight increases, more parasitic drag, or cost considerations.

Winglet works because they efficiently produce side forces that divert the inflow of air from tip vortex & therefore the drag, so lift is not affected as it is with the normal wing and there is an improvement in lift to drag performance resulting in lesser fuel consumption.

Here is decoding Inventive Principles with their interpretation. We chose 9 out of 20 which appear more appropriate for ideation or already have solutions that is contributing to vortex force reduction. (Table 1)

Another insight from the above method we got is the commonality of inventive principles suggested for technical & physical contradictions. So, inventive principles 14,03,17,07 find application in all winglet design options. So, this type of contradiction formulation offers reduction in ideation time and faster implementation of solutions.

Table 1: Inventive Principles and Interpretation of Most Relevant Principles

Inventive Principles	Interpretation of Relevant Inventive Principles
14 Curvature	Turn straight edges or flat surfaces into curves
03 Local Quality	Change things around the system from uniform to non-uniform. Enable each part of a system to function in locally optimised conditions. Enable each part of a system or object to carry out different useful functions.
17 Another Dimension	If system contains or moves in a plane, consider use of dimensions or movement outside the current plane
07 Nested Doll	Put one object & system inside the other
35 Parameter Changes	Change the pressure, change the concentration & consistency. Change in parameter has to be a step change and not intended to be an optimisation strategy
05 Merging	Physically join or merge identical or related objects, operations & functions
27 Cheap Short Living Object	Replace an expensive object or system with a multitude of inexpensive short living objects
04 Asymmetry	Where an object, process or system is symmetrical or contains lines of symmetry, introduce asymmetries
02 Taking Out	Temporally separate different elements of an object or system

We see application of these inventive principles in various winglet design that are in existence to reduce the vortex force and improve fuel efficiency. [11]

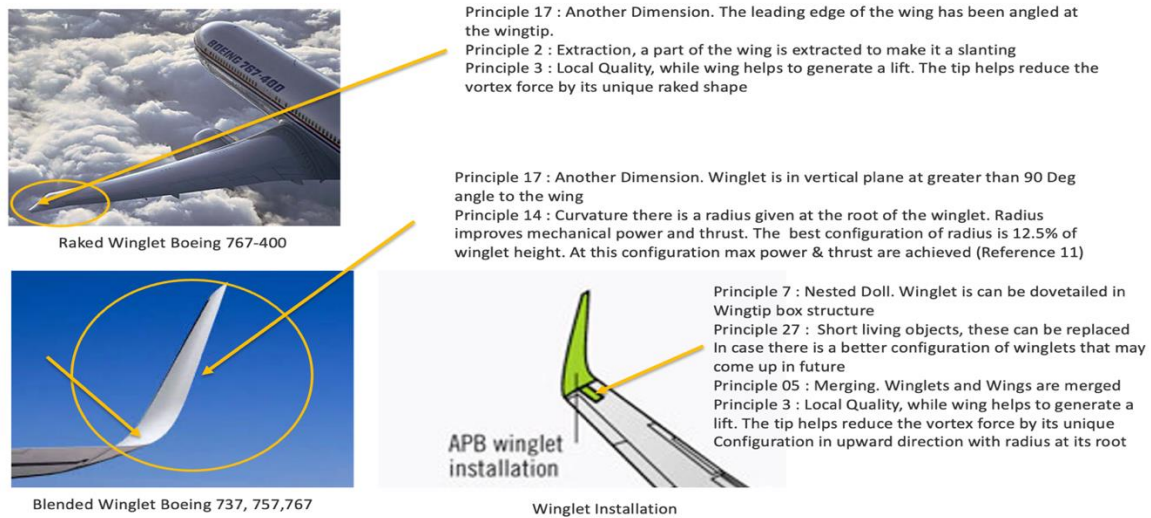


Figure 14: Winglet Designs and Applicability of Inventive Principles

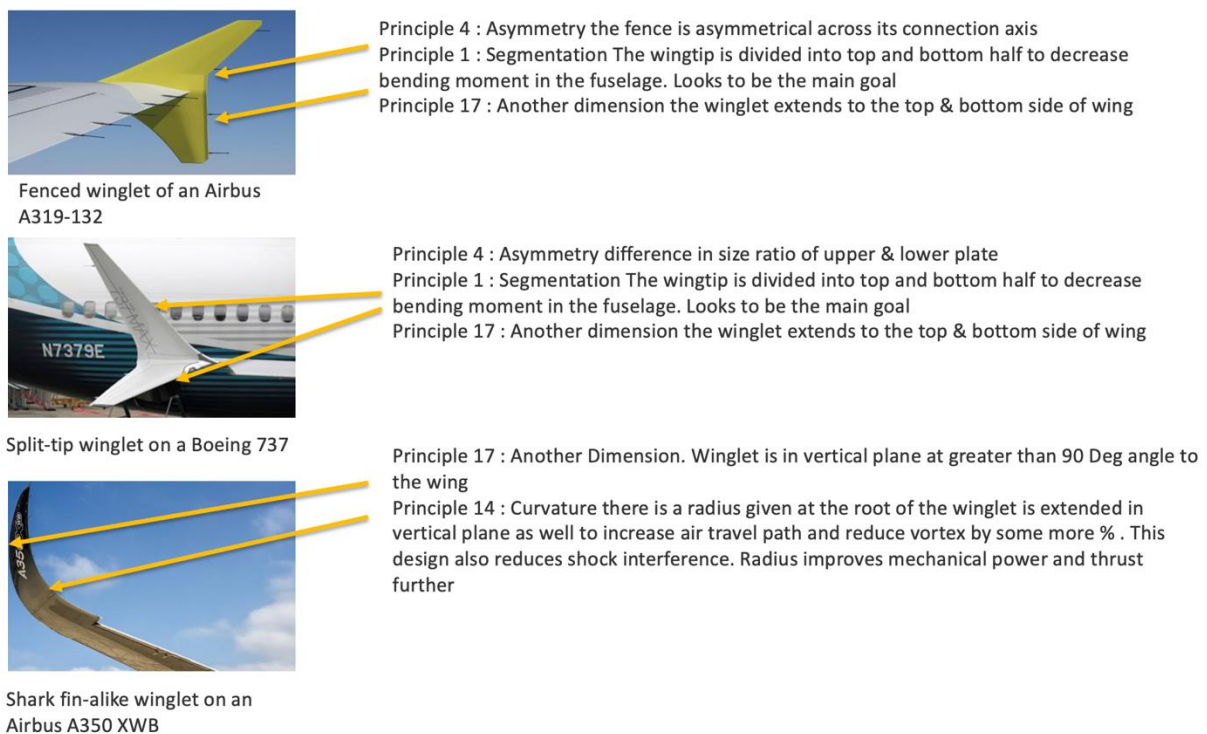


Figure 14: Winglet Designs and Applicability of Inventive Principles

Benefits of Introducing Winglets

- a) Fuel consumption reduced over 7 % at speeds between 0.75 Mach to 0.80 Mach
- b) Typical 737 operators save @ 95,000 – 1,30,000 gallons per aircraft per year and this is for the entire economic life of the aircraft
- c) It has also environment benefits which reduces carbon monoxide and nitrous oxide by 4 % & 5 % respectively
- d) Increase in the flight speed, improved stability & also faster climb to initial cruise altitude

e) Reduction in the take-off distance also benefits the airline operator to use airports having the shorter runways.

f) The increased lift offered by the sharklets also provides a larger amount of cargo to be loaded.

3. Conclusions

TRIZ is a wonderful innovation science. Several of its problem formulation and solution generation tools have been validated by extensive research conducted over past 70 years and being continued today to help present-day every changing business & technology landscape.

“Someone somewhere has solved a problem “is the basic premise of TRIZ. The case discussed here shows how to formulate correct contradictions and how we can use tools from other world class approaches like TOC to help us generate innovative solutions.

It is my experience that if organisations use TRIZ for problem definition and ideation, they will get breakthrough ideas which will help them stay ahead of their competition. The process should work best when you have TRIZ facilitator & subject matter experts working as one team. One of the ways teams can learn TRIZ with reverse ideation that is by looking at the solution which is already there then thinking on the contradictions that it has overcome.

If 20th Century was of experts creating SILOS, then 21st century is of Innovation Generalist who will use systematic Innovation Process & Toolkit to connect the domain experts to create ingenious innovative solutions that are well & truly IDEAL or at least close to ideal.

References

1. Darrell Mann, Hands on Systematic Innovation for Technical Systems, IFR Press, 2007
2. Air foil Geometry <https://en.wikipedia.org/wiki/Airfoil>
3. Understanding Airflow around the air foil [https://en.wikipedia.org/wiki/Lift_\(force\)](https://en.wikipedia.org/wiki/Lift_(force))
4. Understanding Winglets Technology, Minister of Education, Israel's government services and information website https://cms.education.gov.il/NR/rdonlyres/D9F6FC7B-A508-43C8-BB34-5C6D8AE0346D/178686/Understanding_Winglets_Technology.pdf
5. Upwash and Downwash Effect. International Journal of Science & Technology, Volume 8, Issue 4, April 2020 <https://www.ijraset.com/files/serve.php?FID=27724>
6. Oleg Lisitsin, Wingtips, Winglets & Sharklets- Airplane's Fuel Assistants, <https://engre.co/blogs/articles/wingtips-winglets-sharklets-airplanes-fuel-assistance/>
7. Beginners Guide to Aeronautics, Glen Research Centre, NASA <https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/wing-geometry/>
8. Beginners Guide to Aeronautics, Glen Research Centre, NASA <https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/downwash-effects-on-lift/>
9. Here is why wings don't fall of airplanes, Seeker by the Verge, a YOU TUBE Channel https://www.youtube.com/watch?v=jMsoKy_MV6w
10. Darrell Mann, Matrix 2010, Re-updating the contradiction matrix, ID, IFR Press, UK 2009

11. Niel Nomark Sorensen, Numerical Analysis of Winglets on Wind Turbine Blades using CFD, Technical University of Denmark, January 2007

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TRIZ APPROACH TO INNOVATION PORTFOLIO ANALYSIS

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Abstract

Selection of the right object for innovation is the first stage of the New Product Development (NPD) Stage Gate Process. Traditional Project Portfolio Management (PPM) focuses on doing the right projects at the right time by selecting and managing projects as a portfolio of investments. Effective PPM increases business value by aligning projects with a company's strategy, making the best use of limited resources, and building synergies between projects. Unfortunately, organizations often do portfolio management poorly. As a result, they fail to deliver strategic results because they attack wrong projects or cannot say "no" to too many projects. Unfortunately, there are no specific methodological tools for effective PPM.

TRIZ provides a practical rigorous systematic approach to the company's Innovation Portfolio Analysis (IPA). Unlike traditional PPM, TRIZ approach includes developing new generation product concepts and identifying enabling technologies for new products and new distribution channels.

TRIZ tools that are effective for IPA include Main Parameters of Value Discovery, Evolutionary Trends Analysis, Technology Landscaping, Benchmarking, and Roadmapping.

The deliverables of the IPA process are a set of product portraits and enabling technologies for the short-term, mid-term and long-term business opportunities. From the business standpoint it allows a company commanding premium pricing, recognizing higher margins, and increasing profitability

Keywords: New Product Development, Project Portfolio Management, Innovation Portfolio Analysis, Evolutionary Trends, Main Parameters of Value, Value Landscaping, Technology Roadmapping, Innovation Agenda

1. Background

1.1 Prior studies

Many prior studies concentrated on how to manage single new product development projects rather than on how to manage the corporate or business unit level's portfolio of innovation projects [1]. However, the use of different tools and techniques for planning, analyzing, and evaluating a firm's portfolio of ongoing innovation projects may help to reduce many firms' managerial difficulties in innovation management. This paper discusses the particular characteristics and key goals of innovation portfolio management. In addition, it provides specific TRIZ-based tools for managing innovation portfolios.

Innovation Portfolio Management (IPM) is increasingly regarded as an important driver of a firm's innovation performance. While the new product development process refers to "managing innovation projects right", innovation portfolio management addresses the issue of "managing the right innovation projects". These portfolio-level activities may be complementary to the well-known New Product Development (NPD) process, and this complementary nature suggests that innovation portfolio management may be an understudied driver of innovation success [2].

IPM addresses the resource allocation across a firm's portfolio of new product development projects consistent with corporate strategy. There are four categories of company's perspectives: optimization perspective, strategic perspective, decision-making perspective, and organizational perspective [3]. These different approaches to IPM have been largely disconnected so far, but they can complement one another to provide new theoretical insights into innovation research. The different approaches are therefore integrated into an overarching perspective and a detailed approach to the Innovation Portfolio Agenda is proposed.

1.2 Sources of company revenue growth

There are five major strategies for a company revenue growth [4] (see Table 1).

Table 1. Strategies for a company revenue growth

Source of Growth	Description	Comment
Base Retention	Keep existing customers from switching to competitors	<ul style="list-style-type: none"> To grow, you have to first not lose customers Loss of existing customers (churn) is a common byproduct of acquisitions
Share Gain	Induce customers to switch from competitors	<ul style="list-style-type: none"> The hardest way to grow as competitors will defend valuable customers Acquiring competitors is one way to gain share
Market Positioning	Play where growth is expected to take place	<ul style="list-style-type: none"> Growth through innovation - capture new customers due to the better features of your product Easiest way to grow → potentially uncontested
Adjacencies	Apply existing capabilities and technology to related market opportunities	<ul style="list-style-type: none"> New market segments or new services to existing segments Reconfiguration of existing technologies and competencies
New Line of Business	Create new business	<ul style="list-style-type: none"> Transformational innovation – addressing newly discovered MPVs

2. Innovation Portfolio Analysis and Innovation Agenda

2.1 Innovation Portfolio Analysis – Goals, Activities, and Deliverables

The main goals of Innovation Portfolio Analysis (IPA) are as follows [5]:

- Select current products or product categories for further development
- Develop new product concepts
- Identify enabling technologies for new products and new distribution channels

The Ultimate Goal is to generate a business-wide Innovation Agenda for a company. The Innovation Agenda is a coordinated multi-year plan for innovation initiatives across a company's business that is directly linked to its business growth objectives.

The main activities of the IPA process are as follows:

- Client's assets audit (material, human, intellectual, etc.)
- Identification of latent market needs (Main Parameters of Value)
- Markets potential assessment

The deliverable of the IPA process is a set of product portraits and enabling technologies for the short- term, mid-term and long-term business opportunities. It allows a company to:

- Command premium pricing
- Recognize higher margins
- Increase profitability

2.2 GEN TRIZ Approach to Innovation Portfolio Analysis – Process

The IPA process is shown on Fig. 1.

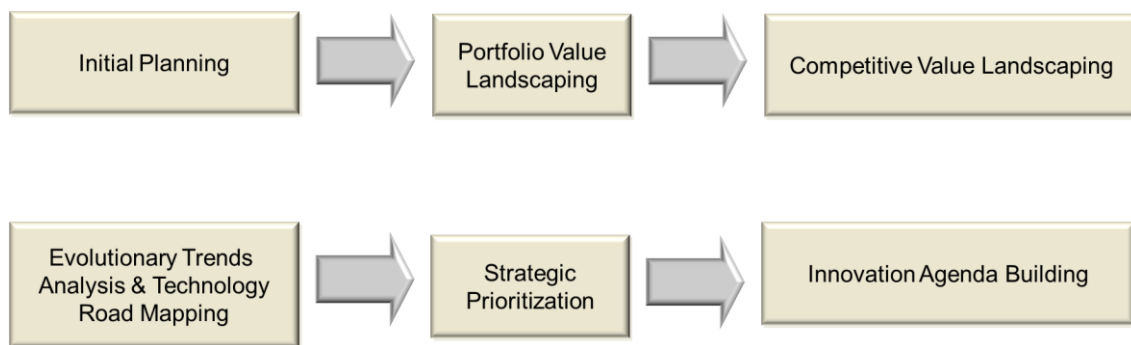


Figure 3. The IPA process

2.2.1 Initial Planning

The process of Initial Planning includes Markets Segments Definition, Project Scaling, and Main Parameters of Value (MPV) Identification [6, 7, 9]. We first define the market segments within which our products/services are distributed. Next, we scale the project, i.e., we determine the number of company's business units and customer categories that should be involved, as well as resources, timetable, and the degree of granularity for the analysis.

The most important part of Initial Planning is MPV Identification. MPV is an attribute or feature of the product that is currently unsatisfied on the market and is important for a customer's purchasing decision. MPVs may be derived from existing market surveys (Voice of the Customer) or through the TRIZ-based MPV Discovery process (Voice of the Product).

The outcome of the Initial Planning are as follows:

- Major Product Categories
- Set of Main Parameters of Value
- Work Plan

2.2.2 Portfolio Value Landscaping

The goals of Portfolio Value Landscaping are as follows:

- Characterization and prioritization of innovation opportunities based on a room for improvement (in terms of MPVs) and Gross Profit Potential (market size and gross profit potential)
- Form a basis for an initial filtering of innovation opportunities

The process of Portfolio Value Landscaping includes Product Categories Selection, MPV Identification, MPV Performance and Price Determination, and Product Landscaping.

In the **Product Categories Selection**, we cluster very different products (specs, markets, cost, etc.) into a Product Categories (families) Inventory, which in subsequent steps will be compared using the same scale.

During **MPV Identification**, we identify the MPVs of each product category through Voice of the Customer and Voice of the Product procedures.

During **MPV Performance and Cost Determination**, we collect the data that in the next step (Product Landscaping) will allow us to compare widely different products. We compare very different products in terms of three parameters that they have in common:

- Performance in terms of main functions. Every product in order to address some MPV performs functions. The first comparison parameter is how well it performs them. In order to evaluate this performance, we determine the market requirements for those MPVs. We also determine how well the MPV actually performs with regard to those requirements. In addition, we determine how important each MPV is relative to the other MPVs.
- Relative Price - is the product more or less expensive than the competing product; this ratio (not the \$) is our second comparison parameter. Relative price is the ratio between the price of a company's product and mean price of competitive products.
- Gross Profit Potential - how much money can a product potentially derive from its market segment; GPP is our third parameter. To determine Gross Profit Potential, we collect various market data for each product: Market Size, Market Growth or Decline Rate, Gross Profit Margin, Market Share, etc.

The outcome of this stage is the Portfolio Value Landscape with an inventory of the major product categories, their MPVs, performance, and cost, as well as Gross Profit Potential.

An example of Portfolio Value Landscaping is shown on Fig 2.

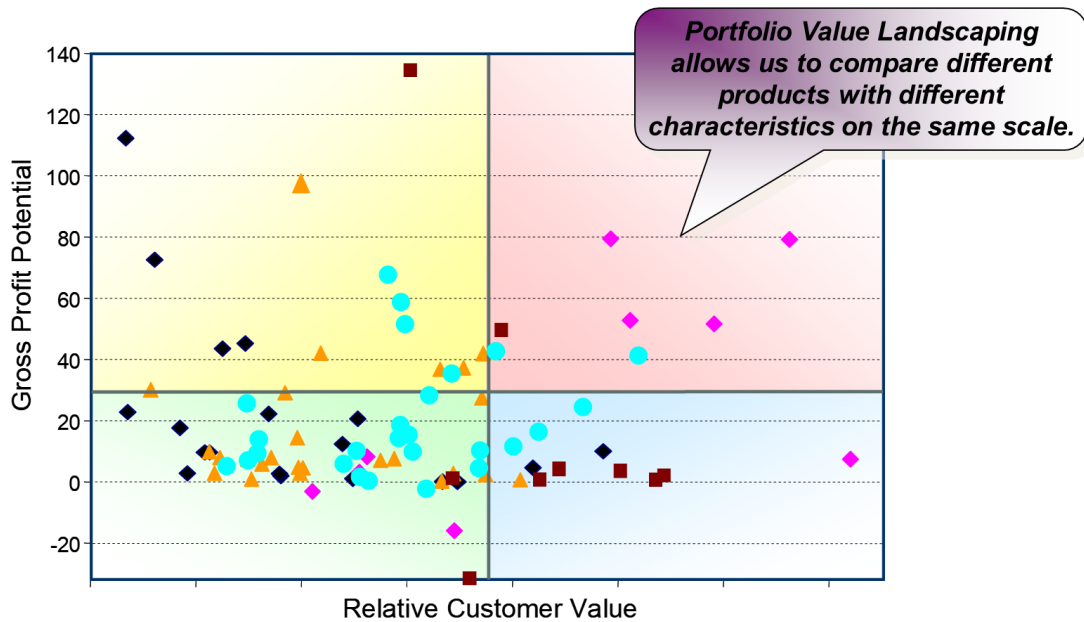


Figure 4. Portfolio Value Landscaping

Portfolio Value Landscaping allows us to compare different products with different characteristics on the same scale.

The last stage of Portfolio Value Landscaping is **Product Landscaping**. It consists of the following activities:

- **MPV Performance vs. Price Landscape.** It shows how products in the portfolio perform relative to market requirements; and how products are priced relative to competitors. MPV Performance is the single measure of the extent to which a product achieves customer requirements. The gap between actual performance and customer requirements is a measure of scope for improving the performance of a product. MPV Performance (P) is the average performance relative to each MPV, weighted by the importance of each MPV; a perfect score is 1.0. The formula for MPV Performance is:

$$P = \frac{1}{10} \sum_{i=1}^N \alpha_i p_i; \quad \sum \alpha_i = 1; \quad p_i \in \langle 1..10 \rangle, \quad N = \text{number of criteria}$$

p_i = performance relative to Major Parameter of Value i

α_i = importance of Major Parameter of Value i

Relative Price is the ratio of company's pricing to average pricing by competitors. Both of these elements are used as foundation to derive various perspectives on the product portfolio.

- **Gross Profit Potential vs. Customer Value Landscape.** It shows the value of products in the portfolio delivered to customers and the aggregate profit potential from each product category. Gross Profit Potential (GPP) is a total profit pool available to participants in the market. It is the theoretical maximum profit to be gained for a player with 100% market share. GPP is the projected market size (current market size adjusted for three years of compound growth) multiplied by the projected gross margin. Customer Value is the MPV Performance of a company's product divided by relative price.

A sample of a Gross Profit Potential vs. Customer Value Landscape is shown on Fig 3.

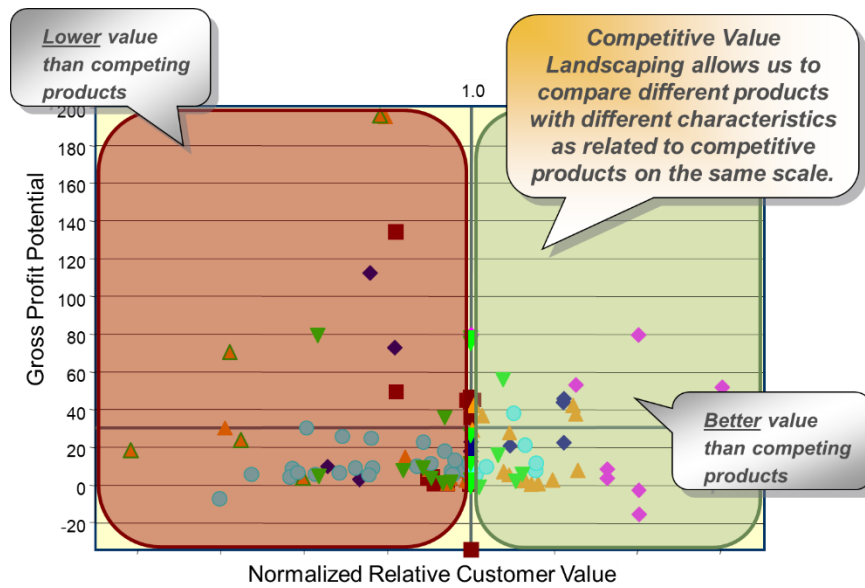


Figure 5. Gross Profit Potential vs. Customer Value Landscape

Products in the northeast quadrant of Figure 3 are delivering significant value in attractive markets and should barring other barriers to success, enjoy a strong market share and corresponding profits.

Products in the northwest quadrant of Figure 3 have high profit potential but are (or may become) vulnerable to competitive products with superior value. These are the high-priority candidates for performance improvement.

Products in the southwest quadrant of Figure 3 may have fundamentally low profit potential and should be given low priority. However, in some cases it makes sense to evaluate their potential for improving their profit margins and/or expanding market demand.

And finally, products in the southeast quadrant of Figure 3 are delivering high value to unattractive markets. It is possible that the same competencies that created this high value could be applied to more attractive adjacent markets.

- **Market Potential vs. Profit Margin Landscape.** Products with low gross margins in small markets can be safely considered to have low Gross Profit Potential. However, some products with a low calculated Gross Profit Potential are in markets of significant size. These products may have gross margin issues that can be addressed through pricing, cost-reducing / price-enhancing innovations, changes in raw material pricing, etc. They remain under consideration for the Innovation Agenda. Similarly, for products with high gross margins and a small market size, which may benefit from market-expanding innovation
- **Opportunity Set formulation.** The products in the northwest quadrant of Figure 4 are the primary targets for product innovation; they're the Opportunity Set for product innovation.

2.2.3 Competitive Value Landscaping

The goals of Portfolio Value Landscaping are as follows:

- Characterization and prioritization of innovation opportunities based on the intensity of the competitive environment
- Forms a basis for an additional filtering and prioritization of innovation opportunities

The outcome of this stage is the Competitive Value Landscape with an inventory of main product categories and their key competitors, their performance in terms of MPVs relative to that of their key competitors, and their cost competitive positioning.

An example of Competitive Value Landscaping is shown on Fig 4.

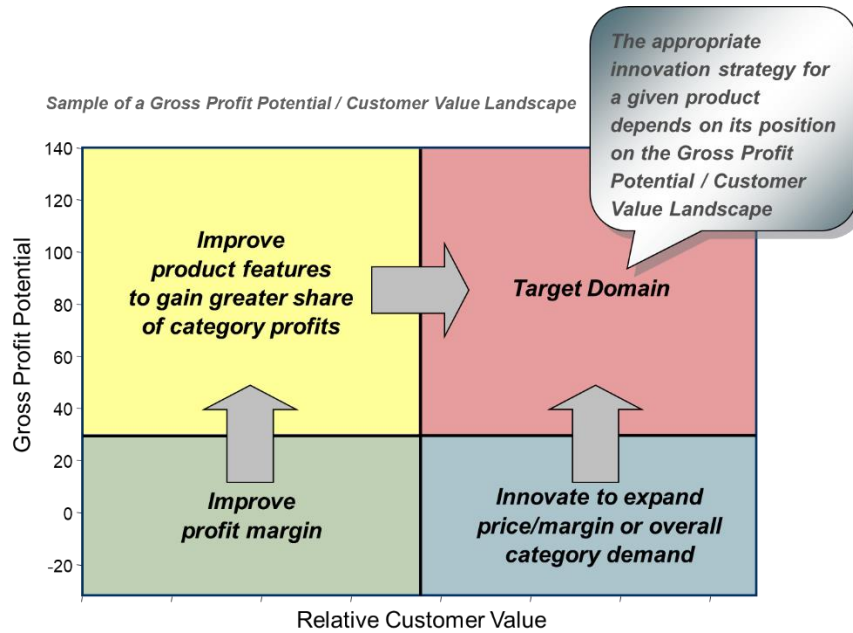


Figure 6. Competitive Value Landscaping

Competitive Value Landscaping allows us to compare different products with different characteristics as related to competitive products on the same scale.

Portfolio and Competitive Landscapes are used to objectively identify the Opportunity Set: products that are the best candidates for innovation activities to achieve company’s strategic business goals.

2.2.4 Evolutionary Trends Analysis and Technology Roadmapping

The goals of this stage of analysis are as follows:

- Determine the technical maturity of the Opportunity Set products and their development potential
- Visualize the direction of improvement of Opportunity Set product categories by applying general trends of technology evolution
- Validate and clarify their MPVs and identify their latent (non-obvious) MPVs

The main tool for this stage is the set of objective Trends of Engineering System Evolution developed by G. Altshuller and his followers [8].

The outcomes of this stage are short-, mid-, and long-term innovation initiatives focused to improve the MPV performance of the Opportunity Set products.

2.2.5 Strategic Prioritization

Strategic Prioritization serves as a second filter of prioritization of the Opportunity Set based on business strategy sectors

The outcomes of this stage are Opportunity Set innovation initiatives ranked according to Product Competition Intensity, Long-Term Market Attractiveness, Synergy of Technical Challenges, and Strategic Importance of product contribution.

Product Competition Intensity is a degree to which competitive products rival the company's ones with regard to the customer's selection criteria (MPVs).

Long-Term Market Attractiveness is a measure of the profit pool and the relative ease with which a company can tap into a market.

2.2.6 Building Innovation Agenda

The goal of this stage of analysis is to match the Opportunity Set innovation initiatives with the company's strategy, growth objectives, and core competencies.

The outcome of this stage is an Innovation Agenda of high-priority innovation initiatives sequenced in accordance with the company's growth objectives and mapped into innovation project types.

3. Case Study

3.1 Background

Our client was the world's biggest producer of aluminum products. They manufactured hundreds of different products in several product categories: rolled Al, Al wheels, Al vehicle frames, Al consumer products (foils, etc.).

The company made a decision to focus on the most promising current product categories and diversify its business toward new lucrative products. GEN TRIZ was invited to provide an innovation project portfolio management program. GEN TRIZ executed this program in 2010-2011.

3.2 GEN TRIZ process

GEN TRIZ applied its TRIZ-based Innovative Portfolio Analysis process that included Portfolio Audit and Value Landscaping, Evolutionary Trends Analysis, Technology Roadmapping, MPV Discovery, Strategic prioritization, and Innovation Agenda building.

3.3 Business results

It was recommended (and implemented) to sell out one of the company's product categories / business units – Al consumer products.

The new product category was developed and introduced - Al computer frames (see Fig 5).

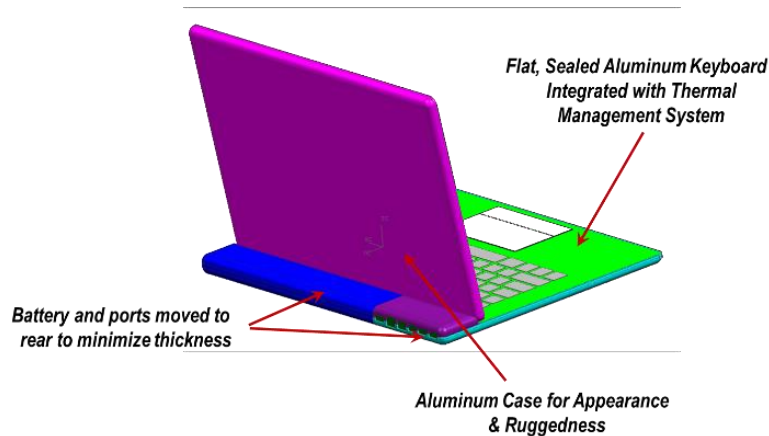


Figure 7. AI computer frames

Value proposition for the company:

The proposed new product provides thin, high-performance laptops by removing battery from base and using flat keyboard with integrated thermal management system. Laptop attractiveness improved through use of aluminum case and assembly friendliness increased through part consolidation.

Differentiation factors / technical advantages of the proposed new product:

- Thinnest laptop available
- Flat keyboard technology (optical or pressure sensors)
- Sealed keyboard
- Thermal conductivity of aluminum
- Aluminum surface finishing technology

Key Success Factors:

- Effective consolidation of keyboard and thermal management components
- Cool (attractive) surface finish

4. Conclusions

TRIZ provides a practical systematic approach to company's Innovation Portfolio Analysis (IPA). Unlike traditional IPA, TRIZ approach is practical results oriented. It includes developing new generation product concepts and identifying enabling technologies for new products.

The deliverables of the TRIZ-based IPA process are a set of product portraits and enabling technologies for the short-term, mid-term and long-term business opportunities. From the business standpoint it allows a company to command premium pricing, recognizing higher margins, and increasing profitability.

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References

1. Coulon M., Ernst H., Lichtenthaler U., and Vollmoeller J., An overview of tools for managing the corporate innovation portfolio. *International Journal of Technology Intelligence and Planning*, Vol. 5, No. 2., March 30, 2009, pp. 221-239. <https://doi.org/10.1504/IJTIP.2009.024191>
2. Ernst H. and Lichtenthaler U., Innovation portfolio management: an understudied driver of innovation success? *International Journal of Technology Intelligence and Planning*, Vol. 5, No. 2. March 30, 2009, pp. 111-117. <https://doi.org/10.1504/IJTIP.2009.024173>
3. Meifort A., Innovation Portfolio Management: a Synthesis and Research Agenda. *Creativity and Innovation Management*, Volume 25, Issue 2. March 9, 2015, pp. 251-269. <https://doi.org/10.1111/caim.12109>
4. Treacy M., *Double Digits Growth: How Great Companies Achieve It - No Matter What.*, Penguin Books, 2005. ISBN 10: 0144000865
5. Verbitsky M, Casey P. *Quantitative Diagnostics of Product Portfolio and Creation of Innovation Agenda*. 2006.
6. Treacy M., Innovation as a Last Resort, *Harvard Business Review* (July/August 2004)
7. Treacy M., Reinventing Innovation. Annual PDMA International Meeting, Innovation in Global Product Development: Driving Sustainable Growth and Productivity across the Value Chain (October 22 – 26, 2005)
8. Altshuller G., *The Innovation Algorithm: TRIZ, Systematic Innovation and Technical Creativity*”, 1999. Technical Innovation Center,
9. Litvin S., MPV: from Business Challenges to Technical Problems. 2nd International Conference on Systematic Innovation, Shanghai, China, 2011

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SPACE-TIME-PARAMETER OPERATOR FOR ADVANCED FUNCTION ANALYSIS

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Abstract

This paper proposes an extension to the Advanced Function Approach developed by Simon Litvin *et al.* An extension is the Space-Time-Parameter (STP) operator applied to the Space-Time-Parameter Function Interface (STPFI), which considers where, when, and at what parameter values a function is performed. The STP operator suggests mental shrinking and expansion of the STPFI in space, in time and along function parameters to see if any of these mental modifications yield a benefit for some main parameter of value (MPV) of the technical system under consideration. As a result of applying this operator, we can identify exact time slot, space zone or/and a specific parameter in which the function is insufficient or excessive. This knowledge can help the TRIZ practitioner identify innovation opportunities that might have been overlooked otherwise. Three case studies are included to illustrate the proposed approach.

Keywords: space-time-parameter function interface, function analysis, TRIZ

1. Introduction

The scope of the present paper includes the application of TRIZ in any technological innovation project, through a general TRIZ roadmap or a specific TRIZ roadmap used in GEN-TRIZ methodology [1]. The typical goal of such project is either to develop conceptual solutions for an innovative Engineering System (ES), or to generate ideas (i.e. portraits, not solutions) of the innovative ES. In the analytical part of the roadmap, the TRIZ practitioner performs Function Analysis of the initial ES and its supersystem (in case of sustainable innovation) or Function Analysis of the benchmarked system and its supersystem (in case of radical innovation).

It should be noted that in a New Product Development (NPD) project, Functional Analysis is the most important source of the Main Parameters of Value (MPV) [2] to be implemented in the new product.

However, some important functional weaknesses, and thus potential MPVs, can be missed in "classical" Function Analysis since this analysis does not consider the space where functions are performed and their timing.

Therefore, the Advanced Function Approach (AFA), has been suggested [3] to address this flaw. As compared to regular Function Analysis, AFA suggests a more precise analysis by:

- Indicating the time interval during which a useful function is performed and dividing it into smaller intervals at which the performance of the function is different.

- Indicating the spatial location where a useful function is performed and dividing it in smaller zones where the performance of the function is different.

An illustrative example of the AFA is the fragment of the function model of a toothbrush presented in Table 1 below. This example shows that the main useful function (MUF) of the toothbrush is performed differently during different time intervals and in different spatial locations, which allows for determining functional flaws more precisely, for example:

- Toothbrush insufficiently removes plaque on the palatal side surface of teeth during t30.
- Toothbrush insufficiently removes plaque on the side surface of teeth during t40.
- While the harmful function “teeth hold plaque” under gum during t0 is fulfilled, there is no useful function “toothbrush removes plaque under gum” at all.

Table 1: Illustrative example of the AFA applied to a toothbrush [3]

Time	Function			Type/rank and level of performance	Location	Comments
	Function Carrier	Action	Object of Function			
t0	Teeth	hold	Plaque	Harmful	Whole surface of teeth: external, chewing, palatal, between teeth, under gum.	
t10	Toothbrush	removes	Plaque	Basic, normal	External side of teeth	
t20	Toothbrush	removes	Plaque	Basic, normal	Chewing side of teeth	
t30	Toothbrush	removes	Plaque	Basic, insufficient	Palatal side of teeth	
t40	Toothbrush	removes	Plaque	Basic, insufficient	Side surface of teeth (between teeth)	
t10-t40	Toothbrush	damages	Teeth	Harmful	Whole surface of teeth	
t10-t40	Toothbrush	damages	Gums	Harmful	Near teeth	Different sides of gums could be considered as well: external, between teeth, etc.
...	

Basically, AFA allows to identify functional flaws in specific space zones and/or time intervals where:

- A useful function is underperformed or performed excessively,
- A useful function is absent (this can be treated as a function with zero performance), or
- There is a harmful function.

However, AFA [3] does not specify the way how these flaws can be reliably detected, and the goal of this work is to partially fill this gap. The focus of the paper is on useful functions (first two bullets on the list above).

2. Space-Time-Parameter Function Interface

Noteworthy when the authors mention for instance “side surface of teeth”, it is a simplification: according to the basic rules of Function Analysis, the real location of the “toothbrush removes plaque” function is the interface between the toothbrush (actually, its bristles) and the plaque on the side surface of the teeth. This interface evolves as the plaque is eroded by the bristles.

In the most general case, at any given time, the spatial intersection between a function carrier and a function recipient is the location (point, curve, surface or volume) where a function is performed through the interaction of those two components that touch each other (i.e. have an intersection in space at a given time): this is the function interface (see Fig.1).

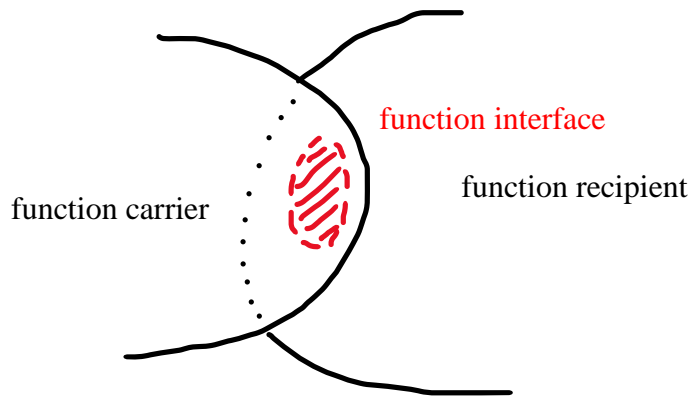


Figure 1: Schematic drawing of the function interface (in red shaded area) at the spatial intersection of a function carrier and a function recipient

The shape of the function interface evolves over time. Along a positively oriented time axis, it usually appears and disappears at least once. Let us consider the usual case of a single, intrinsic parameter P characterizing the performance of the function. A new TRIZ object is proposed: the combination of all functional interfaces at different moments of time and the related combination of all numerical values of functional parameters at these interfaces is denoted as Space-Time-Parameter Function Interface (acronym: STPFI; see Fig. 2 for a schematic representation). At each point in time, the numerical values of a function parameter at the functional interface can be either a global, unique value or a set of local values. Thus, STPFI is an object of geometric nature, and if N is the number of function parameters, then the dimension of the STPFI is $4 + N$.

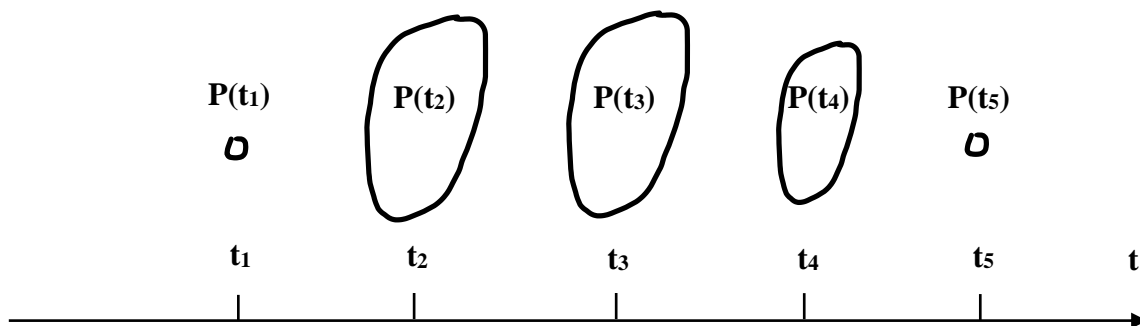


Figure 2: Schematic representation of the Space-Time-Parameter Function Interface (STPFI) of a function with performance parameter P that depends on time and possibly space (only some discrete time “shots” are shown)

The STPFI is worth being examined in detail, because its parts (space, time or parameters) could be characterized by:

- Insufficient or, on the contrary, excessive functional performance as measured by one or more intrinsic function parameters.
- Redundant or, on the contrary, missing functions in space and/or time.

These considerations may lead us to the idea that the performance of a function can be defined and measured not only with respect to function parameters that are intrinsic to the recipient of the function, but also with respect to universal parameters such as space and time. Therefore, it is proposed to modify the table template of the AFA (see for instance Table 1) by:

- Separating the column “type/rank and level of performance” into “type” and “level of performance”
- Separating further the column “level of performance” into 3 sub-columns “intrinsic parameter”, “space” and “time”.

3. Relativity of the function performance

While the harmful type of a function is usually unambiguous, a useful function’s performance might be equivocal, because of its relativity: it depends on the project’s goals and/or requirements which are often arbitrary defined. As a matter of fact, project’s goals and requirements often suffer from the psychological inertia of the TRIZ practitioner, team, not forgetting the customer, if any.

Although there is an objective method for determining excessive or insufficient performance of a function [4], this method has only been used in conventional functional analysis and has never been used in AFA, not speaking about its application to the SPTFI described above.

However, even if this method [4] was used in AFA instead of functional analysis, it would still be possible to miss some functional flaws, and thus some innovative opportunities.

Therefore, there is a clear need for a method that will help you not miss some functional flaws.

4. Mental modification of the SPTFI

As a general tool, we propose the mental modification of the SPTFI as follows:

1. Compress the STPFI in time and check whether any advantage appears (relative to one or more already known MPVs or hidden MPVs).
2. Expand the STPFI in time and check whether any advantage appears.
3. Compress the STPFI in space and check whether any advantage appears. This mental spatial compression of the STPFI can be performed in any direction of space.
4. Expand the STPFI in space and check whether any advantage appears.
5. Decrease one intrinsic parameter of the function performance other than space and time (note that from a geometrical point of view, this is a compression of the STPFI along a parameter) and investigate what happens to the STPFI and the object of the function. Resolve any conflicts that could potentially arise during this operation and check whether any advantage appears.
6. Increase one intrinsic parameter of the function performance other than space and time and investigate what happens to the STPFI and the object of the function. Resolve any conflicts that could potentially arise during this operation and check whether any advantage appears.
7. Perform the last two operations for all other intrinsic parameters of the function, if any.

All these mental operations can be performed either for some specific STPFI time slots and/or for some specific STPFI locations, or for all STPFI time slots and locations.

As can be seen from the above list, all the suggested mental operations are performed independently on the carrier of the function (as if the carrier did not exist) but dependently on the recipient of the function (which usually cannot be changed).

The proposed mental operations on the STPFI are of the same nature as the Size-Time-Cost (STC) operator that is widely used in TRIZ to reduce psychological inertia [5]. Therefore, the seven-step procedure described above could be called the Space-Time-Parameter operator or STP operator.

When the STP operator reveals any advantages for some MPVs (already known or hidden), it simultaneously identifies one of the following functional disadvantages that must be addressed to achieve those advantages:

- Excessive or insufficient performance of the function in time (to be detailed), or
- Excessive or insufficient performance of the function in space (to be detailed), or
- Excessive or insufficient performance of the function against some of its intrinsic parameter(s) (to be detailed).

The STP operator complements the AFA by reducing the potential omission of some functional disadvantages and related opportunities for innovation.

This new approach is illustrated by the case studies described below.

5. Retrospective and prospective case study: a car sun visor

A usual automotive sun visor is useful during sunrises and sunsets or more generally when the sun is close to the horizon, and it allows a safe driving under these specific conditions. However, it is not very convenient for the driver who has a limited view of the front environment of the car. Let us consider an innovation project focused on the radical innovation of a conventional car sun visor, with the following MPV: vision quality. In modern TRIZ terms, the usual opaque car sun visor fulfils the following function: sun visor stops sunlight. It helps eliminating the potential, harmful function: sunlight glares driver's eyes. Let us now consider the STPFI of the former, useful function: in general, in space-time, it matches the external surface of the car sun visor. Let us apply the STP operator before, during and after a conventional sun visor is deployed by the driver.

1. The STPFI is mentally eliminated at all time intervals when the driver's eyes are not glared by sunlight for a reason or another (a momentaneous cloud or vehicle which intersects sunlight, or the end of glaring conditions, for instance). As a result, the performance of the MPV "vision quality" is improved.
2. To the current STPFI are mentally added all time intervals when the driver's eyes are glared by the sunlight and the sun visor is not yet deployed or not deployed completely. Therefore, the MPV performance is improved.
3. The STPFI is mentally shrunk to a much smaller surface, which geometrically intersects the path of the sunrays towards the driver's eyes' pupils (see Fig. 3). As the relative positions of the driver, of the car and of the sun evolve over time, the shrunk STPFI moves. Furthermore, as a pupil's diameter is variable against lighting conditions, the shrunk STFI shrinks and grows accordingly, although slightly. Therefore, the MPV performance is improved.

4. Expanding the STPFI in any direction either does not modify or deteriorates the MPV performance.
5. The performance of the sun visor's useful function can be simply measured by the sun visor's following parameter: absorbance (defined as light is stopped divided by incident light). In the current situation, the absorbance is 1. The absorbance is mentally decreased to a value $a(t)$ which varies over time between 0 and 1 and adapts to a minimum depending on the lighting conditions. Consequently, the MPV performance is improved.
6. Increasing the absorbance is not possible, for it is already 1.
7. No other parameter evaluating the useful function performance has been found.

Consequently, several function disadvantages of the conventional sun visor are revealed, along with corresponding conceptual directions or ideas (not solutions, obviously).

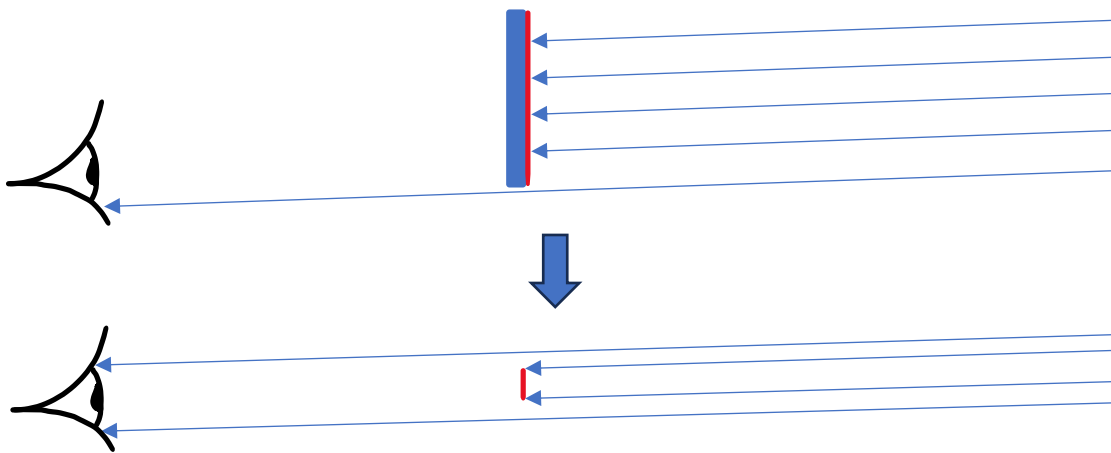


Figure 3: The initial STPFI (above, in red) which matches the external surface of the car sun visor is mentally dramatically shrunk into a new STPFI of minimal area (below, in red) that relates to the driver's eyes' pupils (on the left) which possess variable diameters

A suboptimized concretization of the conceptual direction elaborated at step 5 is a translucent shield that which has the same properties as sunglasses [6]. Also, Bosch materialized the conceptual direction elaborated at step 3 by presenting a prototype of smart visor at CES 2020 [7] (see Fig. 4). It is mainly based on a "AI-enhanced LCD screen that links with a driver-monitoring camera". Noteworthy, it can be concluded from the broad shadow on the driver's face of Fig. 4 that this prototype involves a STPFI which is far from the STPFI of minimal area of Fig. 3. Also, the grid of the hexagonal LCD cells and the visor frame constitute a part of the STPFI which is clearly superfluous.



Figure 4: Bosch smart visor prototype [7]

To innovate more radically, it is possible to start from the STPFI of minimal area shown in Fig. 3, without any component that carries it for the moment. Constraining ourselves to avoid the use of any car sun visor, one may then project this STFI along the sunrays on a component of the supersystem: the windshield. It immediately appears the new idea of a windshield displaying moving pairs of small varying diameter black spots, each pair being linked to the driver and possible passengers. It is believed that this idea can be concretized with the identification and adaptation of some well-identified technologies from the current Technosphere. Interestingly this idea can be transferred to analogous situations like civil or military aircraft windshields, motorbike or F1 helmets, sunglasses, etc.

6. Retrospective case study: car blade wipers

Nowadays, when driving a car under a strong continuous rain or under a short-time shower, the driver's vision quality becomes mediocre, even if the water on the windshield is evacuated by the blade wipers at full sweeping speed (typical frequency: 1 Hz to 1,5 Hz) (see Fig. 11). Let us then consider an innovation project whose goal is to generate radically innovative solutions allowing a clear vision of the driver under a strong shower (the aimed MPV).

A usual Function Analysis easily determines among many functions at stake in a usual driving situation under a strong shower:

- A harmful function: water deviates light (remark: here, we consider as a component water that has deposited onto the external surface of the windshield).
- A useful function: wiper displaces water.



Figure 5: Typical view of the driver of a car in a heavy rain when blade wipers are at full speed [8]

At a given time, the STPFI of the useful function is limited to a thin surface of contact between the advancing side of the wiper blades and water. On the other side, the harmful function manifests on a major part of the external windshield surface. Let us apply the STP operator.

1. The shrinking of the STPFI in time brings no improvement of the MPV performance.
2. The expansion of the STPFI in time brings no improvement of the MPV performance, if there is an automatic detection of rain.
3. The shrinking of the STPFI in space brings no improvement of the MPV performance.
4. The expansion of the STPFI in space is done by adding to it the full external surface of the windshield, and possibly all other glass windows of the car. This brings a dramatic improvement of the MPV (clear vision of the driver) performance.
5. The performance of the useful function can be measured by the sweeping frequency. Its increase might bring some improvement of the MPV performance, although probably less dramatically than with step 4.
6. The decrease in sweeping speed brings no MPV performance improvement.
7. No other parameter evaluating the useful function performance has been found.

Consequently, some function disadvantages of the conventional car blade wipers are revealed, along with corresponding conceptual directions.

The conceptual direction revealed in step 4, which corresponds to a huge insufficiency in space of the useful function, can be interpreted as the idea of an automotive windshield where the water is displaced (expelled) from it all over its external surface at any time. An immediate complementary idea is a windshield that does not interact at all with the rain drops, through a prevention system still to be invented. This last conceptual direction can be linked to a mental displacement of the STPFI at a distance and ahead from the windshield. Actually, the idea of a wiperless windshield is not new, and a valuable, technical article [9] reviews its different patented solutions, starting with the first patent, US 3171683 A, filed in 1963 (see Fig. 6 below). Several functioning principles have been developed in patents (travelling waves, air or liquid jets coupled with specific surface treatment, water vaporization modes, ...). In 2013 in the Sunday Times Mc Laren disclosed publicly its intention to introduce commercially on one of its car models a wiperless windshield based on “ultrasonic force fields”. It also spoke about a military source for the technology [9]. However, ten years later, no commercial Mc Laren model seems to be equipped with such a technology [10]. Finally, this retrospective case shows how

a mental modification of the STPFI of the useful function of an engineering system can lead to a radically new, general conceptual direction, which on turn can trigger much research work in different, more specific, conceptual directions. Also, interestingly, it shows that 60 years after the first engineering concept of wiperless windshield in the car industry, a wiperless windshield technology, whatever its functioning principle, is still stuck in its stage 1 of evolution along its S-curve. It means that some difficult technological problems are still preventing this S-curve jump. Obviously, TRIZ could be used to tackle these remaining challenges.

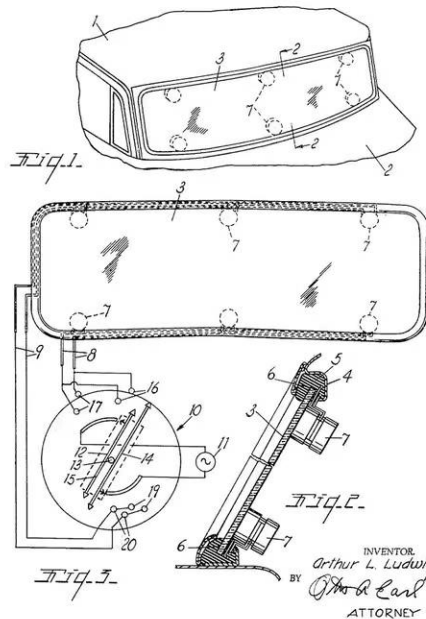


Figure 6: Wiperless windshield patent US 3171683 A, based on a high frequency oscillator which drives ultrasonic transducers, which on their turn generate stationary waves on the windshield, preventing raindrops to stick on it [9]

7. Retrospective and prospective case study: a tennis ball box overcap

Let us consider a usual tennis ball box (see Fig. 7) that always contains 4 tennis balls. At first opening, the plastic overcap (in blue, on the right of Fig. 7) is taken away, then the metal cap underneath is taken away and put in a recycling bin. Later the balls are put back in the box and the plastic overcap is put back on the box in its initial position (in non-modern TRIZ, usual words, “the overcap closes the box”). Then, depending on the relative positions of the box and the balls, the overcap can fulfill its most important function: overcap stops ball. The intrinsic parameter of the tennis ball that is maintained is its position along the box cylindrical axis.



Figure 7: Usual tennis ball box [10]

Let us imagine an innovation project aimed at developing an innovative overcap with reduced environmental impact (this will be our MPV in this project). Before applying the STP operator, let us observe the initial STPFI of the function “overcap stops ball”: it is close to a small disk, due to the elasticity of the ball and its fibrous external surface. In Fig.8 below, a cut of the ball box (in black), the plastic overcap (in blue) and the 4th tennis ball is shown (in yellow), as well as the STPFI (in red).

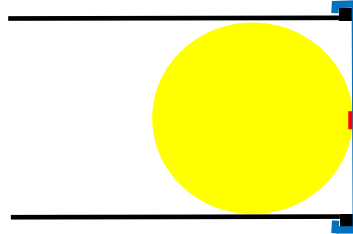


Figure 8: Schematic view of the box, the extremity tennis ball, the overcap and the STPFI (in red) of the function “overcap stops ball”

Now let us apply the STP operator:

1. The mental shrinking of the STPFI in time does not lead to any MPV performance improvement.
2. There is some free space for the balls along the box axis, therefore the 4th ball is not permanently in contact with the overcap. In this refined context, the mental expansion of the STPFI in time also implies a space deformation of the overcap towards the 4th ball, so that the useful function is always fulfilled. Consequently, more material is used and the MPV performance decreases. Noteworthy this implication is a must because the box itself is out of the scope of the project. If the box was within the project scope, it could be shortened, and the MPV performance could be enhanced, however, not in relationship with the overcap.
3. The STPFI is already a surface of small size. It is not obvious which kind of STPFI mental shrinking might lead to the enhancement of the MPV performance.
4. Let us mentally expand the STPFI, for instance like in Fig. 9 below: the STPFI compulsorily expands along the tennis ball. Consequently, the overcap should spouse the ball along this new STPFI. This obviously leads to an expansion of the overcap which decreases the MPV performance. As an alternative scenario, if the box was in the scope of the project, it might be possible to envisage a deformation of the 4th ball against the overcap to concretize another way to mentally expand the STPFI. The box should be shortened, and to support the pressure exerted by the balls onto the overcap, the latter should probably be stiffened, and therefore its thickness should be increased, leading to a decreasing of the MPV performance.
5. Seemingly the only parameter that measures the useful function performance is the 4th tennis ball position (more precisely, of its gravity center, if it is not deformed) along the box cylindrical axis. Now let us expand mentally the STPFI in this parameter's space, i.e. let us increase the position of the 4th ball (towards the right direction) to some extent. This results in an impossible situation where the tennis ball partly occupies the same space as the overcap (see Fig. 10 below). As the tennis ball is out of the scope of the innovation project, there seem to be only two possible solutions to this contradiction of spatial character, which concerns also the STPFI. Either the overcap is locally “deformed” by the tennis ball (see Fig. 11), which leads to a similar STPFI as in step 4 that is just displaced on the right, and as a result, the MPV performance decreases; or the

overcap is “cropped” by the tennis ball and becomes annular and the STPFI as well. The function “overcap stops ball” is still performed correctly, and the MPV performance increases. In this case, the revealed function disadvantage (excessive function performance) is immediately translated into a solution.

6. If we mentally shrink the STPFI in the parameter’s space, in other words if the position of the 4th ball decreases, it goes towards a situation analogous to that described in step 2.

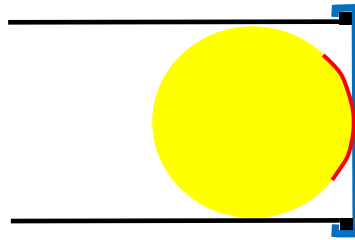


Figure 9: Schematic view of the box, the extremity tennis ball, the overcap and the mental expansion of the STPFI in space (in red)

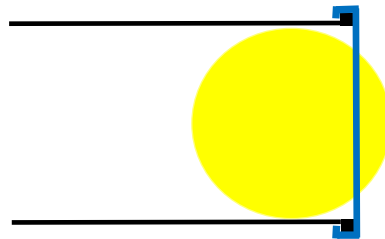


Figure 10: Schematic view of the box, the extremity tennis ball, the overcap and the STPFI, when one mentally increases the position of the ball, leading to a spatial conflict

Consequently, some function disadvantages of the current tennis box overcap are revealed, along with corresponding conceptual directions, of diverse potential interests. Interestingly, in the present, particular case, the second situation of step 6 exactly matches a concretized solution that the Wilson company developed and called the Eco Overcap [12] (see Fig. 7) which cuts the plastic use by 50%, and that was unveiled at the 2020 US Open [13]. This corresponds to a partial Trimming of the component “overcap”. Also, this solution is very simple and could have been developed decades ago: the sole psychological inertia carried out by the tennis ball box and its overcap is responsible for this long development pause.

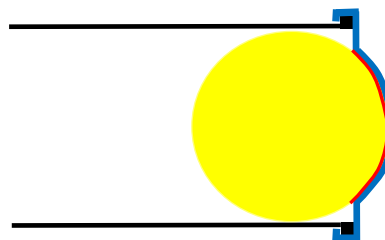


Figure 11: Schematic view of the situation depicted in Fig. 10 whose spatial contradiction is solved by the deformation of the overcap induced by the ball translation towards the right



Figure 12: Eco Overcap of tennis ball box developed by Wilson [11]

Based on that solution developed by Wilson, one may perform mental modifications further and mentally shrink the STPFI in space between the ball and the Eco Overcap (i.e. apply step 3 of the STP operator). As said before, its STPFI is annular and is rather linear. The shrinking of the STPFI into two small segments instead of an annular line is advantageous: the MPV performance increases. Thus, the function disadvantage “excessive function performance” is determined again. A concretization is shown on Fig. 13 below.

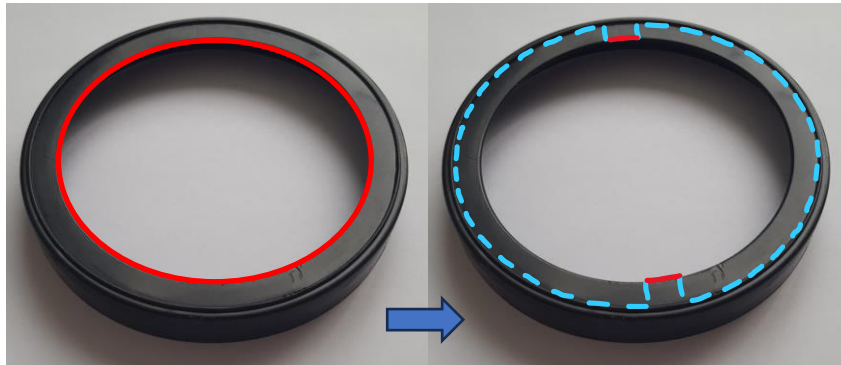


Figure 13: Shrinking of the initially annular STPFI of the Eco Overcap (left) into a smaller STPFI made of two segments (right), concretized by the overcap cutting along the blue dotted lines

However, because of a lack of stiffness of the strips, in some specific circumstances, the overcap may not stop the ball: the function is no more reliable. This draws a contradiction between the overcap weight and its function reliability which might be solved easily by satisfaction through the local reinforcement of the strips, possibly by a change of dimension: thus, the two strips become perpendicular to the global plane of the overcap (that of the blue dotted lines) and the STPFI is further reduced: it becomes almost punctual, at two points.

8. Conclusions

A new TRIZ tool, the Space-Time-Parameter operator, has been introduced to improve the Advanced Function Approach proposed in 2010 [3].

First, the Space-Time-Parameter Function Interface (STPFI) of a given useful function is defined as the set of the geometrical intersections between the function carrier and the function recipient in space and time, and the associated set of numerical values of the function performance parameter. Thus, the STPFI provides a very detailed representation of operating zone and time of each function, as well as their space- and time-dependent performance parameter values.

Second, the STP operator is introduced. This operator involves mental operations (like the STC operator [5]) of shrinking or expansion of the STPFI in space, in time and along function performance parameters, and evaluating the consequences of these operations for the function recipient.

Third, it is suggested to evaluate if these mental operations provide an advantage for some MPVs (already known or hidden) of the system of interest. If such an advantage is revealed, it allows to define corresponding function flaws that must be eliminated to achieve the advantage. These flaws could be excessive or insufficient function performance in certain space and/or in certain time slot, or insufficient or excessive performance of the function with respect to some of its intrinsic parameter.

Consequently, the STP operator allows the identification of innovation opportunities which might have been overlooked with the usual Function Analysis and even with the Advanced Function Approach.

Finally, as a perspective, this newly developed tool may open a new field of research in TRIZ. In particular, a robust set of rules for its utilization shall be developed, including the interplay of STPFI, function recipient and function carrier; expectedly those rules shall depend on the project goals (e.g. sustainable and/or radical innovation), the project scope (the components that might be modified, including the function recipient) and the extensive or intensive nature of the MPVs. In addition, its extension to harmful functions might be developed. Also, new steps proposing other mental operations on STPFI might be added; one such possible step could be the spatial translation of the STPFI and possibly its projection onto other components which seems to match a specific Trimming mode. Last, this tool may benefit from its “areas of intersection” with other TRIZ tools, like for instance the Trends of Engineering Systems Evolution, and the Su-Field Analysis / 76 Standard Solutions.

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References

1. GEN-TRIZ training materials (level 1 of MATRIZ Official).
2. Abramov O., Medvedev A., Tomashevskaya N. “Main Parameters of Value (MPV) Analysis: Where MPV Candidates Come From”. In: Borgianni, Y., Brad, S., Cavallucci, D., Livotov, P. (Eds.): Creative Solutions for a Sustainable Development. TFC 2021. IFIP Advances in Information and Communication Technology, vol 635, pp. 391-400. Springer, Cham, 2021.
3. Litvin S., Feygenson N., and Feygenson O. “Advanced Function Approach”. *Proceedings of the 10th ETRIA World TRIZ Future Conference 2010*, 3-5 November, Bergamo, Italy. pp. 79-85.
4. Abramov O. "Excesses in Engineering Systems: A Helpful Resource". In: Cavallucci, D., Brad, S., Livotov, P. (eds) Systematic Complex Problem Solving in the Age of Digitalization and Open Innovation. TFC 2020. IFIP Advances in Information and Communication Technology, vol 597, pp. 159-171. Springer, Cham, 2020.
5. Souchkov V. “Glossary of TRIZ and TRIZ-related Terms”. Version 1.2, MATRIZ, 2018. https://matriz.org/wp-content/uploads/2016/11/TRIZGlossaryVersion1_2.pdf. Last accessed: June 26, 2023.

6. <https://www.fruugo.be/car-sun-visor/p-146762510-309431517?language=en>. Last accessed: June 26, 2023.
7. <https://spectrum.ieee.org/boschs-smart-virtual-visor-tracks-sun>. Last accessed: June 26, 2023.
8. <https://taylorautoglass.com/windshield-wipers-just-smear-rain/>. Last accessed: June 27, 2023.
9. <https://newatlas.com/mclaren-ultrasonic-windshield-wiper-washer/30205/>. Last accessed: June 28, 2023.
10. <https://cars.mclaren.com/en/models>. Last accessed: June 28, 2023.
11. https://www.amazon.com/Babolat-Championship-Court-Tennis-Balls/dp/B08169K6M1/ref=sr_1_3?crid=9YDKPLEI1J52&keywords=tennis+balls+babolat&qid=1687703528&srefix=tennis+balls+babolat%2Caps%2C153&sr=8-3. Last accessed: June 26, 2023.
12. <https://www.wilson.com/en-us/product/championship-regular-duty-3-ball-can-t100300>. Last accessed: June 26, 2023.
13. <https://twitter.com/WilsonTennis/status/1346545449034002434>. Last accessed: June 26, 2023.

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LEVERAGING GENERATIVE AI AS A RESOURCE FOR INFORMATION RETRIEVAL IN TRIZ PROBLEM SOLVING AND IDEA GENERATION

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Abstract

In the process of problem-solving and generating new ideas using TRIZ tools, one essential tool for thinkers is the problem solver, referred to as a "resource."

In practice, resources can be classified as follows:

1. Individual resources: These encompass personal memories, background knowledge gained through education or work experience, specialized skills, ideas generated during brainstorming sessions, and other relevant insights.
2. Observational resources: These are derived from analyzing legacy systems with a focus on improvement. They include resources found in the environment, resources obtained through analyzing customer needs, resources available in systems that fulfill certain functions (supersystems), and TRIZ terminology that guides the analysis of resources in terms of matter, energy, time, space, and their derivatives.
3. Research-based resources: This category includes scientific foundations used to describe the problem, relevant patents, scientific papers, expert interviews, well-developed technological systems that can be utilized as part of the resource pool, technologies related to the key problems at hand, and models and methods used in the same or different industries. Function Oriented Search (FOS) can be employed, along with listening to customer questions or needs, to obtain these resources.

These resources are gathered based on the capabilities of resource seekers, and there is a designated timeframe for the collection process. Individuals generating new ideas can directly utilize these resources. However, if the resources, including individual resources, analytical resources, or search resources, cannot directly solve the problem, they can be further developed or modified to align with the parameters of the inventive problem, which often focuses on resolving conflicts.

When utilizing resources obtained through research, it may be necessary to consult subject matter experts, search for new patent information, and use search engines on the internet. This process can be challenging and time-consuming.

Today, there are advanced tools available that surpass traditional information searches, such as Generative AI (e.g., ChatGPT, Bing, Bard). Generative AI learns from data and produces results based on given commands, following the boundaries set as "prompts."

The use of Generative AI significantly reduces search time and expands search coverage. It can be applied to various research areas, including identifying the root causes of problems, studying the evolution of technological systems, examining past solutions, exploring data from different industries with FOS expertise, and instructing the AI to learn and respond to tools like the TESE 40 Principles and other TRIZ tools.

However, since Generative AI primarily relies on past data, the results are dependent on the instructions given (prompts), which may lead to discrepancies due to a lack of understanding of certain logic.

Therefore, it is recommended to verify the accuracy of the results and consider Generative AI as an aid in collecting informational resources rather than relying solely on it to find the final answer.

Keywords: *TRIZ tools, Problem-solving, Individual resources, Observational resources, Research-based resources, Inventive problem, Generative AI, Informational resources.*

Abbreviation:

TRIZ: Theory of Inventive Problem Solving

AI: Artificial Intelligence

GPT: Generative Pre-trained Transformer

FOS: Function Oriented Search

TESE: Technical and Engineering Systems Evolution

1. Introduction

Problem-solving and idea generation are essential processes in various fields, and thinkers rely on a range of tools to facilitate these endeavors. One crucial tool for thinkers is the problem solver, often referred to as a "resource." These resources play a vital role in helping individuals overcome challenges and generate innovative ideas. Understanding the different types of resources available and their significance is key to effectively harnessing their potential.

Informational Resources:

In practice, resources can be classified into three main categories. The first category is individual resources, which encompass personal memories, background knowledge acquired through education or work experience, specialized skills, ideas generated during brainstorming sessions, and other relevant insights. These resources are unique to each individual and serve as a foundation for problem-solving and idea generation.

The second category is observational resources, derived from analyzing legacy systems with a focus on improvement. Observational resources include various elements found in the environment, insights gained from analyzing customer needs, resources available in systems that fulfill specific functions (referred to as supersystems), and TRIZ terminology that guides the analysis of resources in terms of matter, energy, time, space, and their derivatives. Observational resources provide valuable insights into existing systems, allowing thinkers to identify areas for enhancement and innovation.

The third category of resources is research-based resources, which encompass a wide range of information sources. This category includes scientific foundations used to describe the problem,

relevant patents, scientific papers, expert interviews, well-developed technological systems that can be utilized as part of the resource pool, technologies related to the key problems at hand, and models and methods used in the same or different industries. Obtaining research-based resources often involves employing techniques like Function Oriented Search (FOS), listening to customer questions or needs, consulting subject matter experts, searching for new patent information, and utilizing internet search engines. These resources provide a broader perspective and facilitate cross-industry insights, enabling thinkers to explore diverse avenues for problem-solving.

Modification of Resources:

While individuals generating new ideas can directly utilize the resources mentioned above, there are instances where these resources, including individual resources, analytical resources, or search resources, may not directly solve the problem at hand. In such cases, it becomes necessary to modify or further develop these resources to align them with the parameters of the inventive problem, which often revolves around resolving conflicts. This process involves adapting and tailoring resources to better address the specific challenges being faced.

Statement of the Problem:

Despite the availability of various resources, there are challenges associated with their effective utilization. Resource gathering relies on the capabilities of the individuals' seeking solutions, and there is a designated timeframe within which resources must be collected. Additionally, the process of obtaining resources through research can be challenging and time-consuming, often requiring consultation with subject matter experts, searching for new patent information, and utilizing internet search engines. These traditional methods, while valuable, may limit the breadth and efficiency of resource collection.

To address these challenges, advanced tools such as Generative AI have emerged, surpassing traditional information searches. Generative AI, exemplified by platforms like ChatGPT, Bing, and Bard, learns from data and produces results based on given commands within defined boundaries referred to as "prompts." The use of Generative AI significantly reduces search time and expands search coverage, offering its application across various research areas. It can aid in identifying the root causes of problems, studying the evolution of technological systems, examining past solutions, exploring data from different industries using FOS expertise, and instructing the AI to learn and respond to specific problem-solving tools such as the TESE 40 Principles and other TRIZ tools.

However, it is important to recognize that Generative AI's reliance on past data makes the results contingent on the instructions given (prompts). Misunderstanding or incomplete instruction may lead to discrepancies in the outcomes, highlighting the need to verify the accuracy of the results generated by Generative AI. Consequently, while Generative AI offers significant advantages.

2. Approach

1. Introduction to Performing TRIZ Tools by Generative AI: In this paper, we present an approach to leverage generative AI for performing TRIZ (Theory of Inventive Problem Solving) tools. TRIZ offers a systematic framework for problem-solving and innovation, and by combining it with generative AI, we aim to enhance the efficiency and effectiveness of the problem-solving process. Generative AI models can be trained to understand TRIZ concepts

and apply them in generating creative solutions. This approach has the potential to accelerate innovation and provide novel insights in various domains.

2. **Definition of Prompt Designer or Prompt Engineering:** Prompt engineering refers to the process of designing prompts that guide generative AI models in applying TRIZ tools effectively. The prompt designer plays a crucial role in crafting prompts that elicit desired responses from the AI model. They possess a deep understanding of TRIZ principles and techniques, as well as domain knowledge, enabling them to create prompts that facilitate innovative solution generation.
3. **Definition of "Context" and "Instruct":**
 - **Context :** Context to prompt refers to the relevant information provided to the generative AI model in order to set the problem-solving context. It includes the problem statement, domain-specific constraints, objectives, and any other contextual information necessary for the AI model to understand the problem space. Providing appropriate context helps the model generate solutions that align with the problem domain.
 - **Instruct:** Prompt instruct involves providing specific instructions to guide the generative AI model's thinking process. These instructions can take various forms, such as guiding questions, constraints, or prompts that direct the model's attention to specific aspects of the problem. Clear and well-defined prompt instructions enable the AI model to focus its generation process and generate relevant solutions.
4. **List of Some Basic Prompt Engineering Techniques**

Table 1. Basic Prompt Engineering Techniques

Prompt Engineering Technique	Description
Zero Shot	Prompting the AI model to generate solutions without specific training examples.
Chain of Thought	Guiding the AI model to follow a sequence of logical steps or associations to generate solutions.
Tree of Through	Encouraging the AI model to explore multiple branches of thinking and generate diverse solutions.

5. The uses of Generative AI in this paper cover the following TRIZ tools:
 1. Beyond Function Analysis (System Oriented Synthesis; Petrov V.)
 2. Function Analysis
 - Component Analysis
 - Interaction Analysis
 3. Function Oriented Search (FOS)
 4. Cause Effect Chain Analysis
 5. TRIMMING and TRIMMING Rules
 6. Feature Transfer

7. 40 Principles
8. Scientific Effect Database
9. Extension FOS
 - Problem Search
 - Property Search
 - Parameter Search
 - Mechanism Search
 - Disadvantage Search
10. Trend of Engineering System Evolution

3. Example: Application of Generative AI and TRIZ Tools.

3.1 Beyond Function Analysis (System Oriented Synthesis; Petrov V.)

User Prompt:

Please explore the 5 solutions of technical system which able to perform "To capture and to move dust by airflow"

ChatGPT:

Table 2. Function Analysis with ChatGPT

Solution	Description
1. Air Filtration System	Utilizes high-efficiency filters to capture dust particles from the air and moves the filtered air.
2. Dust Collection System	Combines suction and airflow to collect dust from various sources and transports it to a collection point.
3. Electrostatic Precipitator	Attracts and collects dust particles from the airflow using an electrostatic charge.
4. Vacuum Cleaner System	Draws in dust particles through suction and transports them into a collection bag or container.
5. Pneumatic Conveying System	Transports dust particles through pipes or ducts using compressed air or an air stream.

3.2 Function Analysis: Component Analysis and Interaction Analysis

User Prompt:

Please write the function analysis ; ("Tool" action to "Object") for Wood pelleting Machine; in tabulated format including of "Tool" , "object" , "Type of energies" , "The action between tool and object" and "Function of tool and object".

ChatGPT:

Table 3. Component Analysis and Interaction Analysis with ChatGPT

Tool	Object	Type of Energies	Action between Tool and Object	Function of Tool and Object
Cutting Blades	Wood Logs	Mechanical Energy	Blades cut the wood logs into smaller pieces or chips.	The cutting blades chop the wood logs into smaller sizes, facilitating the pelletization process.
Hammer Mill	Wood Chips	Impact and Mechanical Energy	Hammer mill pulverizes the wood chips into finer particles.	The hammer mill crushes the wood chips, reducing their size for further processing into wood pellets.
Pellet Mill	Wood Particles	Mechanical and Thermal Energy	Pellet mill compresses the wood particles and applies heat to form wood pellets.	The pellet mill compacts the wood particles, applying heat to bind them together, producing wood pellets.

3.3 FOS

User Prompt:

Could you please find the 4 industries which perform similar main-useful functions of pellet mills? Consist of Main Function, Technology leading in tabulated format.

ChatGPT:

Table 4 Component Analysis and Interaction Analysis with ChatGPT

Industry	Main Function	Leading Technology
Biomass Power Generation	Converts biomass materials into pellets for energy production.	Biomass pellet mills utilizing high-pressure and high-temperature processes.
Animal Feed Manufacturing	Processes raw materials into pellets for animal nutrition and feed supply.	Feed pellet mills equipped with precision grinding and mixing technologies.
Aquaculture	Produces pellets as specialized feed for aquatic organisms.	Aqua pellet mills with extrusion and steam cooking methods for pelletization.

Industry	Main Function	Leading Technology
Wood and Biomass Pelletizing	Converts wood and biomass materials into dense pellets for fuel or heating.	Wood pellet mills employing compression and heat treatment techniques.

3.4 Cause Effect Chain Analysis

User Prompt:

CECA is Cause and Effect Chain Analysis. This tool is very close to Why-Why Analysis. CECA can find root causes and deeper root causes until finding key disadvantages.

CECA can find the key disadvantages at specific parameters and their value (maximum or minimum).

What's different from Why-Why is; CECA may identify the key disadvantages (possible root causes) which have a specific value that causes the first problem but when trying to change that value oppositely, the first problem is gone but may create a new problem. We call this situation a "Contradiction".

Let's try to create the CECA of the problem "Uncomfortable breathing Mask"; consisting of multiple columns of the potential root causes at the specific parameters level of the related system components.

Identify key disadvantages, and if possible, identify the contradiction at each specific parameter at maximum or minimum value. Display in tabulate format. Finally add a column for the "Key problem"; Key problem is the problem statement in term of "How to adjust the parameters of each root causes to eliminate the first problem without creating the new problem?".

ChatGPT:

Table 5. Cause Effect Chain Analysis with ChatGPT

Root Cause	Parameter	Value	Contradiction	Key Problem
Poor Fit	Mask Size	Incorrectly Sized	When resizing the mask to be smaller, it may cause tightness.	How to adjust the mask size to eliminate discomfort without causing tightness?
	Mask Material	Non-Breathable Material	Using a more breathable material may compromise filtration.	How to select a mask material that balances breathability and filtration efficiency?
Improper Strap Design	Strap Tension	Too Tight	Loosening the straps may cause the mask	How to adjust strap tension to

			to slip or lose fit.	provide a comfortable fit without compromising mask stability?
Inadequate Ventilation	Ventilation Design	Insufficient Ventilation	Increasing ventilation may decrease filtration effectiveness.	How to optimize the mask's ventilation design to provide sufficient airflow without compromising filtration?

3.5 TRIMMING and TRIMMING Rules

User Prompt:

There are 4 Major components of Hot coffee: Hot coffee, Sugar, Cup, Spoon. Please analyze the function of each component. The main function of Spoon is typically used to stir the coffee. If I try to take off “Spoon”, and I expect you as inventor to invent following. The cup that able to perform function as spoon. The sugar that able to perform function as spoon. Please explain How to do those?

Google Bard:

Cup with built-in stirrer: The stirrer could be attached to the side of the cup with a magnet. The stirrer could be made of plastic or metal.

Sugar cubes shaped like spoons: The sugar cubes could be made of a material that is easy to dissolve in coffee, such as sugar or artificial sweetener. The sugar cubes could be shaped like spoons using a mold.

3.6 Feature Transfer

User Prompt:

I would like to create new formula of coffee; I need you to help for bring some feature of beer to coffee and explain the result.

MS Bing:

Coffee beer is a combination of beer and coffee, a specialty type of brew that changes the flavor of both ingredients. By adding coffee to a stout or beer, it completely changes the flavor profile of the drink and adds a little caffeine to the brew¹. The most traditional beer styles that go well with coffee are porters and stouts².

If you want to create a new formula of coffee with some features of beer, you can try adding some roasted malt or barley to your coffee. This will give your coffee a slightly bitter taste and a hint of nuttiness. You can also try adding some hops to your coffee. Hops are what

give beer its bitterness, so adding them to your coffee will give it a slightly bitter taste as well².

3.7 40 Principles

User Prompt:

Do you know 40 principles of TRIZ? /

If I ask you to select a principle which able to modify "coffee" and get the result like "function of spoon", which principles above you might be select?

Google Bard:

Table 6. 40 Principles with Bard

Principle	Bard selection
Universality	Principle 17: Partial or excessive actions. This principle states that a problem can be solved by either partially or excessively performing an action. In the case of coffee, we could partially or excessively perform the action of stirring. For example, we could stir the coffee very slowly, which would allow the coffee to cool down more gradually. Or, we could stir the coffee very quickly, which would create a more frothy and flavorful cup of coffee. This would allow us to use the same object (coffee) for multiple purposes (cooling down coffee and creating a frothy cup of coffee).
Copying	Principle 21: Another dimension. This principle states that a problem can be solved by changing the dimension of an object or system. In the case of coffee, we could change the dimension of the coffee by making it into a frozen coffee drink. This would allow us to enjoy the flavor of coffee without having to stir it.

3.8 Scientific Effect Database

User Prompt:

The physical Scientific effect name COANDA Effect can be able to perform the function for "separate the particle and liquid". Please apply COANDA Effect to the general fan for home-use in each component if possible? In tabulated format.

ChatGPT:

Table 7. Scientific Effect with ChatGPT

Component	Coanda Effect Application
Blades	The curved shape of the blades utilizes the Coanda effect to redirect airflow. As air passes over the curved surface of the blades, it adheres to the surface, causing the air to follow the curvature and

Component	Coanda Effect Application
	change direction. This redirection of airflow helps in separating particles and liquids suspended in the air.
Housing/Casing	The design of the housing/casing of the fan can incorporate curved surfaces that leverage the Coanda effect. These curved surfaces aid in directing the airflow and enhancing the separation of particles and liquids from the air.
Ventilation Grille	By utilizing the Coanda effect, the design of the ventilation grille can be optimized to guide the incoming airflow along specific paths. This controlled airflow can aid in separating particles and liquids, preventing them from entering the fan's interior.
Airflow Diffuser	The Coanda effect can be employed in the design of the airflow diffuser to control the direction and spread of the air exiting the fan. By using curved surfaces, the diffuser can guide the airflow and enhance the separation of particles and liquids from the air.
Airflow Concentrator	The Coanda effect can be utilized in an airflow concentrator attachment for the fan. The attachment can be designed with curved surfaces to concentrate and control the airflow, thereby improving the separation of particles and liquids.

3.9 Extension FOS:

User Prompt: **Problem Oriented Search**

In the wood pellet mill, we found a quality problem; a crack of the pellet. Could you please find the 3 different industries which same or similar problems? Consist of the Problem, root causes, Technology, or solution that is used to solve the problem. in tabulated format.

ChatGPT:

Table 8. Problem Oriented Search with ChatGPT

Industry	Problem	Root Causes	Technology/Solution
Animal Feed Manufacturing	Cracks in feed pellets	Inadequate moisture content, excessive heat during pelleting	Adjusting moisture levels, optimizing conditioning and pelleting parameters
Pharmaceutical Manufacturing	Cracks in tablet or pill forms	Inconsistent compression forces, excessive drying or moisture content	Optimizing tablet press settings, implementing controlled drying processes

Industry	Problem	Root Causes	Technology/Solution
Ceramic Tile Manufacturing	Cracks in ceramic tiles	Inadequate drying or firing temperatures, uneven pressure distribution	Precise temperature control during drying and firing, ensuring uniform pressure application

User Prompt: Mechanism Oriented Search

My problem-solving experience I would like to share with you; I once had a question about feeding in a commercial fishpond that is raised to be used as food for humans. Good fish farming (grow fast, get weight as needed, and loss during rearing) is required to provide appropriate water management. no residual waste no water waste with good aeration. One of the factors contributing to water pollution is fish feed. too much food or staying in the water for too long will waste water if we put in too little food, the fish will grow slowly and not reach the desired weight. While thinking about those methods, it was realized that there was a similar "problem mechanism" that may be used to solve the problem, namely when a man is hungry There will be a cry from the abdomen. At that time, it led to the question that when fish are hungry. We can measure vocals or other different sounds. Caused by the behavior of fish that are hungry or not. If measured, it will bring timely feeding. / Please find a new "problem mechanism" in specific 5 technical systems and 3 natural systems that are similar to what happens when a fish is hungry. in tabulated format.

ChatGPT:

Table 9. Mechanism Oriented Search with ChatGPT

Natural System	Problem Mechanism	Effect/Indication	Potential Solution
Insect Pheromone Communication	Release of specific chemical signals by insects	Attraction or communication between individuals	Monitoring pheromone trails for insect behavior analysis
Plant Stress Response	Emission of volatile organic compounds (VOCs)	Indication of environmental stress or insect attacks	Analyzing VOC emissions to identify plant stressors and provide appropriate care
Bee Waggle Dance	Unique dance patterns	Indicating food source location and distance	Observing and decoding the waggle dance to locate food sources and guide foraging behavior

User Prompt: Disadvantage Oriented Search

For the root cause of "Inadequate moisture content": Could you please find the 3 industries which face of same "root cause"? Consist of root causes, effect from that cause, Technology or solution that is used to solve the problem. in tabulated format.

ChatGPT:

Table 10. Disadvantage Oriented Search with ChatGPT

Industry	Root Cause	Effect from the Cause	Technology/Solution
Animal Feed Manufacturing	Inadequate moisture content	Poor pellet durability, reduced nutritional value, increased dustiness	Adjusting steam conditioning, implementing moisture control systems
Paper Manufacturing	Insufficient moisture in paper fibers	Brittle paper, reduced strength and flexibility, increased breakage	Implementing steam injection systems, optimizing wet end operations
Brick and Tile Manufacturing	Low moisture in clay mix	Cracked bricks or tiles, weak structural integrity, difficulty in molding	Adding water to the clay mix, implementing controlled moisture measurement system

3.10 TESE Mono-Bi-Poly

User Prompt:

There are some devices had improved the efficiency by using hybrid such as Camera + Infrared. Please generate possible poly-system of height measure technologies. in tabulated format, with columns of 1. Main Function 2. heterogeneous functions and 3. Inverse Function.

Google Bard:

Table 11. TESE Mono-Bi-Poly with Bard

System	Main Function	Heterogeneous Functions	Inverse Function
Camera + LiDAR + Stereo Vision	Creates a highly accurate and detailed 3D model of the environment.	LiDAR provides depth data, stereo vision provides depth data, and camera provides high-resolution images.	Calculates the distance between the camera and the object in the scene.

Camera + Li-DAR + Structure from Motion (SfM)	Creates a highly accurate and detailed 3D model of the environment.	LiDAR provides depth data, SfM provides motion data, and camera provides high-resolution images.	Calculates the position of the camera in the scene.
Radar + Ultrasound + Stereo Vision	Creates a highly accurate and detailed 3D model of the environment.	Radar provides range data, ultrasound provides depth data, and stereo vision provides depth data.	Calculates the distance between the radar, ultrasound, and stereo vision sensors and the object in the scene.
Radar + Ultrasound + Structure from Motion (SfM)	Creates a highly accurate and detailed 3D model of the environment.	Radar provides range data, ultrasound provides depth data, and SfM provides motion data.	Calculates the position of the radar, ultrasound, and SfM sensors in the scene.
Camera + Li-DAR + Radar + Ultrasound + Stereo Vision + Structure from Motion (SfM)	Creates the most accurate and detailed 3D model of the environment possible.	All of the above technologies are used.	Calculates the position and distance of all of the sensors in the scene, as well as the distance between the sensors and the object in the scene.

4. Discussion and Conclusion

Overall, we can conduct research on resource-oriented information to support the process of generating new ideas with the assistance of Generative AI. The characteristics of utilizing each resource are classified as follows:

- Analysis of resource information systems, such as Function Analysis and CECA.
- Researching different industrial technology systems in terms of resource information, such as FOS.
- Application of resource information tools to aid in generating TRIZ ideas, such as the 40 Principles, Scientific Effect Database, and TESE.

It has been discovered that Generative AI technology can be used to help solve initially identified problems, such as significantly reducing research time. In the past, obtaining data from different industries was challenging.

Generative AI's ability to collect and summarize data has also led to the development of branching tools based on the concept of Function Oriented Search. For example:

- Problem Oriented Search: enables us to search for similar problems in other industries.
- Key Disadvantages Oriented Search: assists in identifying the root cause of a problem by examining similar or different problems from other industries.

- Mechanism Oriented Search: helps us find mechanisms for similar problems encountered in other industries, regardless of their differences.

Previously, the problem solver might have had the newly adapted TRIZ instrument in mind but lacked efficient data collection tools. Generative AI can assist in organizing the display of data, contributing to the increase of information resources that can lead to a variety of ideas.

However, it has been found that generative AI may have limited access to patent information. It might not provide patent details, claims, patent mapping, or patent summaries like ChatGPT 3.5. However, MS-Bing does offer patent summaries, while Google Bard has the most extensive patent capabilities, providing partial information on patent details, claims, patent mapping, and patent summaries (based on our testing).

Additionally, it has been observed that ChatGPT 3.5 uses pre-trained data until September 2021, which suggests that its completeness and up-to-dateness may be affected. It is important to stay up to date with the latest information.

During the testing, several issues were identified when providing command prompts:

- Lack of introductory information: Focusing solely on obtaining answers in the form of questions for immediate responses (Zero Shot Prompt).
- Incomplete contextualization.
- It is not advisable to assume that the nature of the TRIZ tool is initially known by the Generative AI, as it may affect the accuracy of the received answers.

In summary, using Generative AI with the TRIZ tool involves a step-by-step process, starting from using the Problem Formulation tool and gradually moving towards defining the Key Problem, searching for resources, and modifying them. This approach resembles advanced-level engineering prompts such as Chain of Thought and Tree of Thought.

From the results of utilizing Generative AI to find information resources, we have observed a significant reduction in search time and the ability to access previously difficult-to-find information.

However, due to the possibility of errors, both in the prompts and the generative AI model itself, the author strongly recommends verifying the accuracy of the data before utilizing it.

References

3. <https://learnprompting.org/docs/intro>
4. <https://www.cloudskillsboost.google/paths/118>
5. <https://platform.openai.com/docs/introduction>
6. <https://bard.google.com/>
7. <https://www.bing.com/>
8. <https://www.deeplearning.ai/short-courses/chatgpt-prompt-engineering-for-developers/>
9. <https://www.elementsofai.com/>

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DEMAND - TREND MATRIX: QUICK ROADMAPPING FUTURE INNOVATIONS

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Abstract

In general, there are two alternative strategic approaches being used today to innovatively improve existing products/ technologies and generate ideas for new products and technologies: market pull and technology push. The first approach is to use the results of market studies (voice of the customer) to generate new ideas and concepts that would meet the identified customer and market demands. However, the shortcoming of such approach is that new ideas are generated randomly and chaotically; or in case if classical tools of TRIZ are used, we obtain a number of ideas which are not ordered accordingly the market demands or we can miss some important evolution steps.

In modern TRIZ, the second approach (technology push) is implemented in form of “Evolutionary Potential Assessment and Product/Technology Forecast” and involves the of resources available within a selected product/technology for further evolution according to the TRIZ Trends and Lines of Technology Evolution.

The most widespread use of this approach is to build an “Evolutionary Radar Plot” of a selected product or its part and then further evolve the product along the undeveloped lines of evolution. The shortcoming of this approach is that the results obtained do not correlate with market demands and requirements and only use the inner potential of the existing product/technology.

Keywords: market requirements, TRIZ, Trends and Lines of Technology Evolution

1. Demand-Trend Matrix

A **Demand-Trend Matrix (DTM)** is a rather simple tool which brings together technology push and market pull approaches. A principal idea behind DTM is to organize a new ideas generation process in a systematic way by establishing mapping between market requirements and demands (including revealed market trends) and the TRIZ Trends and Lines of Technology Evolution (Fig. 1), also known as “Trends of Engineering Systems Evolution” under abbreviation TESE [1]. Each Trend includes one or more specific lines of evolution.

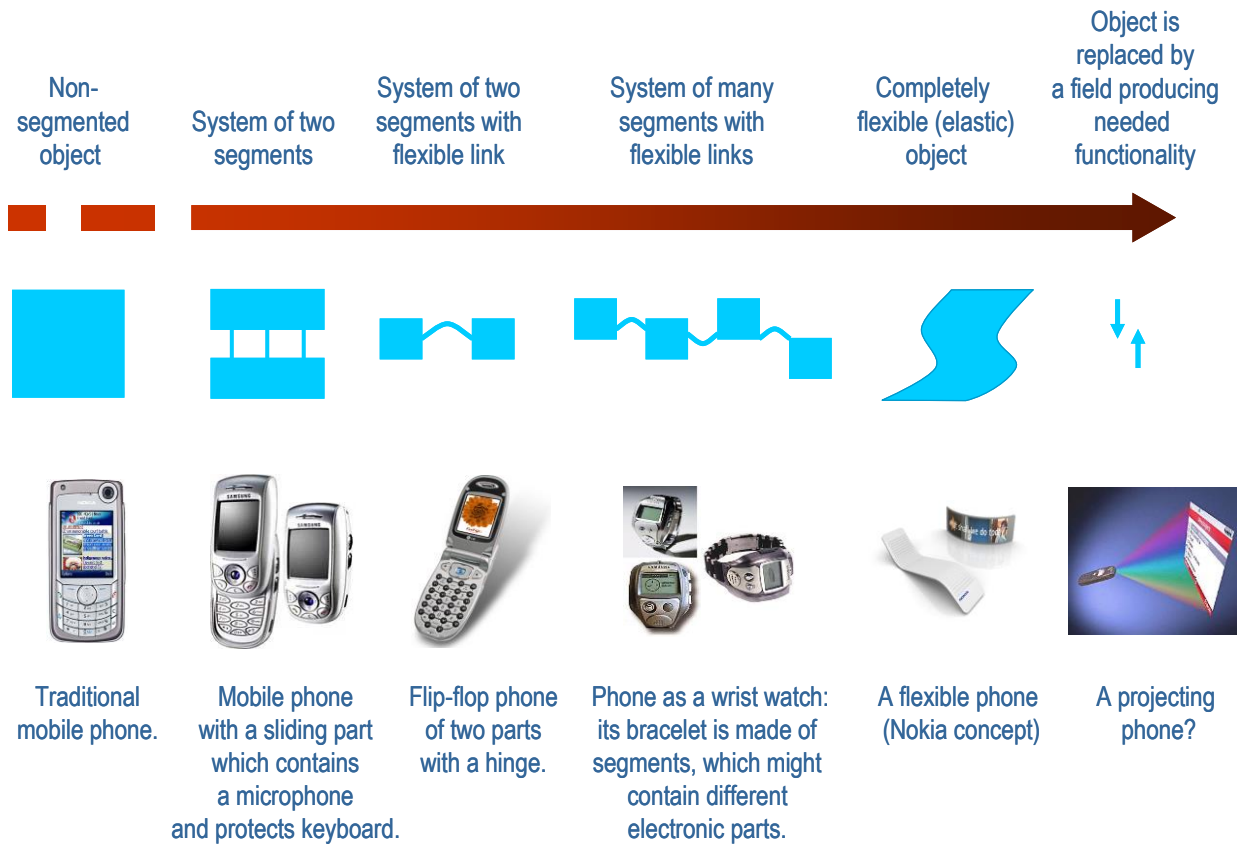


Fig. 1: Example of the TRIZ Line of Evolution of increasing physical system dynamics

In DTM (Fig. 2), each customer requirement or market demand is identified with a specific subsystem (part) of a system (product) which we want to improve, and then each TRIZ Line of Evolution is applied to this part to see if a solution can be proposed on the basis of this TRIZ Line that would meet the corresponding customer/market demand.

Thus, by evaluating opportunities in each cell of the matrix, the entire space of couples “customer requirement/market demand vs. TRIZ line of technology evolution” is explored. After completing DTM, each cell might include either a single idea, or several ideas, or remain empty if no ideas were proposed.

MARKET DEMANDS AND REQUIREMENTS		Demands 1	Demands 2	Demands 3	Demands 4	Demands 5	Demands 6	...	Demands N	Trend Score
TRIZ TRENDS/LINES OF EVOLUTION										
Line of Evolution 1										
Line of Evolution 2										
Line of Evolution 3										
Line of Evolution 4										
Line of Evolution 5										
...										
Line of Evolution 24										
		Subsystem 1	Subsystem 2	Subsystem 3	Subsystem 4	Subsystem 5	Subsystem 6	...	Subsystem 7	

Fig. 2: Demand-Trend Matrix (DTM)

If there are one or more ideas in a cell, then the cell is marked with “+”. In case if there are no ideas, or the trend is inapplicable, with “-”. This gives a possibility to assign a score to each trend at the stage of evaluation, after the entire DTM is completed. Finally, a total score against each customer/market demand and TRIZ evolution trend can be calculated.

To apply the Demand-Trend Matrix properly, knowledge of the TRIZ trends of evolution is expected. Alternatively, this knowledge can be provided by an experienced facilitator (TRIZ expert) while a team generates ideas by using specific patterns of evolution as thinking triggers. In such cases, the team members are not required to be familiar with TRIZ. At this moment we use 24 lines of evolution.

It might take a long time to explore all possible combinations, thus we recommend breaking the process with DTM to a number of phases. Each phase might concentrate on a certain subsystem or a specific demand.

2. Completing Demand-Trend Matrix

The process of completing DTM is as follows:

- 1) Identifying specific customer/ market requirements and demands with respect to a selected product and completing the upper horizontal list in DTM.
- 2) Identifying important subsystems in the product selected and listing them in the bottom list.
- 3) A list of TRIZ Trends of Technology Evolution is fixed and remains the same for any product.
- 4) Each cell is checked against possible ideas. In fact, it is a step at which ideas are gener-

ated. If there are more ideas than one, all ideas are recorded in a cell. The ideas generation process might be somewhat time-consuming process since we need to generate ideas for each cell. However, this process can be limited to only those market demands which we consider as most important.

- 5) A total score for each TRIZ trend of technology evolution is identified. It consists of a number of cells which are not empty and belong to the selected TRIZ trend of technology evolution.
- 6) All ideas in each cell are evaluated and decisions are made on further implementation of the most potential solution candidates.

In case if there are no ideas available with respect to some demand after completing the matrix, or new ideas contradict to other demands, then the TRIZ principles of separating conflicting demands and the databases of effects can be used to generate ideas based on the identified contradiction. The resulting matrix also structures the contradiction space and provides a possibility to “uncouple” contradicting requirements. In addition, the ideas generated can be evaluated and structured according to the importance of the demands and requirements to define short-term and long-term product/technology innovations.

3. Case: A Hose Pump Evolution (fragment)

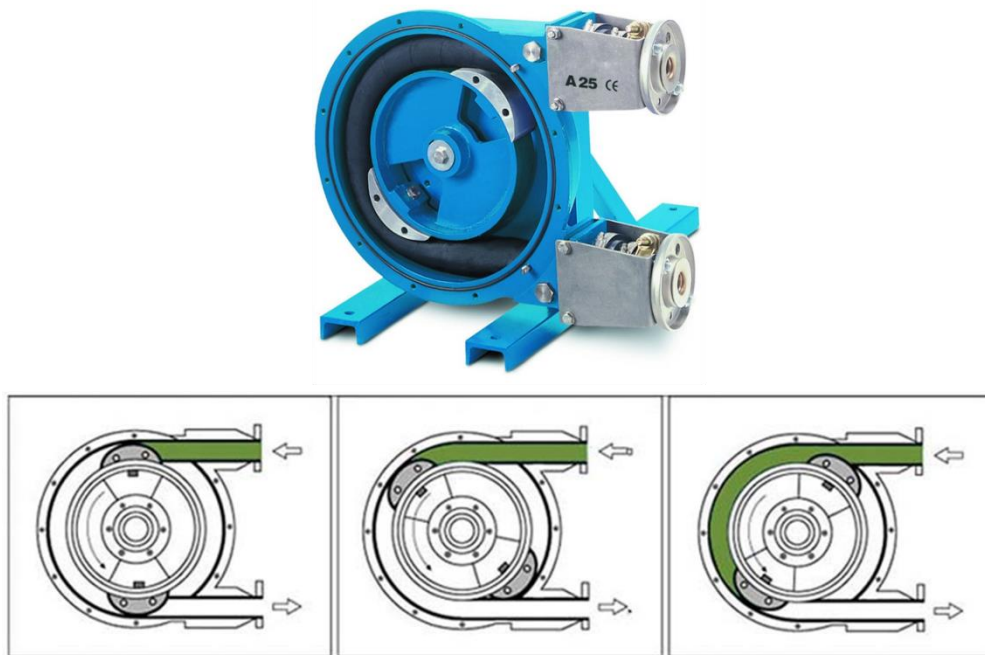


Fig.3 A hose (peristaltic) pump

A typical hose (peristaltic) pump consists of the following subsystems of upper level according to TRIZ Function Analysis:

- Hose
- Shoe
- Connection
- Drive
- Housing
- Rotor

The Demand-Trend Matrix presented below establishes mapping between market demands for a hose (peristaltic) pump and the TRIZ trends of technology Evolution (only a fragment is presented):

CUSTOMER/ MARKET DEMANDS AND REQUIREMENTS				
TRIZ TRENDS/LINES OF EVOLUTION	<ul style="list-style-type: none"> - Lifetime - High chemical resistance - Abrasive resistance - Suction capability - Discharge pressure - Capacity - Hygienical - Easy to install - Low hysteresis - Ability of failure detection 		<ul style="list-style-type: none"> - Lower friction - Lower volume pressed to the hose - Better compression control - Mechanical strength - Retractability - Chemical resistance 	Demands N Trend Score
Trend 1	...	...	...	...
SEGMENTATION OF SURFACE	<ul style="list-style-type: none"> • Introduce profile to inner and/or outer surfaces of the hose; • make the inner surface rough and softer 	<ul style="list-style-type: none"> • Cover shoe with lubricant • Feed lubricant continuously	...	...
STRUCTURE TRANSPARENCY	<ul style="list-style-type: none"> • Introduce cavities - lowers hysteresis; • local quality cavity prevents fatigue; • introduce cavities with gel; • introduce spiral; • use foamed rubber; • use foamed elastomeric compound; • use gel-filled foamed elastomeric compound. 	<ul style="list-style-type: none"> • Make shoe perforated • Push gas flow through pores in metal • Replace metal shoe with high-pressure gas flow	...	...
Trend 4	...	...	...	...
...
		Hose	Shoe	...

Fig. 3: Example of Demand-Trend Matrix (DTM) application

As we can see, application of the TRIZ trend “Structure Transparency” to a subsystem “Hose” of the hose pump resulted in generation of seven ideas how to modify the hose while application of the TRIZ Trend “Segmentation of Surface”. In turn, application of these two trends to a subsystem “Shoe” resulted in two and three ideas of further evolution of the subsystem “Shoe” of the hose pump. Each idea can be checked to see if it satisfies one or another market requirement listed in DTM. If not, the idea should be deleted.

Furthermore, after DTM has been completed, evolution of each subsystem can be visualized with the help of Evolutionary Radar Plots, introduced in [2] where each radar plot depicts both initial state of a subsystem evolution and final state of evolution after completion of DTM (Fig. 4).

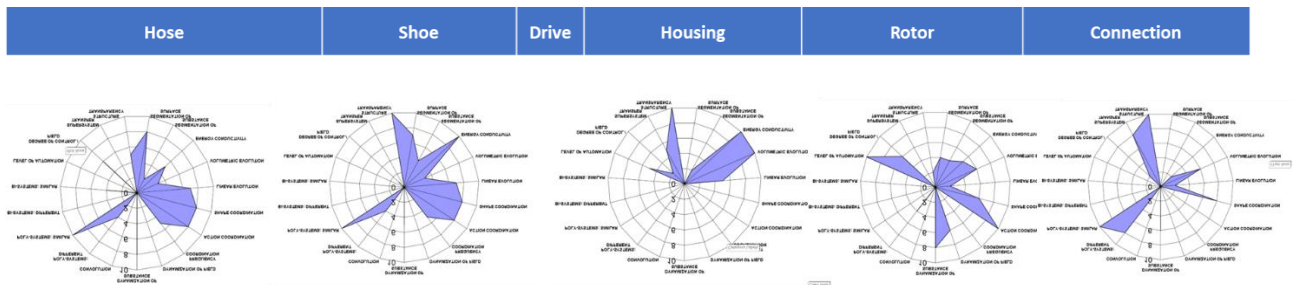


Fig. 4: Collection of Evolutionary Radar Plots indicating ideas for future development of each specific subsystem

4. Benefits of the Demand-Trend Matrix

Summarizing, the use of DTM provides the following:

- Integration of market-based and technology-based methods for forecasting and developing new ideas and concepts for future products and technologies.
- Direct application of the TRIZ Trends and Lines of Technology Evolution to fulfill market demands.
- Providing more opportunities for idea generation by creating and exploring the entire space of demands related to the TRIZ Trends of Technology Evolution.
- Enabling quick scan of future opportunities by application of the TRIZ Trends of Technology Evolution.
- Reducing probability of missing important evolution step.
- Providing information for identifying demand-related contradictions.
- Helping better identify and structure short-term and long-term product/technology innovations.

Since 2008, DTM has been applied within a number of projects by ICG T&C partners and customers on product innovation. In each project, a list of new patentable ideas were produced both for short- and long-term innovative improvements. Currently we are considering how to integrate DTM and Innovative Technology Roadmapping [3].

References

1. Alex Lyubomirskiy, Simon Litvin, Sergei Ikovenko, Christian M. Thurnes, Robert Adunka. Trends of Engineering System Evolution (TESE): TRIZ paths to innovation. TRIZ Consulting Group; 2018
2. Darrell Mann. Hands On Systematic Innovation for Technology and Engineering. IFR Press, Second Edition, 2007
3. Phaal R., Farrukh C., Probert D. Roadmapping for Strategy and Innovation: Aligning Technology and Markets in a Dynamic World Institute for Manufacturing. Cambridge: University of Cambridge, 2010.

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INNOVATIVE DESIGN OF HEAT PUMP AIR CONDITIONING BASED ON TRIZ

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Abstract

With the improvement of people's living standards, the demand for heating is increasing day by day. However, 83% of northern China still relies on coal for heating, which is very serious for air pollution. In response to this problem, the state has issued a series of policies to promote clean energy heating. Air-source heat pump air conditioning is an innovative technology that is mainly promoted. But at present, air source heat pump only accounts for 5% of heating in the north. Then why is the proportion of air source heat pump air conditioning heating small? The project team sorted out the customer voice (VOC) through the user survey, and obtained a number of user pain points; Aiming at these pain points, the customer data is analyzed by Pareto diagram to determine the key needs of customers; Determine the key quality characteristics (CTQ) according to the key requirements of customers through QFD; According to the key quality characteristics (CTQ), the specific MPV is determined through MPV analysis. Through S-curve analysis, it is determined that the product is in the growth stage and the corresponding coping strategies; Through benchmarking analysis, understand the current situation of the industry and the strategic guidance of S curve analysis, and determine the project objectives of this project; Aiming at the project objectives, the analysis and solution are carried out by means of Functional analysis, Flow analysis, Cause-Effect Chain Analysis, Value flow analysis (ECSR principle), Stand solution application, Effect library, ARIZ, Trend of flow enhancement, Villain method, Cost map design, DOE and other tools. Finally, the technical problems of the project were solved, and the products were successfully listed, and many patents, economic benefits and various awards were obtained.

Keywords: TRIZ,VOC,QFD,CTQ,DOE

1 Project analysis:

1.1 Project Background:

With the improvement of people's living standards, the heating demand is growing, and the annual heating coal consumption is 400 million tons, carbon (CO₂) emissions are 529 million tons, and the haze in most areas of the country reaches more than 100 days. In the north of China, 83% still rely on coal for heating in winter. In response to this problem, the state has introduced a series of policies to promote clean energy heating. Among them, air source heat pump is an innovative technology that the state focuses on. However, the current air source heat pump accounts for only 5% of heating in the north, which is a very low proportion.

1.2 Customer needs:

1.2.1 User Research:

Why does the air source heat pump account for so little of the heating in the north? The project team conducted user research and summarized, analyzed and sorted out customer needs through affinity charts, as shown in the following table:

Table 1.VOC

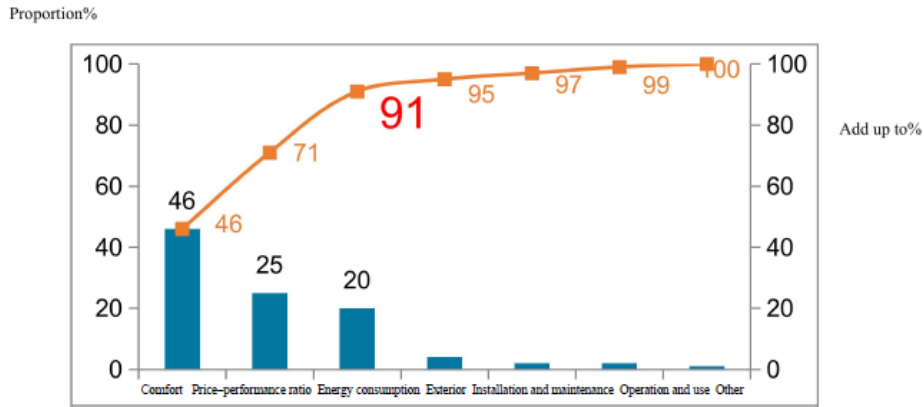
VOC					
Number	Category	content			
1	Comfort	Hot head and cold feet	The room won't heat up	Slow temperature rise	Loud noise
2	Price-performance ratio	Expensive			
3	Energy consumption	High power consumption			
4	Exterior	Single shape			
5	Installation and maintenance	Not easy to install	Inconvenient maintenance	Take a place	
6	Operation and use	Not easy to clean	Complex keys		
7	Other	Not smart enough			

1.2.2 Identify key customer needs:

Through the analysis of user data in pareto chart, the cumulative proportion of comfort, cost performance and energy consumption is 91%, and finally it is concluded that the key needs of customers are high comfort, cost performance and low energy consumption.

Table 2. Pareto chart

Customer data analysis (pareto chart)



1.2.3 Determine key engineering characteristics:

Through QFD, the above-mentioned customer's key requirements are analyzed, and finally the key engineering characteristics are obtained: cost, noise and power consumption.

Table 3.QFD

Engineering characteristics		Customer demand					Market competitiveness			
Customer demand	Importance degree	cost	Heat exchanger design	noise	Compressor design	energy consumption	This product	Competitor 1	Competitor 2	Competitor 3
High comfort	Uniform thermal distribution	○	△			◎	3	4	4	3
	Rapid heating	○			△	◎	4	3	2	4
	Small voice	◎	○	◎			4	3	3	3
Cost-effective	3	◎	◎	◎	○	○	4	2	2	3
Low energy consumption	2	○		△	◎	◎	5	3	2	3
		Control labor cost and parts cost	Efficient heat exchange	Reduce noise	Energy-efficient compressor	Improve energy utilization rate	0.787	0.6	0.52	0.653
	Importance of engineering	81	39	56	31	90	Market competitiveness index M			
Technical competitiveness	This product	3	4	3	4	3	0.68	Technical competitiveness index T		
	Competitor 1	3	3	3	3	4	0.69			
	Competitor 2	4	2	2	2	2	0.53			
	Competitor 3	2	3	3	3	3	0.56			

1.3 Target confirmation:

1.3.1 MPV analysis:

Furthermore, the above three indicators (power consumption, noise and cost) are decomposed by MPV, and finally it is determined that vertical temperature difference, volute noise, number of personnel and number of parts are the most important MPV.

MPV					
	MPV	Level 1 MPV	Level 2 MPV	weight factor	
Innovative design of heat pump air conditioning		System energy efficiency	-	3	
		Auxiliary electric heating power	-	3	
	power consumption	Vertical temperature difference	Height of tuyere		5
			Air outlet temperature		
			Air output		
			Angle of air outlet		
	noise	Noise of volute	-	4	
		Noise of wind blades	-	3	
	cost	Cost of personnel	Number of people	5	
		Cost of materials	Number of parts	4	
		The cost of research and development	-	1	

1.3.2 S curve analysis:

Through S-curve analysis, it is determined that the air source heat pump is in the growth stage, and its coping strategy: optimization is the main method to improve the technical system.

1.3.3 Benchmarking analysis:

Through benchmarking analysis, we can understand the current situation of products in the industry. The main defects are large temperature difference, large energy consumption, large noise and high cost.

- 1) Temperature difference: the air temperature at human feet is 8°C lower than that at the head;
- 2) Energy consumption: the power consumption for one heating season is 841 degrees/set;
- 2) Noise: The current noise is 47 decibels;

4) Cost: The number of parts is 649 pieces, and the required production staff is 65 people.

1.3.4 Patent Analysis:

In view of the above defects, further patent analysis has not found an effective and comprehensive solution, which is a major technical problem in the industry. Research on core technologies such as temperature difference and noise only accounts for 10%. 80% of the temperature difference and noise are improved by control, with little effect.

1.3.5 Determine the objectives :

According to the above analysis, the project goal is finally determined, which is to reduce the temperature difference by 50%, the number of parts by 15% and the number of personnel by 10%, so as to reach the leading level in the industry.

2 Difficult problem solving

2.1 Reduce the temperature difference

2.1.1 Functional analysis[1]

Table 5.Component analysis

Component analysis			
Technical system	Major function	System component	Hypersystem component
Heat pump air conditioner indoor unit	Heated air	Inlet grille	air
		Diversion ring	people
		volute	\
		fan blade	\
		electrical machinery	\
		evaporator	\
		shell	\
		Air outlet assembly	\

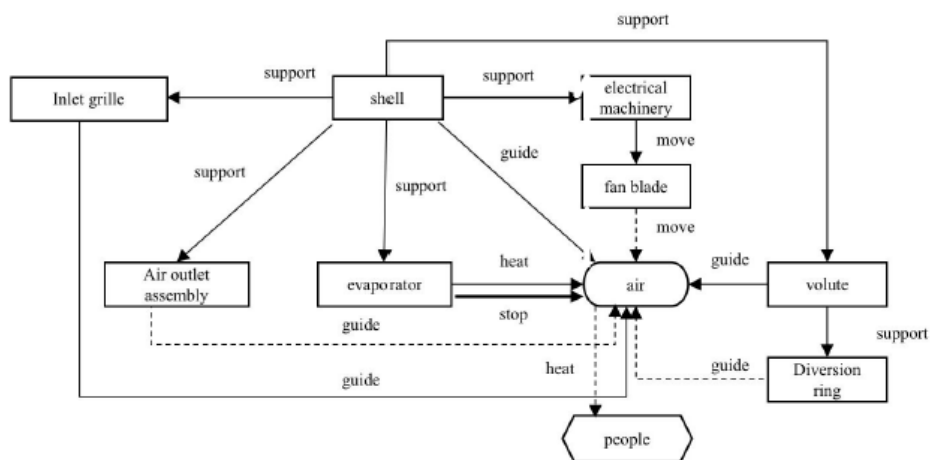


Fig. 1. Functional model diagram

Functional disadvantages: 1) the air outlet assembly has insufficient air guidance; 2) Air heating is insufficient; 3) The guide air of the guide ring is insufficient; 4) The moving air of blades is insufficient; 5) It is harmful for the evaporator to block the air.

2.1.2 Cause-Effect Chain Analysis

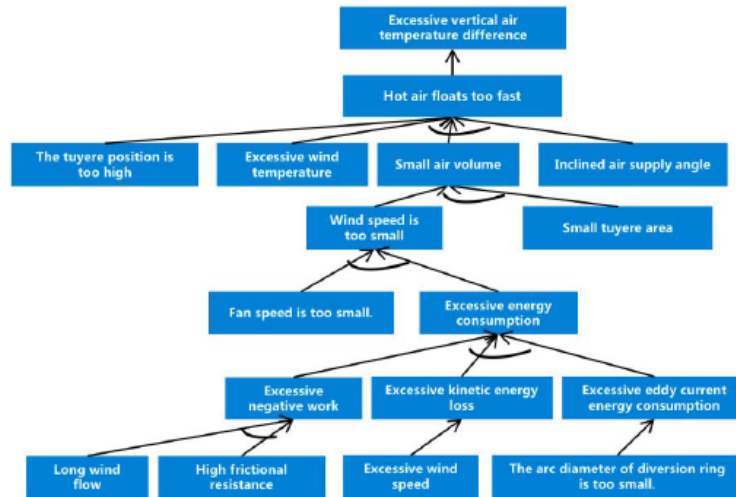


Fig. 2. Cause-Effect Chain Analysis

Table 6.Key Disadvantage

Number	Key Disadvantage	Key problem
1	Inclined air supply angle	How to increase the inclination angle of air supply
2	Friction resistance is too high	How to reduce frictional resistance
3	The arc diameter of diversion ring is small	How to increase the arc diameter of diversion ring

2.1.3 Problem solving:

Key question 1: How to reduce the inclination angle of air supply?

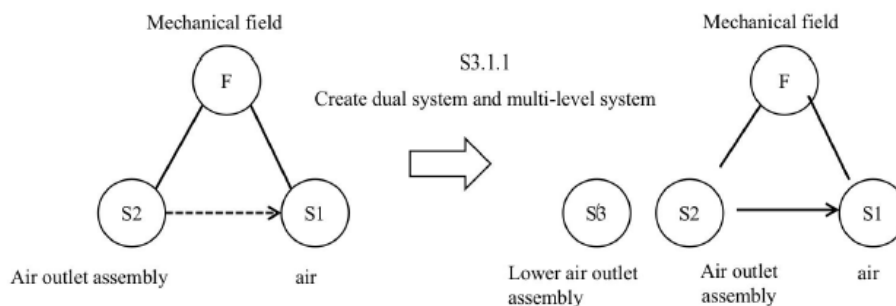


Fig. 3.Standard solution[2]

The standard solution 3.1.1 is adopted to change one air outlet system into two air outlet systems to solve the problem of insufficient air diversion. And the upper air outlet assembly presses the air downwards, so that the floating of hot air is further inhibited, so that more heat can be concentrated in the areas needed by the human body, the ineffective energy consumption is reduced, the energy utilization rate is improved, and the overall operation energy consumption is reduced.



Fig. 4.Solution

Key question 2: How to reduce frictional resistance?

HOW TO: reduce resistance

Recommended scientific effects: inhalation, wing, Cononda effect.

Inhalation: The fluid enters a local vacuum or low-pressure area, and the pressure gradient between this area and the surrounding environment pushes the substance towards the low-pressure area.

Scheme: The evaporator is moved to the low resistance area.

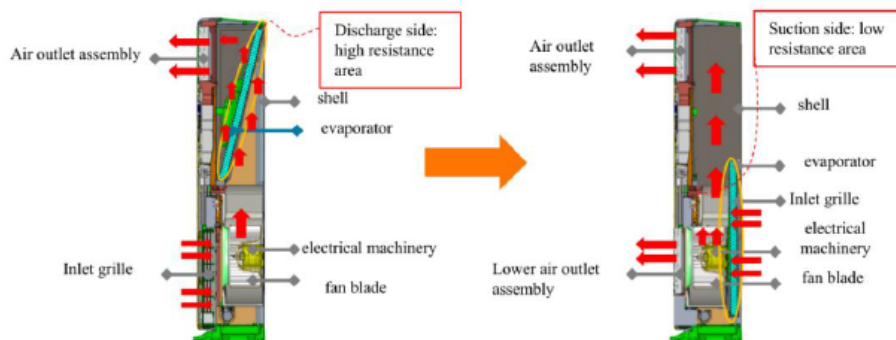


Fig. 5.Evaporator moved to low resistance area

2.1.4 Program evaluation:

According to non-isothermal jet theory, Six Sigma DOE experimental design method, and combined with simulation analysis, the vertical air temperature difference and ineffective energy consumption can be reduced by heating the upper and lower air outlet components. The simulation analysis shows that the blocking effect of the heat exchanger can be reduced after the evaporator is moved to the low resistance area. The air volume is increased by 30% and the noise is reduced by 0.6dB.

2.1.5 Scheme verification:

The measured results show that the temperature difference is below 3°C and the power consumption is reduced by 20%.

2.2 Reduce noise

2.2.1 Cause-Effect Chain Analysis

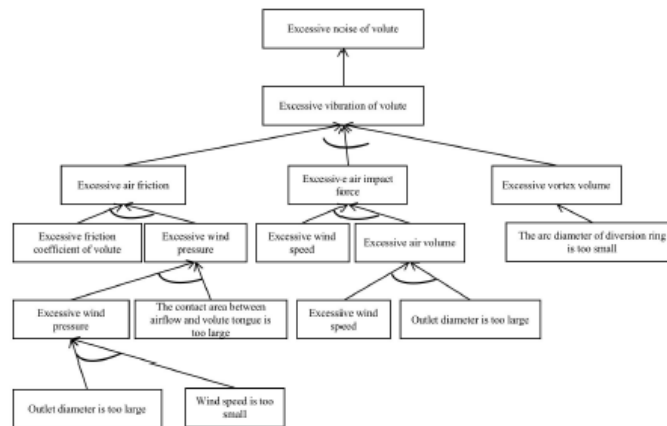


Fig. 6.Cause-Effect Chain Analysis

Through causal chain analysis, it is concluded that the key shortcoming is that the arc diameter of diversion ring is too small, and the key problem is how to increase the arc diameter of diversion ring.

2.2.2 problem solving:

Key question : How to increase the arc diameter of diversion ring?

Through ARIZ analysis and solution, the solution is obtained: the straight section of the diversion ring is changed into an arc structure, so that the fluid can be sucked against the wall.



Fig. 7. Solution

2.2.3 Program evaluation:

The simulation analysis shows that the eddy current loss is reduced, the air volume is increased by 12%, and the broadband noise value is reduced by 0.5dB by using the non-equal arc guide ring.

2.3 Scheme verification:

When the temperature difference is below 3°C, the power consumption is reduced by 20% and the noise is reduced by 1.7dB.

2.4 Analysis and solution of secondary problems:

After preliminary verification, the above scheme can reduce the temperature difference, but there is still a problem that the upper and lower air volume is too low.

2.4.1 Flow analysis:

Aiming at the problem that the air volume of the upper outlet air is too small, the conductivity defect of the upper outlet air is obtained through flow analysis.

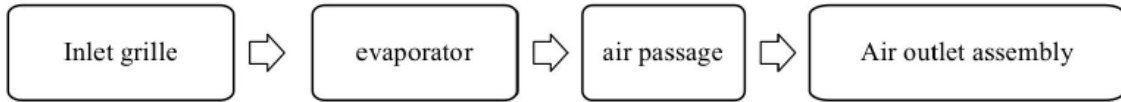


Fig. 8. Flow analysis

2.4.2 Causality chain analysis:

The causal chain analysis is carried out to solve the problem that the air volume of the upper outlet air is too low, and the key disadvantage is that the wind path is too long.

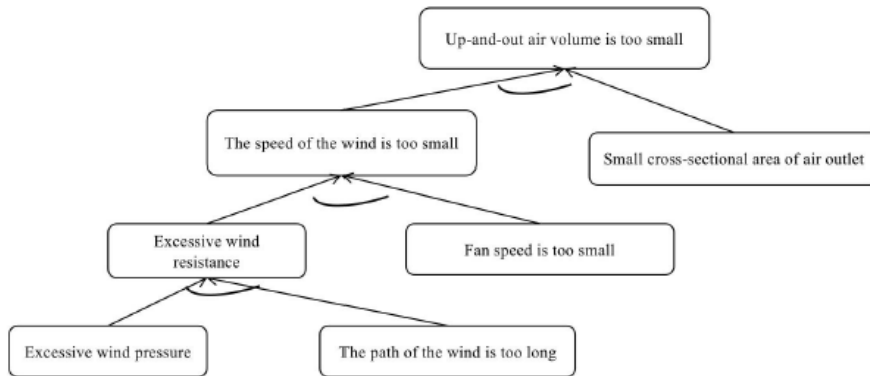


Fig. 9. Cause-Effect Chain Analysis

2.4.3 Problem solving:

Through the suggestion of enhancing the evolution trend of flow-reducing the length of flow, the solution is obtained: reducing the distance from the air inlet to the air outlet. At the same time, add fans and air ducts.

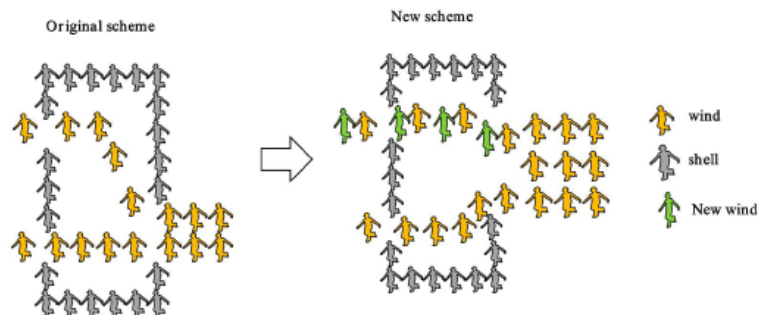


Fig. 10. Villain method[3]

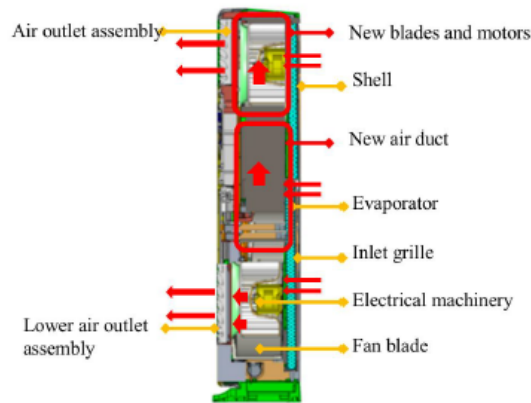


Fig. 11.Solution

2.5 Reduce the number of parts:

Baseline product (existing product): product A. Problem analysis of baseline products (existing products): large number of parts, long assembly time and many fastening actions.

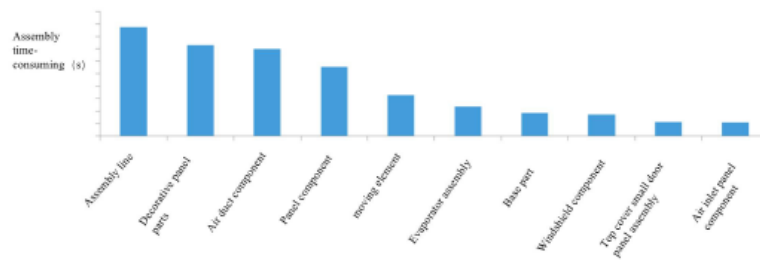


Fig. 12.Time-consuming assembly of baseline products (existing products) (s)

Through the value stream analysis, the ECRS principle (cancellation-merger-rearrangement-simplification) is adopted. The total number of parts is reduced by 31%.

2.6 Reduce the number of employees:

Through the redesign of the cost map, the number of processes was reduced from 170 to 115, a decrease of 32%.

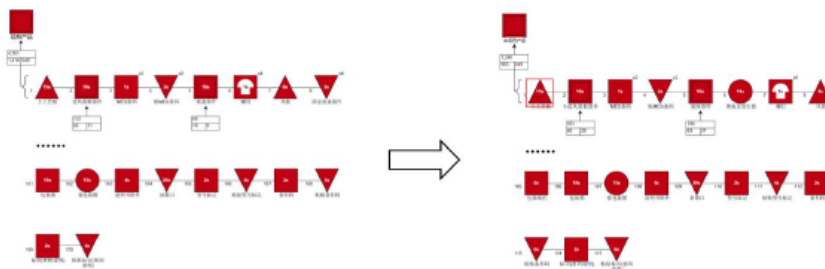


Fig. 13.Cost map

3 Conclusions

1) Project achievement:

- (1) Temperature difference: Target: 50% reduction; Actual: reduced by 73%;
- (2) Noise value: Target: reduce by 1dB; Actual: reduced by 1.7dB;

(3) Number of parts: Target: 15% reduction; Actual: 31% reduction;

(4) Personnel: Target: 10% reduction; Actual: 15% reduction;

(5) Power consumption: target: reduce by 10%; Actual: 19% lower.

2) Project achievements:

(1) Popularization and application: It has been popularized and applied to 5 series and 49 models of products, and no similar or similar products have been seen in the market yet. In response to the national clean heating policy, it has helped to implement the global environmental greening strategy and promoted and applied the products to many heating projects at home and abroad.

(2) Economic and social benefits: After the third-party audit, the cumulative sales volume is 410,000 units, and the new sales volume is 1.86 billion yuan. In the next three years, it will save 3.66 million tons of coal and reduce 9.64 million tons of carbon emissions. Reducing power consumption by 270 million kWh and saving electricity fee by 170 million yuan was selected as one of the "Top Ten Key Products of Light Industry Consumption Upgrade and High Quality Development" in 2019 (it is the only air-conditioning product).

(3) Third-party evaluation: It has won the China Patent Excellence Award, the first prize of provincial and ministerial level scientific and technological progress award, and the ergonomics-thermal comfort certification. It has a perfect intellectual property protection system, and 39 core invention patent groups, 52 derivative patent groups and 5 international patents have been evaluated by China Refrigeration Society. The project results are the first in the world and the technology has reached the international leading level.

Acknowledgements

Thank you master TRIZ for your guidance!

References

1. Sun Yongwei [Sergey Ikevenco]. TRIZ: The golden key to open the door to innovation. Beijing: Science Press, 2015.
2. Zhao Min. TRIZ advanced and actual combat: the invention method of Avenue to Jane. Beijing: Mechanical Industry Press, 2016.
3. Genrich Achille Schul. The inventor was born: TRIZ's theory and method of creative problem solving. Southwest Jiaotong University Press, 2004.

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USE SU-FIELD TO FIND THE INITIAL CAUSE IN THE FISHBONE DIAGRAM

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Yucang TRIZ Workshop

Abstract

When using fishbone diagrams to find the root cause, the user's brainstorming is often too divergent that making it difficult to find the correct direction. But by conducting a Su-field model analysis of potential matter and identifying their logical correlations, initial problems and Initial Disadvantages can be quickly and effectively identified, laying a solid foundation for subsequent cause-chain analysis.

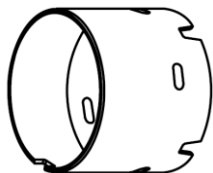
Keyword: *Fishbone Diagram, substance-field model, Initial Disadvantages, standard solution*

Applicable place: when implementing lean improvement in the manufacturing industry: existing fixed plant facilities, machinery, and equipment, implemented process flow and initially stable personnel and management system. The problem to be solved is: Found out the reasons that affect the product quality and improve the product yield and efficiency.

Shortcomings in fishbone diagrams: In the process of quality management of the manufacturing industry, finding the root cause of problems is a crucial action. Fish bone diagram, as a widely used tool, is simple, intuitive, and effective. It starts with Human, Machinery, Materials, Methods, Environments, and Measurements, gradually searching for potential factors. However, when seeking possibility analysis for these elements, it heavily relies on the user's experience and skills. Overly divergent brainstorming can lead to a wrong direction, and even the opposite, sometimes becoming a tool for shirking responsibility.

As shown in the following example.

Example: Quality improvement requirements for one of the following stamping parts



Product has scratches, indentations, smaller inner diameter, higher height, and larger burrs, other defects.

The fishbone diagram analysis of these defects is as follows

The use and drawing of fishbone diagrams can refer to relevant materials and will not be elaborated here.

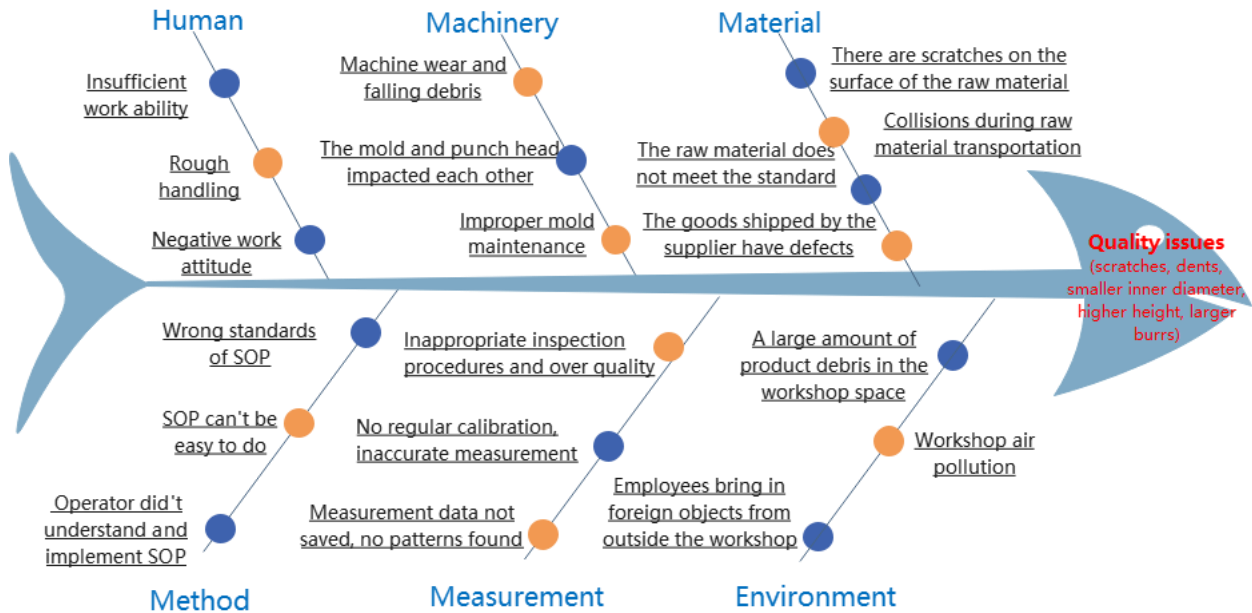


Figure 1: General Fishbone diagram thinking.

The analysis in the above fishbone diagram has the following disabilities:

- **No clear boundary for the problem:** The above reasons include both the input process, the transport process, and the production process. There is no clear definition of the phenomenon, scope, impact, etc. of the cause, and it is impossible to determine the influencing factors and the resulting impacts.
- **Not selecting the appropriate major cause category:** Problems need to be analyzed from different perspectives, but often deviating from the problem itself is called a means of shirking responsibility. If there are problems with materials, it is easy to attribute them to “The goods shipped by the supplier have defects” avoiding the responsibility of internal review.
- **Brainstorming has no direction, relying on experience:** When identifying various factors, one is either very casual, unable to find direction, or limited to experience, ignoring various potential feasibility. If the part requires stainless steel material for stretching, and the hardness increases significantly after stretching, it is highly likely that the surface of the mold will be scratched. However, in the past, the problem was not obvious during flat product punching, and based on past experience, it is not easy to think of hardening factors.
- **Failure to properly categorize and organize various factors:** A considerable number of reasons listed can be attributed to two or more major factors simultaneously, with unclear, repetitive, and chaotic correlations between them. If the production personnel do not understand and implement the operation manual, it can be attributed to a negative work attitude or improper operation methods, and the actual reasons are not clear.

- **Causes and solutions are disconnected:** Finding the cause and implementing a solution are two different stages, which take a long time and are prone to unsolvable cause analysis. Sometimes, there are reasons and solutions related to regulations, human psychological factors, physical methods, and extremely high costs that cannot be implemented. For example, if there are defects caused by “The mold and punch head impacted each other”, the solution may change the process and machine mode, deviating from the work purpose.

So, the use of fishbone diagrams only provides a preliminary framework for dividing the problem. The search for the root cause and the thinking of solutions depends on the user's experience and divergent thinking through brainstorming, which requires a lot of time and effort and cannot truly solve practical problems.

From TRIZ's perspective, every possible cause found in the fishbone diagram can be decomposed into each Su-field model. From the philosophical perspective that things are interconnected, the factor with the highest probability of occurrence of substances and fields is the most likely place for problems to occur. So, consider adding the Su-field model to the fishbone diagram.

TRIZ tool : Su-field model

The Su-field model can describe the minimum system that constitutes the problem. When we need problem points based on the basic elements of Human, Machinery, Materials, Methods, Environments, and Measurements, all possible causes of brainstorming found are modeled as Su-fields, depicting the substances and fields related to these possible causes. After describing all possible causes in the Su-field model, look for the probability of identical or similar substances and fields occurring, and whether there is a logical, time, and space correlation. Find the most likely problem point from it. The initial drawback of this quality issue.

The fishbone diagram will look like the following form:

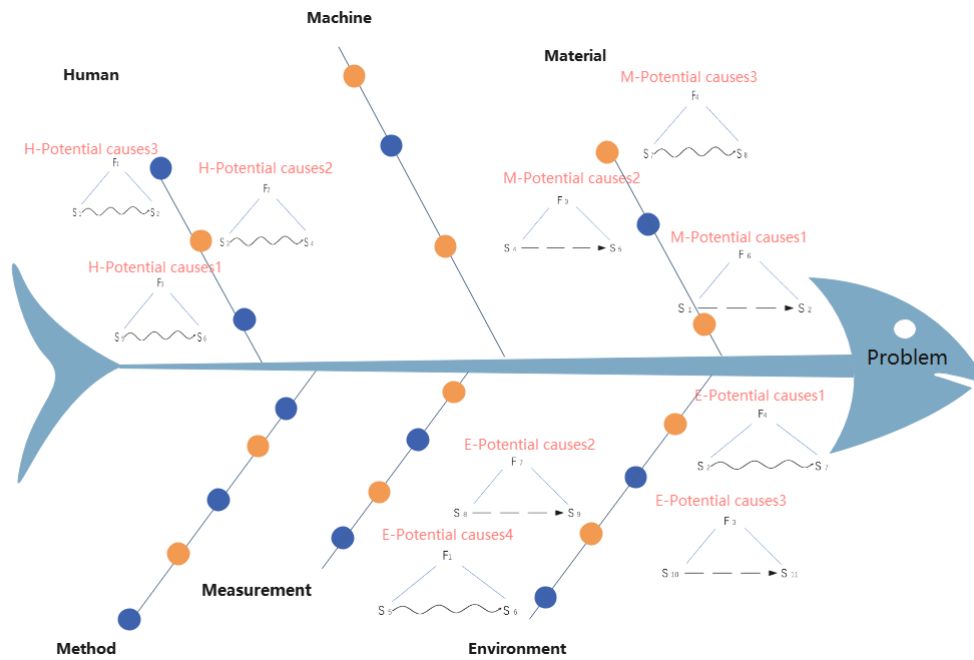


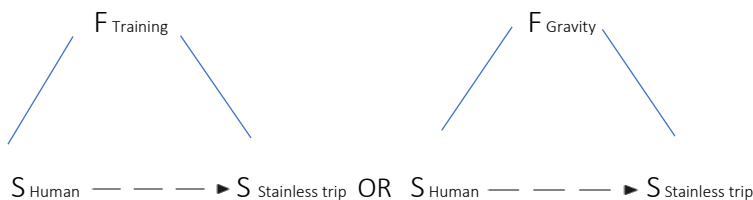
Figure 2: Su-field added to fishbone analysis

Among them, F1, F3, F4, S1, S2, S4, S5, S6, S8 all have repeated occurrences, so it is highly likely that the reason is related to them. Then look for the logical, time, and space correlations between them. Identify initial Disadvantages.

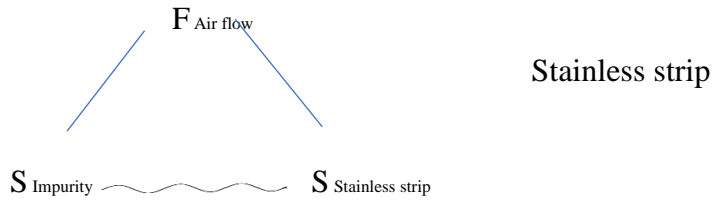
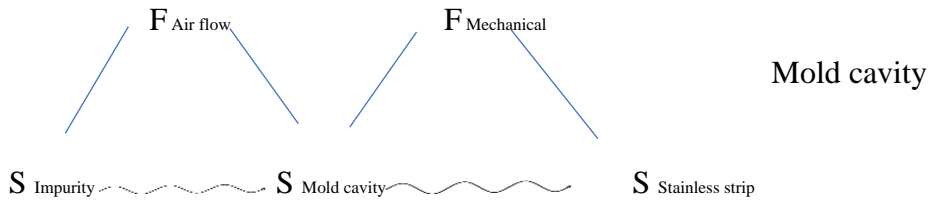
Samples of Stamping part:

In the example above, if there are **scratches** on the stamping parts, then search for potential possibilities through brainstorming:

Warehouse input process: The stainless material handler did not check the surface quality of the stainless during delivery, and rough handling caused damage to the surface of the raw materials.



Production process: The biggest change observed is some particle went into the mold cavity and pasted on stainless strip, that is, impurities enter the mold cavity and attach to the strip, resulting in scratches and bruises during stamping.

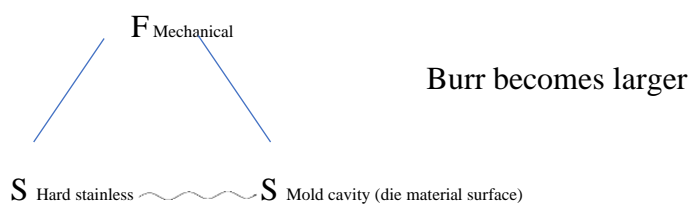
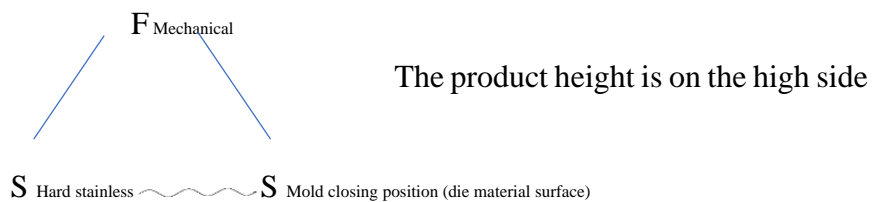
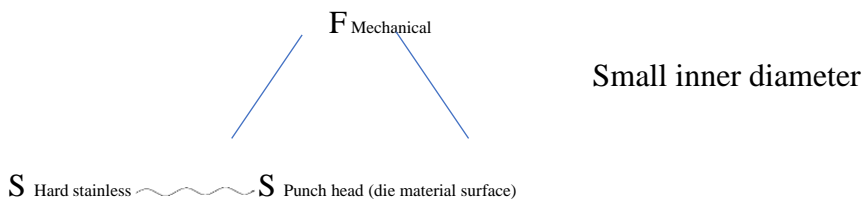


Find repetitive substances and fields such as S_{Human} , $S_{\text{Stainless strip}}$, $F_{\text{Air flow}}$, etc., and consider the logical relationship between them, then transform the problem “reducing product scratches” into another initial problem:” how to protect the surface of the Stainless strip throughout the entire process”. Then conduct causes-chain analysis based on this.

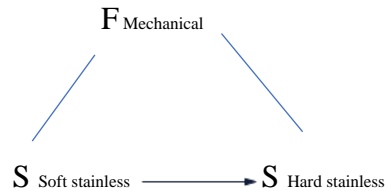
Secondly, using a Su- field model to identify potential reasons of defects can also reveal that different defects come from the same reason.

Defects: smaller inner diameter, higher height, and larger burrs.

Potential reason as follow:



It is easy to find that it is all caused by the work hardening effect of stainless steel.



By the way, another additional effect of using a Su-field model for analysis is that standard solutions can be applied to solve these problems.

As in the example above harden stainless, which according to the standard solution:

1.2.1 Introduce any substance between two substances of the system: *PVD coating on the mold material surface.*

1.2.3 The variant of substance S1 or S2: *Use softer stainless, the hardness after stamping is not so large, and finally increase the hardness by heat treatment. Or the surface of die material is hardened by laser.*

1.2.4 Introduce a victim to absorb harmful effects: *The die components that contact with the stainless surface shall be changed into surface moving parts, which shall be replaced quickly in case of heavy wear.*

While discovering problems, one can also find ways to solve them.

Summary

The addition of Su-field models to fishbone analysis provides a new perspective. Better ability to mine hidden problem, enabling more effective discovery and resolution of problems. Expand the application of TRIZ tool in Lean manufacturing.

Reference:

1. Shan Runhua TRIZ and Applications The process and Methods of Technology Innovation . [J] . Higher Education Press , 2010
2. Zhao Ming , Zhang Wucheng, Wang Guanzhu , TRIZ Enhancement and Practical Applications . [M] . China Machine Press . 2015
3. Simon Litvin , Vladimir Gerasimov, Alex Lyubomirskiy, Sun Yongwei . The Golden Key To Open The Door Of Innovation (II) . [G] . China Science Press . 2020
Darrell L Mann . Hands-On Systematic Innovation For Technical Systems . [J] . IFR Press . 2002
4. Zhang Jian . Quality Management Practice: One Book Of Methods, Skills And Tools Is Enough. [M] . China People's Post and Telecommunications Press . 2021
5. Zhan Bikao . Lean Quality Management: Methods, Tools And Implementation Guide . [M]. China Electronic Industry Press. 2022

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BUSINESS ORCHESTRATION STRATEGY FOR SUSTAINABLE DEVELOPMENT OF ENTERPRISES BASED ON S-CURVE

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Abstract

Technological innovation is an important driving force for enterprise growth. However, the technology environment faced by enterprises is more and more complex, and the rapid iteration of technology makes the technology lifecycle shorter and shorter. In such a technological environment, if the enterprise cannot operate the products on the current technological curve well, or fails to arrange the next generation technology in time (the second S-curve), the enterprise will face a growth crisis or a death crisis. As a law curve of technology development, S-curve can guide enterprises to adopt appropriate product development strategies in different stages of technology development. The second S-curve can well continue the enterprise lifecycle. The paper makes comprehensive use of S-curve, continuous innovation and discontinuous innovation theory to explore “when” and “how” to transform to the second S-curve business. The window of opportunity to explore the second S-curve has been discussed. From the perspective of technology and market, the work divides the path of exploring the second S-curve into four categories: Fusion Mode, Fission Mode, Coupled Mode and Autophagy Mode, which enriches the product evolution theory, and provides an innovation path for the sustainable development of enterprises.

Keywords: *S-curve, lifecycle, continuous innovation, discontinuous innovation*

1. Introduction

In Face of the ever-changing internal and external environment, technological innovation has become the main driving force for economic development and enterprise growth in every countries. Innovation is not only for business survival, but also for growth. As we know, invention is not a random process. In the classic TRIZ theory, Genrikh Altshuller proposed that whether it is the improvement of technology, the iteration of products or the development of enterprises and industries, the final growth form is manifested as an "S" curve over time. Engineers can estimate the stage of the S-curve, and apply the Trends of Engineering System Evolution (TESE) to carry out technical layout, and achieve the strategic reserve of new products and the layout of market promotion in advance in the research and development (R&D). That is, it can jointly use the theories of S-curve and TESE to do incremental innovation, so as to ensure the

rapid development of the enterprise. TRIZ theories, such as TESE and S-curve, provide rich instrumental support in guiding incremental innovation.

However, the economies of scale in the process of technology accumulation will cause the incumbent enterprises to have technology stickiness and path dependence (David, 1985[1]; Arthur, 1989[2]), thus locking the enterprises in the existing technology paradigm. On the one hand, the attention of enterprises is mainly focused on the technology paradigm being used, thus ignoring the attention of other technologies; On the other hand, the self-reinforcing technical specialization in the reproduction process makes the technological base and technical capabilities of the enterprises increasingly narrow, thus undermining their ability to explore new technologies. At the same time, technological path dependence also means that incumbent companies focus their attention mainly on existing customers, ignoring other potential customers (Christensen and Bower, 1996[1]). Thus, core competence becomes core stickiness (Leonard-Barton,1992[2]). Once the market structure changes, companies become very vulnerable. Moreover, any S-curve of growth will slip past the apex of the parabola and then enter into a period of decline. In recent years, with the rapid development of technology, the technology lifecycle is getting shorter and shorter (Fig. 1). For example, the technology lifecycle of information technology represented by ABCDE (Artificial intelligence, Blockchain, Cloud computing, Big data, Edge computing) is shortening in an all-round way, which further intensifies the changes in market structure brought about by technology.

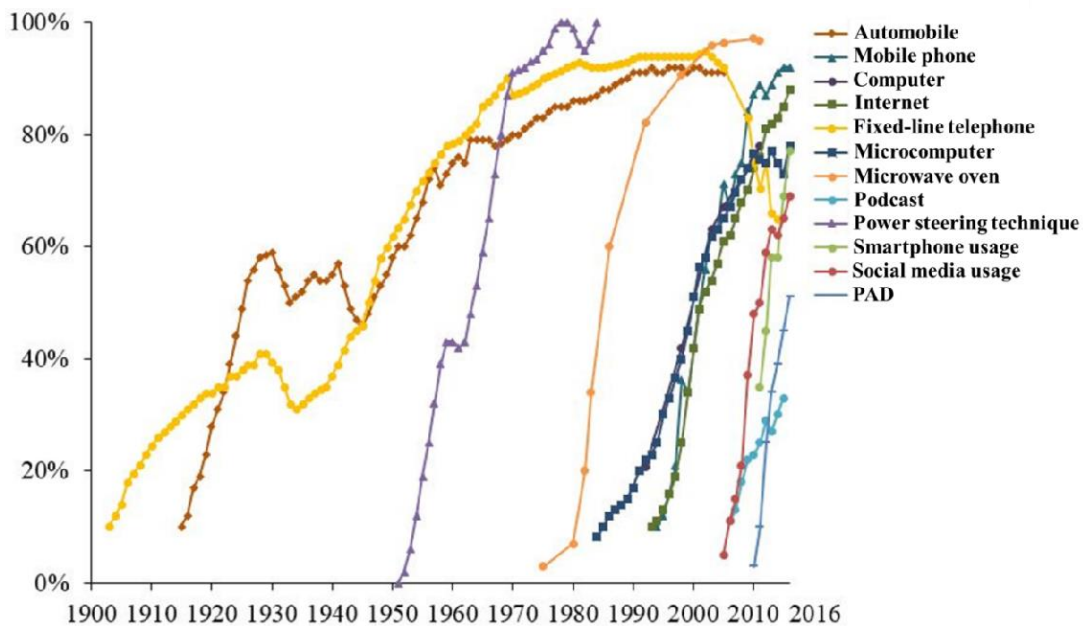


Fig. 1 The development of product technology adoption

Data source: Comin and Hobijn research data from New York university

The development history of multiple industrial technologies shows that the emergence of discontinuous technologies often changes the original industrial structure, making the market leaders reshuffle, and some new entrants will get transcendental development, while the original industry leaders gradually fall behind or even disappear in the market. For example, new entrants can adopt disruptive new technologies to gain market share from incumbents through technological superiority (Christensen, 2018[3]). Rosenberg(1982)[4] pointed out that discontinuous technological innovation is one of the important sources of sustainable growth of a

company. Discontinuous technological innovation provides enterprises with new product innovation opportunities. This innovation activity also opens up new economic development opportunities for the whole economy, so the secret to sustained growth is to keep exploring new S-curves. In this work, the S-curve of the current operation of the enterprise is called the "first S-curve", and the new business (new technology or new product) that replaces the first curve is called the "second S-curve".

Therefore, the synthesis of multiple technology/product second S-curves constitutes the sustainable development lifecycle of the enterprise, that is, if the enterprise can form a continuous cycle of developing a generation of products and planning a generation of products, the second stage of the enterprise lifecycle will be extended and sustainable growth will be formed (Fig. 2). How to handle the orchestration of the first S-curve and the second S-curve has become a prominent problem that incumbent enterprises need to solve in the period of market instability for sustainable survival and development, and at the same time, it represents opportunities and surpassing for new entrants. Therefore, the exploration of the second S-curve is of great significance to both incumbent enterprises and new entrants.

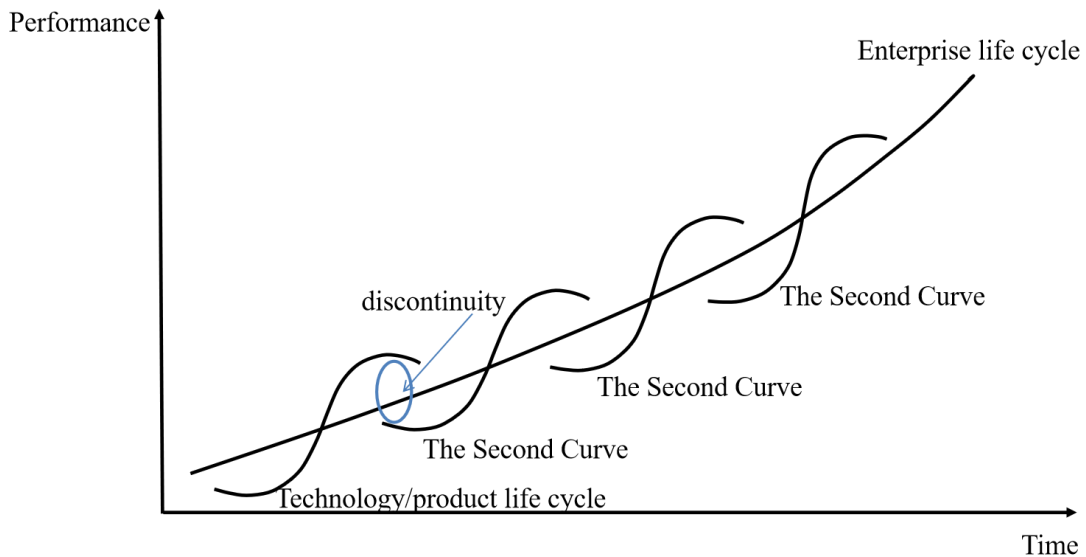


Fig. 2 The relationship between the first curve, the second curve and the enterprise lifecycle

However, the second S-curve is discontinuous from the first S-curve, and there is a gap between the two. Due to the increasing number of development directions, the interweaving and integration of different directions are more close and complex than ever before. Choosing the direction of the second S-curve is not easy, and it has become even more difficult. Therefore, in order to grasp the rhythm of sustainable development, enterprises need to pay attention to the innovative methodology of the transformation of the first S-curve to the second S-curve. This work mainly discussed the business orchestration strategy of enterprise sustainable development from two aspects: "When" and "How". First, when to switch to the second S-curve? Second, how do you find the second S-curve? The solution of these problems is of great significance for perfecting the theories of S-curve and TESE, and promoting sustainable development of enterprises.

The rest of this work is organized as follows. Section 2 introduces the theoretical background, focusing on the classification of continuous innovation and discontinuous innovation, and the methodology of implementing the two kinds of innovation. Section 3 mainly analyzes the breakthrough point, the inflection point, and the limit point of S-curve from the perspective of

time. The opportunity window of the second S-curve conversion was discussed. In Section 4, four kinds of second S-curve transition modes are proposed by using discontinuous innovation theory and TRIZ theory comprehensively, and illustrated by cases respectively.

2. Theoretical background

The path to innovation is fraught with risks - similar ideas, missed opportunities, innovation failures, and misplaced goals that weigh heavily on the shoulders of decision-makers. Because of these risks and heavy pressures, decision-makers often choose to be a follower rather than leader. TRIZ experts and scholars have conducted a comprehensive methodological exploration around these issues.

2.1. Classification and category of innovation

Since Schumpeter put forward the theory of innovation, scholars from different countries have classified innovation according to different criteria and dimensions. This work mainly focused on continuous innovation (that is, innovation is based on the original technological trajectory and knowledge, and constantly improve and introduce new products) and discontinuous innovation (that is, innovation that breaks away from the original continuous technological trajectory). There are two categories of innovation related to the two types of innovation studied in this work.

The first type of classification method is based on the degree of innovation, and innovation is divided into: incremental innovation and breakthrough innovation. Incremental innovation refers to the small degree of improvement and upgrading of products or processes under the original technological trajectory. Breakthrough innovation is a type of innovation that leads to a huge leap in the main indicators of product performance, and it has a decisive impact on market rules, competitive situation, industrial landscape, and even leads to industry reshuffling. All successful technology businesses require continuous (incremental) innovation to meet the changing needs of today's customers. But these innovations must be periodically supplemented by discontinuous innovation. Breakthrough innovation is a major type of discontinuous innovation.

The second type of classification is based on the continuity of innovation and the market division, which divides innovation into: sustaining innovation and disruptive innovation[5]. Sustaining innovation is the continuous improvement and introduction of new products based on the original technological trajectory and knowledge. Disruptive innovation refers to a kind of product or service innovation that introduce performance attributes or combinations of attributes that are valued by low-end or new users, and it based on the principle of good enough technology, and integration of various technologies, which deviates from the performance attributes valued by mainstream market users. This type of innovation is a kind of discontinuous technological innovation that partially replaces or subverts the products or services of the existing mainstream market by occupying the low-end market or new market first, thereby expanding the existing market or opening up new markets. Sustaining innovation is committed to improving existing products in the dimensions that consumers value, and providing better products to existing markets; while disruptive innovations either create new markets or create a new value proposition to reshape existing markets.

In the above two categories of innovation, incremental innovation and sustaining innovation belong to continuous innovation. Breakthrough innovation and disruptive innovation are both

discontinuous innovation, but their positions relative to the first S-curve are different. Breakthrough innovation focuses more on the great leap in the main indicators of product performance brought about by technological innovation; while disruptive innovation emphasizes innovations that meet different market demands. Both breakthrough innovation and disruptive innovation emphasize the development process of emerging technologies or products from 0 to 1. Continuous innovation is an iterative process of optimization from 1 to 100 to 1000. The relationship between these innovation categories is shown in Fig. 3.

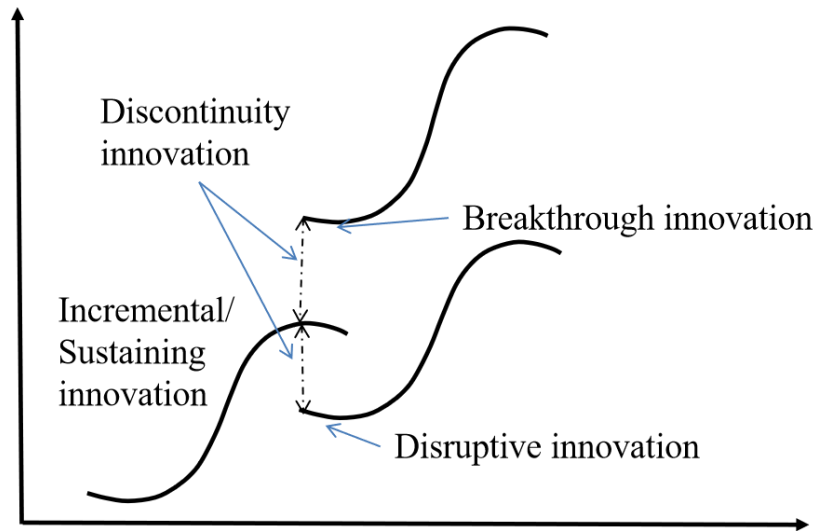


Fig. 3 The relationship between various types of innovation

2.2. Methodology for implementing continuous innovation and discontinuous innovation

On the basis of understanding the types of innovation, it needs to focus on how each type of innovation is developed and implemented.

Methodology for implementing continuous innovation

During the periods of market stability, companies tend to choose to reproduce with existing technological paradigms in order to realize as much value as possible from existing technologies (Raisch et al., 2018[6]).

Almost all the existing methods of TRIZ, including Functional Analysis and Tailoring, Contradiction Analysis and 40-Invention Principles, Standard Solutions, S-curve and TESE, and so on, can solve the invention problems in the continuous innovation process. Specially, the combination of S-curves and TESE is a good way to guide product incremental innovation[7] (Fig. 4), while other methods can address a specific innovation problem in the technology/product development process.

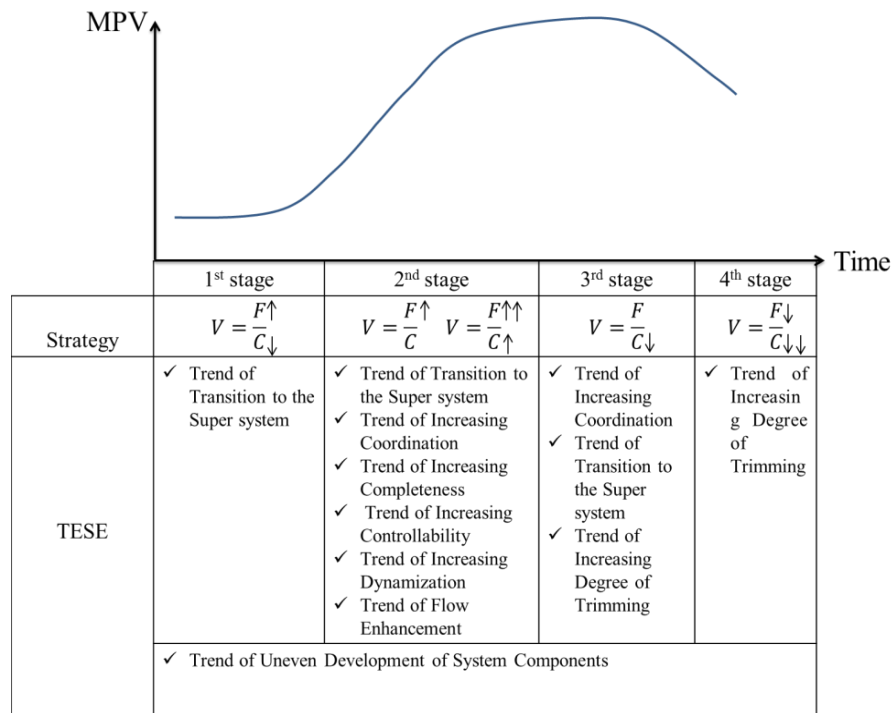


Fig. 4. The S-curve is used in conjunction with TEST to guide technology/product continuity innovation

Methodology for implementing discontinuous innovation

It is not a trivial task for established companies to recognize the potential of disruptive changes and to implement innovations in time[8]. In recent years, the two-wheel drive of technological innovation and consumption upgrading has brought subversive changes and challenges to traditional industries. The discontinuity of innovation model and technology path has been widely concerned (Moerenhout et al, 2018[9]). In the past, most of the research on discontinuous innovation are focused on technological trajectories and technological paradigm.

From the perspective of technological trajectories, relevant studies have basically summarized the main influencing factors of technological trajectories change into four categories: scientific and technological factors (Nelson, 2008[10]), economic factors (Lee & Lim, 2001[11]), institutional environmental factors (Kim et al, 2017[12]) and enterprise factors (Schot & Geels, 2008[13]).

From the perspective of technological paradigm, scholars define technological paradigm as a solution to a specific class of technical and economic problems based on some specific natural discipline principles or specific raw materials (Haupt et al, 2007[14]), or a set of principles, rules, approaches, standards or practices that can solve problems (Christensen & Bower, 2015[15]).

In the transformation process of technological paradigm, not only does technological progress show discontinuity, but also new method systems and thinking models may be

generated (Gao et al., 2019[16]; Svarc et al, 2020[17]), which makes the overall innovation process show mutability and transition characteristics. Therefore, the connotation and extension of the discontinuous innovation formed by the transformation of technology paradigm are no longer limited to the adjustment of the technological development direction limited by the technological trajectories, but instead take the jump of market factors such as demand and product into the research vision, and the denotation of discontinuous innovation is greatly expanded. In the field of technology paradigm transformation, three viewpoints have been formed: technology-driven theory (Foster, 1986[18]), demand-driven theory (Rosenbloom & Christensen, 1994[19]), and co-driven theory of technology and demand. For example, Christensen and Bower (1996) argue that disruptive innovation is the result of a combination of technology and demand, which is the result of the inconsistent between the trajectory of technological progress and product performance available to consumers. The theory of technology paradigm transformation enriches the meaning of discontinuous innovation and expands the boundary of theoretical research.

However, the technology paradigm transformation theory, like the technology trajectories theory, focuses on the post-summary of the technological evolution process and results from a qualitative perspective, so it is difficult to make a forward-looking prediction of the path and direction of discontinuous innovation. It is urgent to make a major breakthrough in theory and research methods for discontinuous innovation research.

3. Business orchestration strategy for when to explore the second S-curve

The second S-curve (technology paradigm transformation) breaks the technical barriers and structural inertia built by advanced enterprises relying on the old paradigm, so that there's an opportunity to take advantage of by the latecomer firm. Therefore, when to transform to the second S-curve (window of opportunity) is of great significance both for incumbents to keep leading and latecomers to catch up.

3.1 S-curve and Windows of opportunity

The period in which an opportunity is evaluated is called the window of opportunity. Being the first in the market during the window of opportunity can lead to significant cash flow. But uncertainty about the stage of the opportunity can create big challenges for startups. If the leader misestimates the duration of the window, then the cash flow will be greatly reduced. According to the window of opportunity theory, the product/technology life cycle provides two Windows of opportunity for latecomers[20] (Fig. 5.). The first window of opportunity occurs mainly at the mature stage of the technological life cycle. At this stage, latecomers can introduce and adopt advanced technologies from leading companies to accumulate technical capabilities. The second window of opportunity mainly occurs during the introduction phase of the technological life cycle. In the early stage of technological system development, scientific and technological knowledge is mostly in the public knowledge domain and laboratory stage, with low requirements for experience and skills and low barriers to entry.

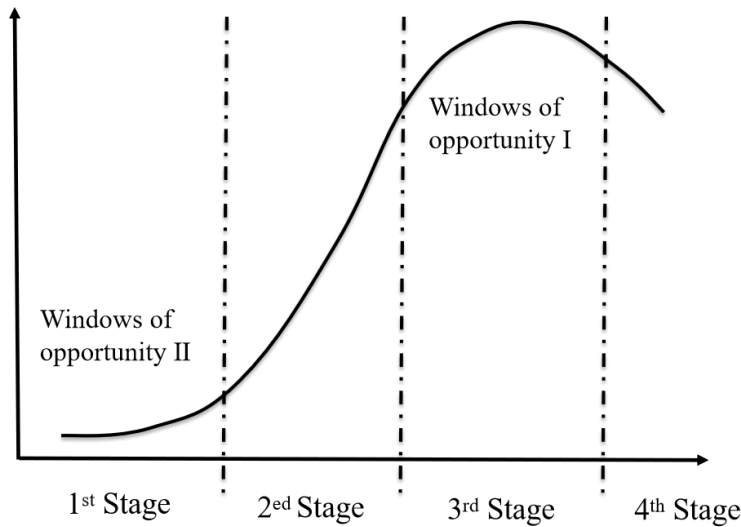


Fig. 5. S-curve and Windows of opportunity

For the first opportunity window, the technology/product has been in the mature stage and is about to enter the decline period. If the pace is slightly slower, the technology/product introduced and developed by the enterprise will become obsolete technology/product. Therefore, it is not easy to grasp the first window of opportunity. For the second opportunity window, both the incumbent firm and the newcomers are at the same starting line. If new companies can enter new technology systems at a faster pace and carry out technological innovation on a larger scale, it is possible to promote the growth of emerging industries faster and effectively narrow the technology gap with previous leading companies. This kind of opportunity window should be grasped.

3.2 Windows of opportunity for exploring the second S-curve

The second S-curve is itself an S-curve, so it is also necessary to pay attention to the second window of opportunity. The question, then, is: at which stage of the first S-curve to develop the business of the second S-curve.

In the development of the S-curve, there are three important nodes: the breakthrough point which is between the first and second stage, the inflection point which is between the second and third stage, and the limit point which is the vertex of parabola in the third stage.

For the breakthrough point, the node is at the demarcation point between the first stage and the second stages, that is, the transition stage between the first stage and the second stage. In this period, engineering systems will soon leave the laboratory stage and will soon enter the market. The engineering system has attracted great attention, and its driving force and resistance force are forming an unstable equilibrium state. The breakthrough at this point represents the engineering system successfully overcoming resistance force to enter the market, i.e. entering a very dynamic growth phase of the S-curve. Then the engineering system can be used the TRIZ to implement continuous innovation. Enterprises with a sense of crisis can begin to expand the second S-curve after breaking through this point.

For the inflection point, the node is at the demarcation point between the second and third stages. Reaching that point marks the end of the S-curve second stage of rapid development.

The engineering system is about to enter the third stage of slow development. Around the inflection point, the engineering system has the best state of resources, and it is also the best time to explore the second S-curve.

For the limit point, the node is at the vertex of parabola in the third stage. The first S-curve meets the development bottleneck. MPV growth turned from "positive" to "negative". This means that there is already a second S-curve that replaces the first S-curve, which enters the second stage of its rapid development. Beyond the limit point, the best period for developing the second S-curve has been missed.

Therefore, the paper holds that the stage between breakthrough point and limit point is the window of opportunity for the exploration of the second S-curve. The best time to explore the second S-curve of development is around inflection point (Fig. 6.).

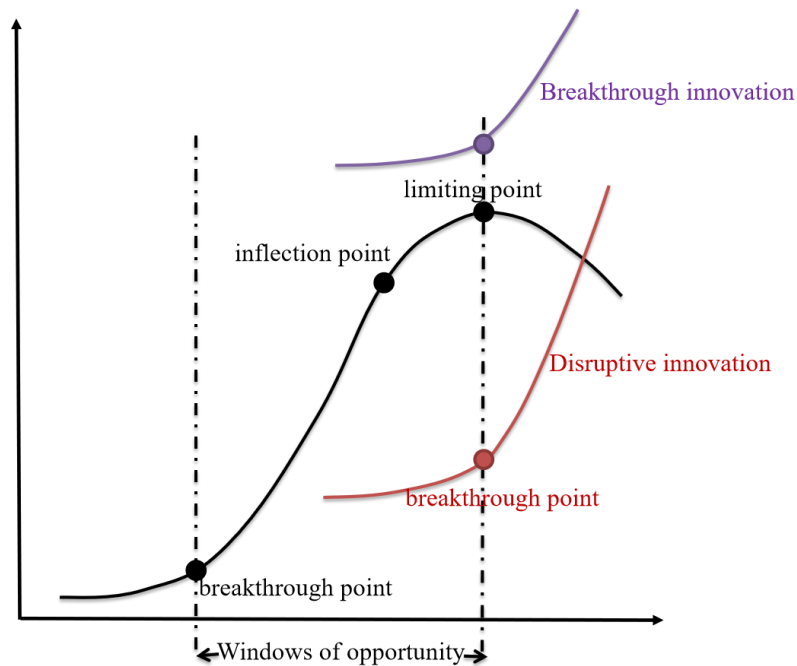


Fig. 6. Windows of opportunity for exploring the second S-curve

4. Business orchestration strategy for how to explore the second S-curve

Discontinuous innovation is a time concept, that is, the transition from the first S-curve to the second S-curve across the stage of discontinuity. Once the discontinuous innovation transformation is complete, the continuous innovation begins immediately. Therefore, exploring innovation opportunities and seizing these opportunities through creative activities has significant significance for second S-curve discontinuous innovation. The development of new technology, the instability of the market and the dynamic competition make the choice of the second S-curve have many possible paths. Based on the theoretical research in Part 2.2, the work divides the path to explore the second S-curve into the following four categories.

4.1 Fusion Mode

The S-curve method in TRIZ theory contains an ecological strategy, that is, in the second stage, it gradually cultivates a product ecology centered on specific user needs by enriching the development and design of technology or products. In the third stage, the adaptive ecosystem of super-system and technology system is formed. The development of the second S-

curve business of Fusion Mode strategy can be achieved by combining with the development strategy of the second and third stages of S-curve and TESE, which can expand the product family ecosystem with the first S-curve product as the core.

Fusion Mode which can be called ecological layout strategy is that forming a series of product families controlled by the first S-curve products or with the first S-curve products as the core by applying the Trend of Transition to the Super system, Trend of Increasing Controllability, and Trend of Increasing Completeness and other evolutionary trends. And then further to form a series of products, and finally these product families gather into a interdependent, resource-sharing ecosystem.

The following takes China's Millets as an example to illustrate the implementation of this strategy. Millets was founded in 2010, and it initially positioned itself as a cost-effective smartphone company. Millets has made a series of improvements in mobile phone hardware and human-computer interaction software, and has become a leader in the smartphone market with cost-effective product design. Beginning in 2015, Millets was affected by the bottleneck of industry development, and shipments began to decline. Millets began to lay out the periphery of the phone, that is, to develop products that can be adapted to the smartphone and products controlled by the smartphone, such as mobile power supply, earphones, protective cases, around different consumption scenarios of mobile phones. At the same time, Millets also focuses on home intelligent hardware products, such as AI audio and video, smart TV, air cleaner, balance car, Intellilamp, etc, which all can be smart link with Millets mobile phone. In addition, the company has also expanded its intelligent hardware offerings, and functional consumable products such as towels, bags, signature pens and mattresses etc. From intelligent hardware to living supplies, Millets has created a “MI fans” lifestyle in an all-round way. Millets’ product ecological expansion along the three circles of “mobile phone peripheral - smart hardware - lifestyle”. As a result, Millets has created a series of ecological chain enterprises owned or controlled by Millets. The product family of Millets is shown in Fig. 7.

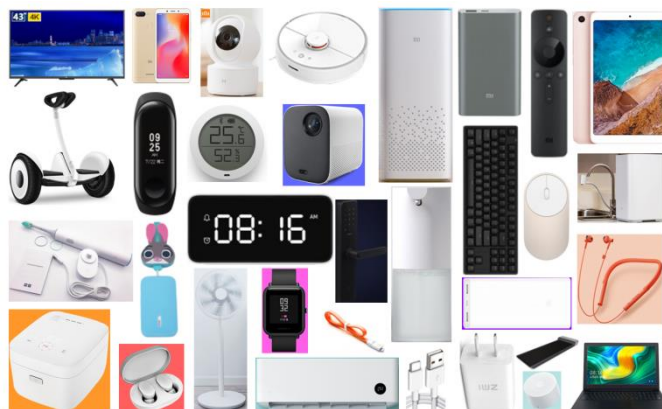


Fig. 7. The product family of Millets

As can be seen from the above case of Millets, When the smartphone business reached the second stage, Millets began to use the Trend of Transition to the Super system, Trend of Increasing Controllability, and Trend of Increasing Completeness and other evolutionary trends to lay out product gradient development circles. When the company entered the mature stage of smart phones, the growth of the company's mobile phone business was weak, but by taking advantage of the evolution trend such as The Trend of Increasing Coordination and the Trend of Transition to the Supersystem, it constantly improved the existing products and new products

formed in the second stage, and built a series of second S-curves growth businesses that could replace the first S-curve, see Fig. 8.

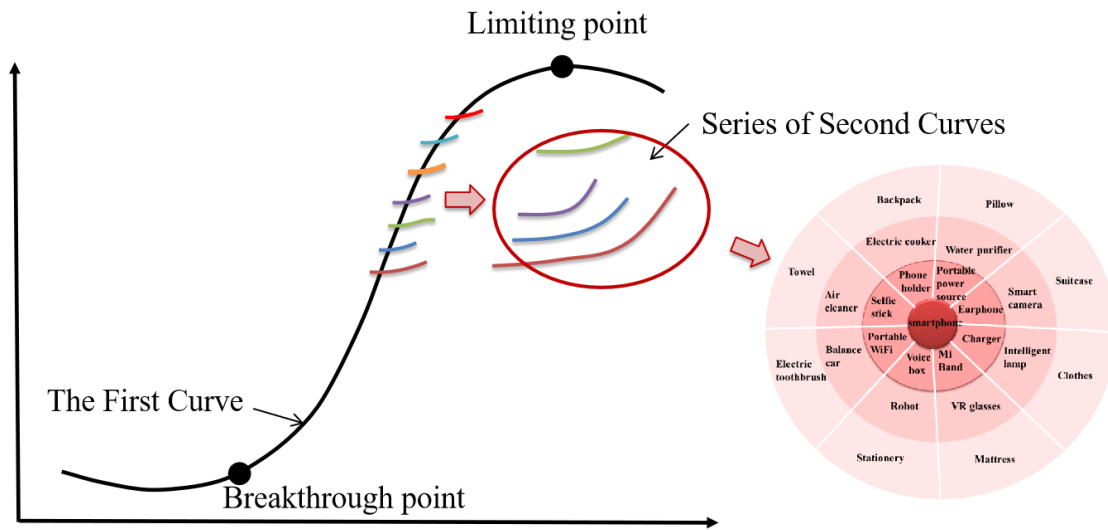


Fig. 8. Ecological layout strategy of Millets

4.2 Fission Mode

Compared with the Fusion Mode (Ecological layout strategy), the Fission Model emphasizes the evolution of the first S-curve business to the super-system, that is, the fission of the first S-curve business into the expansion, extension or matching of the company's existing business or related business, or even a new growth point that has nothing to do with the company's existing business.

From the perspective of business relationship, the new business relationship is not like the ecosystem formed by each business supporting and supporting each other in mode 4.1, but becomes more divergent, so it is called the "Fission Mode". In the Fission Mode, the expansion of the second S-curve business can be implemented according to the sub-trend of the Trend of Transition to the Super system: The parameters of the integrated system are more and more different from those of the original system: replication of the first S-curve business → extension of the first S-curve business → expansion of the first S-curve business → fission of the first S-curve business. In the implementation process, the organizational model adopted can take the form of "intrapreneurship".

4.2.1 Replication of the first S-curve business

This strategy refers to the large-scale replication of the first S-Curve business. Xibei company let their chefs or store managers to expand new stores across China. The initial cost is borne by the company, the entrepreneurial team can obtain 40% of the shares. Through the adoption of this "entrepreneurial competition department" mechanism, Xibei has rapidly achieved the transformation of expanding from a rural store to a catering group worth about 7 billion RMB.

4.2.2 Extension of the first S-curve business

This strategy refers to taking the first S-curve business as the core component, and extending new products to form the second S-curve business on this basis. Take Dyson, for example. Dyson is a typical technology-driven company, and its founder, James Dyson, is an inventor entrepreneur. There are two epoch-making technologies in the history of Dyson technology

research and development - "cyclone technology" and "digital motor technology". Dyson relies on these two technologies to firmly grasp the minds of middle and high-end consumers in the existing categories. Dyson continues to complete continuous innovation in the field of digital motors (V1→V11), at the same time, based on digital motor technology, there are a series of new products with digital motors as the core components had been developed, such as vacuum cleaners, hair dryers, bladeless fans and air-purifying headphones. Relying on the high technical barriers of the core components of digital motors, Dyson has created a series of second S-curve businesses such as vacuum cleaners, hair dryers, bladeless fans and air purification headphones.

4.2.3 Expansion of the first S-curve business

This strategy refers to the continuous expansion of new businesses around the demand of the first S-curve business chain. Auto Boty, for example, was founded in 2010 and its main business is industrial robots. The company observes that most customers' demand for industrial robots is often accompanied by a demand for supporting products related to industrial robots. However, because the company's production capacity is relatively saturated, there is no energy to meet this related demand of customers. To this end, Auto Boty has set up a Maker Technology center. As long as they have the ability to fulfill customer needs and strengthen the function of the industrial chain, both internal makers and external makers in the industrial chain can get the corresponding support provided by the platform. The business that Auto Boty cannot meet the needs of customers is realized through the innovation and entrepreneurship of makers. Through the expansion of the first S-Curve business in the industrial chain, it has now developed into the largest and most powerful professional industrial robot application system integrator in China.

4.2.4 Fission of the first S-curve business

The strategy is to build on the core strengths of the first S-Curve business and develop a second S-curve products that is completely different from the first S-Curve, or the first S-curve business becomes a platform, supporting and incubating a series of new profit growth points. Take PHNIX, for example. In 2002, Zong Yi founded PHNIX Energy Saving Equipment Co., LTD., whose main business is focused on heat pump technology related products. In 2005, PHNIX began to adopt the development mode of "internal entrepreneurship fission", encouraging some key employees to set up their own companies, and becoming a new profit growth point for PHNIX. There are 7 such kind of enterprises that established by PHNIX employees. Their business mainly involved in the production of metal products, energy-saving equipment, electrical, plastic products and other businesses. The fission companies are jointly invested by PHNIX's core employees. These enterprises are independent legal persons, and the employees are the main shareholders of their own enterprises, holding more than 50%. For PHNIX, it controls the key high-profit links, strengthens the competitive advantage, and forms a series of profit growth points.

4.3 Coupled Mode

This strategy emphasizes the coupling of resources within the enterprise. It emphasizes that the newly expanded second S-curve business and the existing business of the enterprise are coupled and promoted each other. Take Amazon, for example. Jeff Bezos founded Amazon in 1994. Amazon has successively built five second S-curve businesses, including e-commerce, Prime, Marketplace, Amazon Web Services (AWS), and artificial intelligence. So that Amazon has been exploring new areas for 30 years, and has been the dominant player in new areas.

Amazon and Bezos himself have repeatedly emphasized a business sense - the Flywheel Effect. The "Flywheel Effect" refers to the fact that the various business modules of a company will push each other organically, like the cogs of the bite. At first, it takes a lot of effort to go from standstill to rotation, but every turn of effort will not be wasted, once you turn, the gear will turn faster and faster. At Amazon, the flywheel effect is made up of three businesses: Prime, Marketplace, and AWS. Prime is Amazon's VIP service. Marketplace allows third-party sellers to sell goods on Amazon's platform. The main function of AWS is to provide enterprise-class cloud services to all types of businesses. Prime, Marketplace, and AWS create Amazon's flywheel effect: the more products, the more choice customers have; The more choices customers have, the more they buy VIP services; The more VIP services you buy, the more often and the more you consume. The more often and volume you consume, the more Amazon can undercut suppliers; The more Amazon cuts prices, the more customers profit... This flywheel keeps spinning, and it has also made the Amazon Empire thrive for three decades(see Fig. 9.).

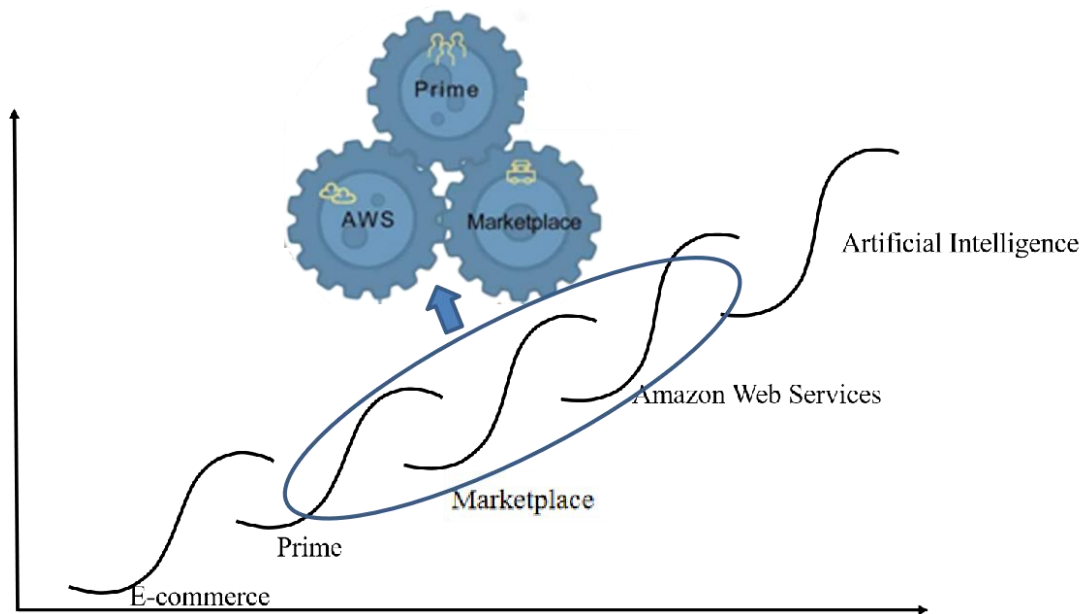


Fig. 9. Amazon flywheel coupled mode

4.4 Autophagy Mode

As technology continue to evolve, the magnitude of change in existing systems will increase, and innovation will eventually evolve into breakthroughs. Therefore, incumbent enterprises need a kind of courage to overcome their own, that is, decisive autophagy. This strategy refers to the phenomenon of introducing new products (the second S-curve business) to compete with the company's existing products(the first S-curve business), or replacing the company's existing products with new products. When companies don't want to introduce new products to compete with existing ones, they often fall under the illusion that if they don't develop new products, no one else will either. When a new opportunity arises, new entrants tend to be more flexible because they don't need to think about an existing product or business. The autophagy model may have a great impact on the existing product business of incumbent enterprises, so incumbent enterprises need some courage to adopt this model.

Take Apple, for example. In 1976, Steve Jobs and Steve Wozniak co-founded Apple. Jobs also ran several classic "second curve" businesses throughout his life. Jobs also ran several classic "second S-curve" businesses throughout his life. Apple's first product was the iMac. It launched

its second product, the iPod, in 2001. After Apple launched iTunes in 2007, the company became known as the "Music Company." Because the iPod accounts for 50% of the company's revenue, and its market share is 74%. At that time when the iPod was the company's flagship product, Apple launched its second S-curve business, the iPhone. The iPhone completely covers the functions of the iPod. In other words, Apple replaced its first S-curve business with a second S-curve business. The development of these two businesses is a complete autophagy model. Thanks to such decisions, this is not only Apple's proudest achievement, but also a memorable turning point in the history of global smartphone manufacturing. Success followed with the iPhone, making Apple the most valuable brand in the world for many years in a row.

5. Conclusions

In the process of technological innovation, continuous innovation is built on the basis of existing products and production processes, while non-continuous innovation needs to deviate from the existing technological paradigm. Once continuous technology reaches maturity, discontinuous disruptive innovation and the revolution of technological paradigm become the driving force of social progress. Therefore, when and how to choose and transform between the first S-curve and the second S-curve of technology/product become the key to sustainable development of enterprises. Using TRIZ theory and discontinuous innovation theory, the work discusses when and how to transform from the first S-curve to the second S-curve.

The work argues that the window of opportunity to explore the second S-curve lies in the stage between breakthrough point and limit point. The best time to explore the second S-curve of development is around inflection point.

From the perspective of technology and market, the work divides the path of exploring the second S-curve into four categories: Fusion Mode, Fission Mode, Coupled Mode and Autophagy Mode. The work explains the four strategies respectively and explains them with cases. On the basis of S curve and TESE, the work carries out the exploration of the second S-curve business, enriches the product evolution theory, and provides an innovation path for the sustainable development of enterprises.

Acknowledgements

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References

1. Christensen, C. M., and J. L. Bower. Customer Power, Strategic Investment and the Failure of Leading Firms[J]. *Strategic Management Journal*, 1996,17(3):197-218.
2. Leonard - Barton, D. Core Capabilities and Core Rigidities: A Paradox in Managing New Product Development[J]. *Strategic Management Journal*, 1992,13(S1):111-125.
3. Christensen, C. M. Disruptive Innovation : An Intellectual History and Directions for Future Research[J]. *Journal of Management Studies*, 2018,55(7):1043-1078.
4. Rosenberg N. Inside the Black Box: Technology and Economics[M]. New York:Cambridge Univ. Press, 1982.

5. Clayton M Christensen. The Innovator's Dilemma[M]. Harvard Business Review Press,21 Jan. 2016
6. Raisch, S., T. J. Hargrave, and A. H. Van de Ven. The Learning Spiral: A Process Perspective on Paradox[J]. *Journal of Management Studies*, 2018,55(8):1507-1526.
7. Zhang Jing, Zhang Xiangmin, Guo Kai. Study on the TESE Application Roadmap under the Strategic Development of S-curve[C]. TRIZfest 2019, September 12-14. Heilbronn, Germany.
8. Melanie W, Regina G, Franz S .Collaborative open foresight - A new approach for inspiring discontinuous and sustainability-oriented innovations[J].*Technological Forecasting and Social Change*, 2018: S0040162517306273-.DOI:10.1016/j.techfore.2018.07.008.
9. Moerenhout, T. et al. E-health beyond technology: Analyzing the paradigm shift that lies beneath[J]. *Medicine, Health Care, and Philosophy*, 2018, 21(1):31-41
10. Nelson, R. R. Factors affecting the power of technological paradigms[J]. *Industrial and Corporate Change*, 2008,17(3):485-497
11. Lee, K. & C. Lim. Technological regimes, catching-up and leapfrogging: Findings from the Korean industries[J]. *Research Policy*, 2001,30(3):459-483
12. Kim, D. et al. Standards as a driving force that influences emerging technological trajectories in the converging world of the Internet and things: An investigation of the M2M/IoT patent network[J]. *Research Policy*, 2017,46(7):1234-1254
13. Schot, J. & W. Geels. Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda and Policy[J]. *Technology Analysis & Strategic Management*, 2008,20(5):537-554
14. Haupt, R. et al. Patent indicators for the technology lifecycle development[J]. *Research Policy*, 2007,36(2):387-398
15. Christensen, C. & J. Bower. Customer power, strategic investment, and the failure of leading firms[J]. *Strategic Management Journal*, 2015,17(3):197-218.
16. Gao, Y.C. et al. How do firms meet the challenge of technological change by redesigning innovation ecosystem? A case study of IBM[J]. *International Journal of Technology Management*,2019,80(3/4):241-265.
17. Svarc, J. et al. A new innovation paradigm: European cohesion policy and the retreat of public science in countries in Europe's scientific periphery[J]. *Thunderbird International Business Review*, 2020,62(5):531-547.
18. Foster, R. *Innovation: The Attacker's Advantage*[M]. New York: Summit Books, 1986.
19. Rosenbloom, R.S. & C. M. Christensen. Technological discontinuity, organizational capability and strategic commitment[J]. *Industrial & Corporate Change*, 1994,3(3):655-685.
20. PEREZ C, SOETE L. Catching up in technology: entry barriers and Windows of opportunity[M]. DOSI G, FREEMAN C, NELSON, et al. *Technology change and economic theory*.London: Francis Pinter, 1988:458-479

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POPULARIZATION OF TRIZ PEDAGOGY AND CREATIVITY DEVELOPMENT AMONG YOUNG CHILDREN AND THEIR PARENTS. ARTISTIC APPROACH

Alisa Faer

Abstract

The practice of using the artistic approach to popularize TRIZ, TRIZ pedagogy and other tools for creativity development. Cartoons, fairy tales, stories, quests, videos as a key to a wide audience.

Keywords: TRIZ popularization, children and parents, TRIZ pedagogy, artistic approach, fairy tales, cartoons.

1. Introduction

My path to the world of creative thinking and problem solving began through "Young Inventor's Fairy Tales by Cat Potryaskin". [1]. This is a collection of interesting open tasks from fairy tales, compiled by Anatoly Guin. As a child, when I solved these problems, it felt like I was helping a character, I wanted to find as many solutions as possible and see if I guessed the one that was finally used in the story. I did not yet know the TRIZ tools that would help me come up with solutions faster and acted intuitively, but it was then that I remembered that amazing feeling when you look for an original way, use your imagination and end up with a non-obvious solution.

I grew up, the tasks became more complicated, but the habit of solving them, and doing it creatively, not stopping at the first option, remained. And I believe that this habit was formed at the time when I joined the world of inventive thinking thanks to fairy tales and an artistic approach to presenting inventive problems. I had a dream to help other people unfamiliar with TRIZ to enter this field, to feel the pleasure of solving problems and challenging their thinking. I see the key to introducing TRIZ to a new audience is to use an artistic approach.

At the moment, my professional path in TRIZ pedagogy is related to the development of materials aimed at an audience unfamiliar with TRIZ. Mostly for preschoolers and their parents.

To increase efficiency, I set myself the task of developing materials that:

1. Work directly with the audience, without any intermediary like teacher or specialist who knows something about TRIZ. Goal: to reach as large an audience as possible; IFR: there is no teacher, but his/her function is fulfilled.

2. Cause the interest of the audience not only as mind developing tasks, but as entertainment. Plot, bright form, intrigue. Learning is given implicitly. IFR: users themselves want to learn. The solution - they do not notice the learning process. There is no need to stimulate motivation, it arises on its own (if the material is composed correctly, interesting, you empathize with the hero and want to help him/her and find out how it all ends).
3. Use modern technology, interactivity, look for an interesting form of materials, use a variety of presentation formats. The goal: to reach a larger audience. Some like books, some like cartoons, some like quests, some like music videos on YouTube. The task: to try different formats of presentation, finding the most advantageous.

Below I tell about my most successful experiments on the introduction of an artistic approach to develop creativity and to get new people acquainted with TRIZ tools.

2. Main body

2.1 Cartoon “TRIZ with Potryaskin the Cat”

Together with Anton Smirnov and Paramult company we released a twelve-minute cartoon on YouTube about how Potryaskin the cat helps the forest dwellers solve problems [2]. According to the plot, the heroes need to get a bag of gold from a dragon in order to stop deforestation. The cartoon introduces viewers to such concepts as: resources, experiment, subtask, main function, contradiction. Since it was an experiment aimed at a younger audience, the concepts were given in a free, simplified interpretation, and the cartoon was made in black and white. What in professional circles is called animatik (the characters don't even move, it's a draft of a cartoon). Despite this, the cartoon has aroused audience interest. At the moment the video has 21 thousand views on YouTube, and the feedback form [3], in which we asked how interested viewers were in this topic and gave tests for understanding the terms, was attended by several hundred people, and the answers are still coming in.

I cannot recommend the cartoon for practical application, because now I see that the wording of the terms is not correct enough and a more systematic approach is needed, at least a separate cartoon for each concept or TRIZ tool. However, the response of the audience at that moment made it clear that the direction was right, and the artistic edging captures the viewers' interest and allows to present the developmental part in an easy and entertaining way.

2.2 "TRIZ and the Cat" - a project in social networks

Together with TRIZ-teachers Elena Buyanova and Alena Popova, we organized a social networking project called "TRIZ and the Cat" [4, 5]. At the moment, the total audience is 6,000 subscribers. The aim of the project was to test new approaches in popularizing TRIZ and TRIZ-pedagogy, the audience being parents and teachers. We tried to present TRIZ theory and practice in the form of interactive exercises, videos, animations, fairy tales, poems, lesson scenarios, and quests. New author's exercises and intellectual games were made available to the public, and the audience played them online. We introduced subscribers to TRIZ concepts (ideality, IFR, contradiction, cause-effect analysis, system approach, system operator, morphological analysis), the history of TRIZ creation and development, and other methods of creative thinking development. A separate niche was occupied by the more understandable for a wide (and especially younger) audience topic "Development of Creative Imagination". In order to systematize knowledge in this area and to add an artistic approach, we decided to combine the techniques of guided imagination in a fairy tale online quest [6]. Parents and children were invited to be

heroes, to save those who got into trouble. Each day of the quest had a new plot twist, new tasks, new piece of the theory and new step on the drawn map of the magical world. More than 400 people took part in the quest, they sent their solutions to the tasks, crafts, drawings and thoughts.

After the project gained speed, we were contacted by a publishing firm with a proposal to publish the games from the quest in books. Thus, three books were published in 1,000 copies each [7, 8, 9]. In addition to developmental games in cards, the books contain information about what TRIZ and TRIZ-pedagogy are and why they are useful. Thus, we got a super effect - by attracting a new audience with an artistic game form of presentation, we also attracted the interest of publishers, who, by publishing the books, allowed us to reach an even larger number of people.

2.3 Continuation of the Tales of the Potryaskin the Cat

This was not the end of the story of the fabulous cat, a guide to the world of TRIZ. Anatoly Guin and VITA-press Publishing Firm offered me to write a sequel to the original fairy tales and inventions from Potryaskin the cat. However, I slightly changed the format.

First, I suggested making not a collection of short stories, but one full-fledged fairy tale story for one full book. As the story progresses, the characters encounter problems that the reader is asked to solve (the answer choices are given in mirror print).

Second, I tried a diversity in approach. One book was written based on the famous fairy tale "The Wolf and the Seven Little Goats" [10]. That is, so that the reader was attracted not only to the familiar form of the fairy tale plot, but also to the familiar characters. And the second book was based on my author's story of Potryaskin the cat's quest for the fruit of the magic tree [11]. This was done to give the reader a choice, to play on the basis of a long-familiar story or, conversely, if the old tales are already boring, welcome to a new one.

Third, I've included more exercises in the stories, tasks that are not only semantic, but also visual. These are coloring books. The reader is encouraged to finish drawing, to imagine. In creating the book were solved several contradictions, for example, how to make the book both a full coloring book, but also a colorful book? The solution – some part of each illustration was left in black and white, and another was colored by the artist.

Two books were published in 1,000 copies each. I want to emphasize that these are basically fiction books, the kind that will not confuse a reader unfamiliar with TRIZ pedagogy, but will allow him or her to softly get in touch with the topic. Inventive problems and exercises are woven into the story. TRIZ concepts and tools are not given directly, but are mentioned in the introduction, thus creating an entry point for a new audience that has not been familiar with TRIZ at all before.

2.4 Partnering with a children's channel on YouTube

The popularization of TRIZ and the search for new formats has borne fruit. I was contacted by the creators of a popular YouTube channel for children, Aleksandr and Anna Kondratevs. At that time, 2018-2019, the number of subscribers to their channel was about 5 million users. They made videos with their two daughters about various family activities and adventures. However, they wanted to produce better and more useful content that would not only entertain, but also develop children's abilities, both mental and creative. So for four years now I've been working as a script and lyrics writer and idea creator for their children's channel, and since then

the audience has grown to 23 million subscribers. We create useful videos, some of which are aimed at instilling in children the habit of thinking creatively, finding different solutions to problems, and developing imagination. The age of the audience is very small, about 5-6 years old, so the topics are chosen to be simple.

For example, the video about how the little sister lost her rattle and the older sister came up with different options of what to make a rattle by herself, using improvised resources (13 million views) [12].

Or a video about a family celebrating the New Year in a hot country, but wanting to create a winter mood. The characters come up with many ways to solve this open task, how to make snow on their own, how to make frost on the windows, how to make a snowman (668 thousand views) [13].

We also create videos that include imaginative exercises, such as the song "What do you see" (27 million views) [14], in which parents and children being on the road play a game of imagination and guess what a cloud or the crown of a tree looks like. A successful format was simple songs in which certain meanings could be incorporated. For example, the game "What do you see in this shape" is easily remembered by the words: "Outside the window you can find a tree! One, two, three... What do you see?" or "Outside the window you can find a cloud! What do you see? Say it aloud!"

Unfortunately, the collaborative format imposes limitations on me in the sense that there is no opportunity to get feedback from the audience, no opportunity to cover TRIZ directly. But YouTube as a potential platform for popularization, as well as the formats of videos, sketches and songs (at least, if we are talking about the youngest audience) - have shown themselves well.

3. Conclusions

The aim of the paper was to demonstrate some of the developments and practices that I have managed to implement within the framework of TRIZ and TRIZ-pedagogy popularization. Of course, these are not all the projects in which I have been involved during the time I have been working on this topic, that is, for the last 8 years. There were books, scripts and ideas that did not see the light of day, at least not yet. But all my work has one thing in common. I believe that the key to the large-scale popularization of TRIZ, TRIZ-pedagogy, creative and thinking practices lies in the artistic approach.

First, when artistic means are involved, i.e. the plot, intrigue (if we are talking about texts), and additionally visual range, emotions (if we are talking about video formats), the audience connects not only intellectual qualities, but empathy with the characters, feelings, there is an interest in knowing what will happen in the end. It gives an additional motivation.

Secondly, with an artistic approach it is possible to implement the principle of "there is no teacher, but his function is performed". That is, the material itself delivers itself to the user without an intermediary.

Thirdly, I have an assumption that it is the artistic format (as well as the game format) that is the future of pedagogy.

I plan to continue developing within this approach, looking for new forms and means, and hopefully someday I will be able to share the following results with the TRIZ community.

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References

1. Guin A.A. Young Inventor's Fairy Tales by Cat Potryaskin, Moscow, VITA Press, 2002.
2. Cartoon "TRIZ with Potryaskin the Cat". 2016.
<https://youtu.be/EjHuK-f40so>
3. Cartoon feedback questionnaire. 2016
<https://paramult.ru/triz/>
4. TRIZ and Cat project on Facebook. 2018-2023
<https://www.facebook.com/trizikot/>
5. TRIZ and Cat project on Vkontakte. 2018-2023
<https://vk.com/trizikot>
6. Quest from TRIZ and Cat. 2018
<https://www.facebook.com/groups/159989291280623>
7. Faer A., Buyanova E. Development of Creative Thinking. Part I. Smart cards for parents. A set of games for the development of imagination and fantasy, Moscow, SOLON Press, 2020.
8. Faer A., Buyanova E. Development of Creative Thinking. Part II. Smart cards for parents. A set of games for the development of imagination and fantasy, Moscow, SOLON Press, 2020.
9. Faer A., Buyanova E. Development of Creative Thinking. Part III. Smart cards for parents. A set of games for the development of imagination and fantasy, Moscow, SOLON Press, 2020.
10. Faer A.S. Adventurous Tasks. Potryaskin the Cat and the Seven Little Goats, Moscow, VITA Press, 2020.
11. Alice Faer: Adventurous Tasks. Potryaskin the Cat and Magical fruits of the Kus-Kus tree, Moscow, VITA Press, 2020.
12. YouTube video – Children’s open task: How to make a rattle, 2019
<https://www.youtube.com/watch?v=ZDbfAncLo6c>
13. YouTube video – Children’s open task: How to create winter look, 2019
<https://www.youtube.com/watch?v=PgjBF8B4FwA>
14. YouTube video – Children’s imagination exercise: Look for shapes in clouds and trees, 2019
<https://www.youtube.com/watch?v=yXE7o79GMVU>

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TRIZ AS A SOURCE OF TOOLS FOR FUTURE EDUCATION

Alla Nesterenko

Abstract

An important aspect of modern education is, in our opinion, working with the future. A modern person needs to remember that the world is constantly changing, to be able to build an image of the future in the field of knowledge with which he works. In the paper, we will touch upon how TRIZ tools help to predict changes in the world around us. We will discuss how it relates to formal education. We will present the experience of using these approaches in our work with teenagers.

Keywords: TRIZ, OTSM-TRIZ, education, future, teenagers, Three Worlds Model

1. Evolution of Education – Where Are We Today?

The education system is an inertial system, it changes slowly and lags behind the rapidly changing world. The new approaches, which proclaim the focus on the formation of key competences instead of subject-specific skills, are struggling to make their way into real schools around the world.

The traditional approach to education can be summarised by the formula 'society teaches you what it thinks you need to learn and does it in ways that are effective from its point of view'. Hence a rather rigid approach to the formation of content, choice of methods and means of education. Society's retreat from democracy often leads to a tightening of this principle. An example of this is the current educational situation in Russia and Belarus, where any variability is consistently eliminated.

In contrast to traditional education, innovations are usually associated with the "learner-centred" approach, with giving students freedom of choice in various parameters, from forms and modes of learning to freedom in the selection of content. In practice, this is realised through game and project-based learning scenarios oriented towards solving specific problems relevant for pupils. However, it is not only the focus on individualisation and variation that determines the future of education.

The reasons for changes in the content of education are well described through the change of information barriers. According to the concept developed by V.M. Glushkov, the contradiction between the information demands of society and its technical capabilities to provide information was solved in different ways in different periods of civilisation development [9].

The first information barrier was the invention of writing, which made it possible to store information. This made it possible to record knowledge and activities and to transmit them in the process of teaching.

The second is associated with the invention of printing. This made it possible to disseminate knowledge widely. Accordingly, it created conditions for the emergence of schools with a common educational content.

The second is associated with the invention of printing. This made it possible to disseminate knowledge widely. Accordingly, it created conditions for the emergence of schools with a common educational content.

The third barrier was overcome by the emergence of computers capable of collecting and processing large amounts of information, but unable to interpret them in a meaningful way. Today we see the active introduction of information technologies into the school curriculum. This dramatically increases the volume and quality of information available to schoolchildren, allows for more complete feedback in the process of mastering skills, and creates conditions for individualization of education. However, in our opinion, the education system has not yet fully coped with the third information barrier. Teaching schoolchildren the technologies of information search and computer data processing should have changed the concept of education. But this is happening slowly and has not yet become a common practice, despite some successful cases, such as the experiments of Indian scientist Sugata Mitra [7].

Probably, today, with the emergence of neural networks, we are approaching the fourth information barrier, when data are not just collected and processed according to predetermined algorithms, but on their basis meaningful selections are made (for example, collections of examples on a chosen topic - what in TRIZ is called "information banks"), problems are solved, and unique artistic texts are created.

What will the education of the future look like? What is the place of TRIZ in this new picture? What can (and should) we do today to bring this future closer? Let us identify the trends that seem significant to us and determine what role TRIZ-based technologies can play in their development.

2. Some Approaches Implementing Education for the Future

2.1 Functional Approach

The traditional approach considers the content of education as separate academic disciplines: maths, native/foreign language, physics, biology, history, etc. Each discipline is built on a certain system of concepts, and its separate study allows to transfer this system to pupils. Any attempt to switch to other ways of content formation, for example, problem-centered or object-of-interest-centered, destroys the system of concepts built in the usual way.

An alternative is the functional approach. Here the system of concepts is formed depending on the problem that the pupil needs to solve. For example, when trying to understand how time is presented in a language through a verb, the student finds the essential parameters that form the category of tense in that particular language. In order to learn in this way, it is important for the student to understand how the knowledge system is organized and to be able to enter this system from a particular problem situation.

The development of the functional approach in the long term will lead us away from static, slowly changing, subject content to the acquisition of general ways of acquiring the knowledge and skills needed to solve a particular problem. It is these general ways that will become the main content of education.

How can TRIZ help here?

Within the framework of problem-oriented learning based on OTSM-TRIZ, universal models are selected and developed to help students understand how knowledge is organized. We use a system of models taken from OTSM and TRIZ and adapted to the learning tasks [4,6,10].¹⁹

The information block of this system of models is represented by three levels. At the lower level, objects of the surrounding world are learnt through their parameters. Concepts consist of parameters. Each parameter has a name and values. Any object can be described through an infinite number of parameters. Depending on the tasks to be solved, different parameters have different values. Parameters are connected with each other by systemic and cause-and-effect relations.

At the next level, by considering the object as a tool for something, performing a certain function, we select the parameters that are important for the fulfilment of this function. It is also important for us to consider the object in a system hierarchy and in development, in order to understand how the function itself and the object that delivers it - the function carrier - will change.

At a higher level there are tools that allow to transform objects in the course of problem solving: problem model - contradiction, solution model - ideal final result (IFR), methods and techniques for solving contradictions and resources that allow to move from the solution model to concrete transformations.

Thus, we see an opportunity to build a meta-subject content of education oriented to the transformation of the world.

2.2 Polymodelling

One of the functions of education has traditionally been the formation of a certain picture of the world. The key word here is "certain". Today it is necessary to operate with different pictures of the world. Those who are familiar with practical psychology know that many problems are solved more quickly and easily through metaphorical description of the world. Perhaps this explains the interest of adolescents in building their own fantasy worlds, within which they solve new problems and develop new relationships.

How can TRIZ help here?

All models of the information block work in different "worlds" described by the context block. It also consists of three models.

2.2.1 Real World

¹⁹ OTSM-TRIZ - General Theory of Powerful Thinking based on TRIZ (N. Khomenko's version) is an applied scientific theory that develops tools for managing sets of problems. These tools do not depend on a specific field of knowledge and represent a kind of constructor that allows one to pave the way from a problem to a solution. The idea to create the theory belongs to G.S. Altshuller, the author of TRIZ.

In the Real World model, the boundaries of parameter values are defined by real conditions. Its study allows building scientific pictures of the world.

2.2.2 Fantasy World

In Fantasy Worlds, the values of parameters and connections between them can change at the will of the author. Mastering such worlds allows students to do many mental experiments. By analyzing the consequences of fantastic transformations, children learn to anticipate the results of the changes they want to implement in the real world. This is important because today's technologies allow a single person to do things that not so long ago were available only to large production plants, which means that every person should be able to foresee and evaluate the consequences of the realization of their ideas.

2.2.3 Looking Glass

Looking Glass is a world of images, or metaphorical world, where the role of objects is played by images. Describing situations through metaphors allows to show the essence of the problem and understand where to look for a solution. This technique is widely used today in practical psychology. By teaching students to build a world of images, we give them a powerful tool for solving their own problems.

3. It is more important to pose a problem than to solve it

Modern schoolchildren will provide for their everyday life by creating clothes, transport, home furnishings, and possibly the house itself using a 3D printer. And if yesterday it seemed to us that for this purpose it is necessary to have a deep knowledge of design and engineering, today it is obvious that the solution of most of the tasks will be taken over by a neural network. What is left for man in this connection? Probably, the ability to set new problems "in the human dimension" will become especially important. Not to predict the next steps in the development of technology and scientific concepts (the neural network will also cope with this), but to find and implement those needs that will make man more human.

How can TRIZ help here?

Obviously, we should refer to the Theory of Creative Personality Development (TRTL) [8], specifically to the research in the field of formation of a worthy goal and upward strategy describing the options for changing goals. But this, in my opinion, is not enough for teaching schoolchildren to set and reach their own goals. The problem is that only a mature person who is conscious of himself/herself as a personality and as part of the world can set and reach the goals that will help society to become a better place. A person who is able to keep in focus the contradictions that inevitably confront everyone who makes responsible decisions, to live with these contradictions, and to be ready to solve them when it becomes possible to find or create the necessary resources. The question of educating such a person is not solved within the framework of a single scientific theory. TRTL is no exception.

The presented problems create an outline for answering the question: "What should a "children's" TRIZ teacher do today? What to teach children and adolescents using appropriate tools?"

I do not have a ready answer to this question, but I have experience in developing and testing several topics in a course for teenagers.

3.1 Developing a Course for Teenagers

I work with a small group of five students, now they are 12-14 years old. They have been studying elements of TRIZ and OTSM since they were 6-7 years old. They do not go to school, they are home-schooled. We meet twice a week. One session is to support learning of the school syllabus, the other one - to build competences. To analyze and solve problems we use the model system described above.

I got some of the ideas for the trainings from Lika Chekalova's online course "Future Thinking", and some of them I developed myself in co-operation with colleagues from the online schools "Knowledge Workshops" and "Lenguateca".

Below are the topics we have studied in the last two academic years.

3.2 Learning and Life

This section was aimed at identifying and solving their own problems arising in the learning process.

The experience of teaching a group of 12–14-year-olds shows that working on one's own problems, understanding and correcting one's behavior when faced with a problem is a relevant topic for students of this age. TRIZ offers tools for problem solving. Psychology teaches to recognize and describe personal resources. TRIZ suggests how these resources can be transformed to obtain a solution. As a result, the pupil has a desire to deal with his/her problems and a chance to develop his/her own strategy for analyzing and solving them.

3.3 Fantasy Worlds

Here we have been building worlds based on fantastic assumptions.

We chose a fantastic assumption and described how it would change the world. For example, "The world is developing, but without the Internet", "People have learnt to photosynthesize", "People hibernate in winter", "Half of humanity can live only at positive air temperatures and the other half only at negative temperatures", "There are no predators in the world", "People periodically fall into time holes". The pupils suggested the topics themselves.

According to the teenagers' assessments, it was a valuable experience for them to consider situations in artificially created worlds through the construction of cause-and-effect chains. In this way, problems were identified, which we then tried to solve. The solutions were considered in three directions, answering the following questions:

- Can the environment itself be changed so that the problem is solved?
- Can the rules of interaction in society be changed?
- Is it possible to change a person, his psychology or physiology?

In each direction, solutions were sought using TRIZ tools.

3.4 Building an Image of the Future

We studied objects of the future, technologies of the future, sets of problems that are important to solve in the future.

When studying objects, we used the Laws of Technical Systems Evolution formulated in TRIZ.

When studying technologies, we paid special attention to the ways of obtaining and transforming energy.

We also learnt to use neural networks to obtain the information we needed.

We started working with sets of problems at the end of the school year. In the future, I will try to organize this work based on the experience gained from building fantasy worlds: cause-and-effect chains, identifying key problems, solving them in three directions: changing the environment, changing the rules in society, changing the person.

We ended the school year with reports on topics chosen by the teenagers. The topics were different: improving the lives of stray cats in the future, walls of houses in the future, development of jewelry, development of sports shoes, positive development of hacking.

The students noted that thinking about the future is difficult but interesting. This process requires tools, and TRIZ has them. The most impressive tools turned out to be the causal networks and the S-curve of systems evolution.

4. Problems and Perspectives

I will outline the problems I encountered in the process of developing the content described above.

The problem of teaching to analyze the situation. Today the "big picture" of the situation and the choice of "points of growth" are more important than analyzing and solving specific problems, because we have reliable tools for decomposing and solving specific problems in ARIZ, function analysis, TRIZ-analysis and other technologies, but there are no reliable enough tools for analyzing the situation as a whole.

The problem of developing imagination as a basis for prediction. Even my students, who have completed many assignments from the course of creative imagination development, who read and try to compose science fiction and fantasy, initially found it difficult to describe the altered worlds.

Teaching to build cause-and-effect chains is closely related to the development of imagination - without imagining a situation, it is impossible to predict its consequences.

Building a reliable bridge to the formal education system. We will inevitably come to an approach in education in which the study of specific topics from certain subject areas will be seen by the student as the development of resources needed to solve problems that they have set or accepted. This approach needs to be developed, and today it is advisable to do it within the framework of additional educational courses.

In the future, it is possible to plan a system of courses under the general title "The Future". The attempt to predict the world of the future and ourselves in it opens up a whole range of directions.

- Think of or anticipate solutions that will change the world.
- Imagine this changed world in detail.
- Find your place in the world, figure out what you want to do.
- Figure out what you need to do today to take that place tomorrow. To build a bridge from today's self to tomorrow's self.

Functional approach, polymodelling and problem-solving will be the basic approaches in this system of courses, and the system of problem-oriented learning models will be the basic set of tools.

References

1. Jonas Svava Iversen. Futures thinking methodologies – options relevant for “schooling for tomorrow” <https://www.oecd.org/education/ceeri/35393902.pdf> Last accessed: August 18, 2023.
2. Khomenko N.N. , Sokol A. New models and methodology for teaching OTSM-TRIZ http://www.trizminsk.org/eng/h_s.htm Last accessed: August 18, 2023.
3. Khomenko N, Murashlovska I. Third millennium: the driving contradiction and other problems of education (2003) https://otsm-triz.org/en/content/knn_in_en Last accessed: August 18, 2023.
4. Khomenko N. “Super Short Introduction into Classical TRIZ and OTSM (2012) https://otsm-triz.org/en/content/super_short_intr_en Last accessed: August 18, 2023.
5. Korzun A.V. “OTSM-TRIZ as a Technology of Training the Expert in Education” (2007) https://jlproj.org/this_bibl_e/pedkollej_ETRIA_eng.pdf Last accessed: August 18, 2023.
6. Nesterenko A.A. “The OTSM-TRIZ Based System of Models for Teaching Students to Organize Their Thinking” (2005) https://www.jlproj.org/this_bibl_e/AN5ETRIA.pdf Last accessed: August 18, 2023.
7. The Child-Driven Education by Sugata Mitra (2012) <https://www.bbc.com/future/article/20120626-the-child-driven-education> Last accessed: August 18, 2023.
8. Altshuller G., Vertkin I. “How to become a genius” (Original title: “Kak stat geniyem”), Minsk, 1994. (in Russian)
9. Informational Barrier: Wikipedia https://ru.wikipedia.org/wiki/Информационный_барьер (in Russian) Last accessed: August 18, 2023
10. Nesterenko A.A. “Knowledge Workshop: Teaching Manual”. — M., BookInFile, 2013 (Original title: “Masterskaya Znaniy: Uchebno-Metodicheskoye Posobie”) (in Russian)

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“NATURE HAS NO BAD WEATHER” OR REASONING ABOUT ANSWERS TO OPEN- ENDED PROBLEMS

Evgenia Guin

Abstract

TRIZ teachers widely use open-ended problems to develop critical and creative thinking of their students. When working with this type of tasks teachers find it difficult to evaluate the children's answers. This article is devoted to the discussion of evaluation problems.

Keywords: open-ended problems, evaluation, TRIZ

1. Introduction

„Nature has no bad weather.” - says a popular wisdom.

In TRIZ-pedagogy it is often said that “There is no wrong answer to a problem”. Let's leave the weather to the weather forecasters, but in this article I propose to discuss the situation with problems and answers in TRIZ-pedagogy. I will be happy to get some feedback from my colleagues, there is a lot to talk about!

2. Types of Tasks

TRIZ-teachers use research and inventive open-ended tasks to develop creative and critical thinking.

3. Examples of Inventive Problems

3.1 Not up, but down

“How good it is to be able to fly!” - many people dream. But it's not so easy to visualize that dream.

One author wrote a book for children whose main characters, ordinary boys and girls, could fly. The book became super-popular.

It seemed perfect. But no. Many young admirers of the book's characters tried to repeat this “trick” after the idols, jumping from a height. Alas, in the real world it was impossible to take off, and the children were injured.

The writer learned about this problem and wanted to fix it. He was just working on a new edition of the book. So, what would he change so that children would stop “flying down”? You can't remove flying children from the book altogether: it would ruin the whole plot. But we must make sure that the children don't repeat the characters' flights.

How would you advise solving this contradiction?

3.2 Too Realistic

The “Homeless Jesus” statue by a Canadian sculptor Timothy Schmalz depicts Jesus as a homeless man sleeping on a bench.

In 2013, the sculpture was installed in Toronto. And now more than a hundred copies have spread around the world.

This statue is very realistic, which also leads to some problems.

Sometimes, especially on dark evenings, people mistake it for a person sleeping on a bench. This mistake has consequences: indifferent passersby call emergency services to help a homeless person. Such calls are especially common in freezing temperatures.

Suggest what the owners of the statues should do, so that while preserving the idea and quality of the sculpture, to save the services from false calls.



Figure 1. Homeless Jesus

As can be seen from the examples above, the very formulation of such a problem implies that there may be several solutions. Does this mean that all of them are equivalent?

Research problems are problems aimed at finding an explanation for something mysterious or incomprehensible.

4. Example of a Research Problem

4.1 Some Lemon?

Many people love the sour taste of lemon. Especially when combined with other flavors.

But... have you ever wondered what good the lemon itself does!

Why did it evolve to be sour?!

All the other fruits are sweet. And it's understandable: they want to be eaten so that animals and birds take their seeds further away from the parent tree.

So why did the lemon choose a different strategy?!

For most educational research problems, science already has an answer, and it can be found on the Internet and in books. But in TRIZ-pedagogy we call for allowing children to discover knowledge themselves through problem solving. This implies independently putting forward many hypotheses and analyzing them.

So, is there or is there not a “right” answer to open-ended problems and what to do with the rest of the answers?

5. Control Answer

In TRIZ-pedagogy, the term “control answer” is widely used, for inventive problems it stands for the answer that has been realized historically, in the story on which the problem is written.

However, we encourage educators not to “drag” children to the control answer, but to motivate them to look for multiple strong solutions. While evaluating it is not considered correct to add points for matching the control answer.

That is, the control answer is just one of the solutions to the problem, some kind of historical solution. But do agree that the word "control" implies that this is a sample for verification, for control! It turns out that there is a clear contradiction between the name and the essence.

I think there is a need to think of another name for this answer.

The following seem reasonable to me: historical answer, original answer, existing answer, plot answer, real answer (children most often ask “What's the real answer?”), E-answer (existing answer).

What do you think? It would be very interesting to hear colleagues' opinions on this.

In research problems, the control answer is the generally accepted scientific explanation. Although there are open research problems, far from science, when the mystery is in someone's mind. In this case, the answer can no longer be called scientific. Here is an example of such a problem:

Unexpected Care

Throughout the eighteenth century in North America there were protracted wars between the colonists and the Indians. However, it is known that the English provided the Indians with warm blankets. Why did they do this since the Indians were their enemies?

What do you call a known answer to such a problem? Historical answer? Real answer? Known answer? Existing answer? Available answer? Original answer?

Is it important for the teacher to find it with the students, or even just to tell them after the problem has been solved, if the known answer hasn't been found?

I think it is. To increase erudition; after all, that is one of the goals of teaching.

Later in this article, I will replace the term “control answer” with “available answer”.

6. Multiple Answers

As mentioned above, for an open-ended problem, there may be many other alternatives besides the available answer. How do we compare them, and do we need to? How to choose the best one? Can there be “wrong” answers with this approach?

I believe that it is necessary to analyze the answers, compare them and evaluate them. This is the only way to cultivate a responsible attitude toward your decisions and develop critical thinking. Otherwise, we will get rampant divergence, where it is more important to say than to think. This is why I think that the “we have no wrong answers” approach is wrong. Wrong answers are those that do not consider limitations, that do not solve the problem, that do harm.

For example, the ideas “Put the sculpture of Jesus upright” or “Build a transparent dome around the bench” for the “Too realistic” problem are not right answers, because they destroy the author's intent.

In TRIZ-pedagogy it is proposed to evaluate ideas according to the criteria of practicality (coefficient of ideality) and originality. But the evaluations turn out to be very subjective. Even in the case of historical problems, we cannot always evaluate the efficiency of an idea, the evaluations turn out to be “smeared”, which is demotivating. When it is not clear whether your idea is good or not, when you are not sure of the result, you want to solve less. For example, in the task “Not up, but down” if the author decides to write in the preface to the book that magic works only in the magic world and do not try to repeat it at home, will the boys and girls listen to him or not? And if he adds stories about kids crashing in the real world, will that solve the problem or vice versa? And if it says that the magic only worked in the presence of adults? Wouldn't that ruin the whole story?

In addition, the very knowledge that there is an answer reduces the desire of students to come up with a lot of options, they try to guess the answer that will certainly solve the problem. And it is clear why: it is certainly "correct", you can experience the desired feeling of "I've solved it! I got it!".

So how can TRIZ educators find a balance? On the one hand, leave a plurality of options. On the other hand, give rigor and confidence in evaluating the results.

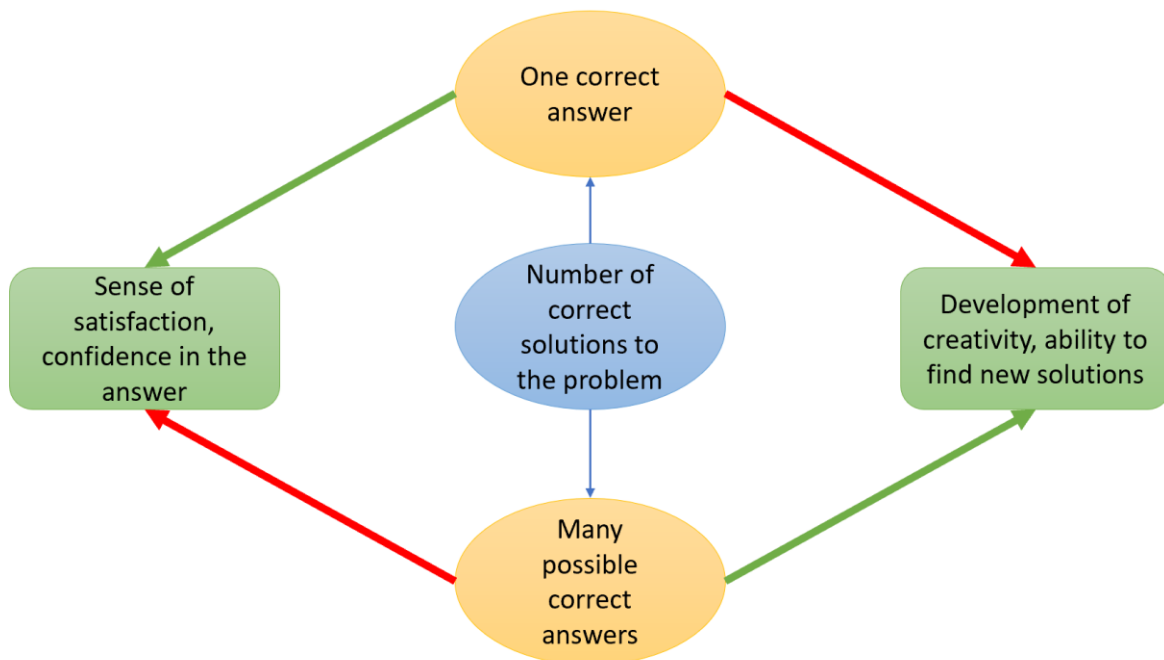


Figure 2. Contradiction

It seems to me that practical problems, where all ideas are immediately tested in practice, are ideal for solving this contradiction. For example, the classic inventive problem “How to throw a chicken egg from two meters away so that it doesn't break?” Here you can test in practice all sorts of ideas and experience the most real excitement and frustration. No more arguments, checks against the written “right answer” and hypothetical evaluations.

However, this solution significantly narrows the range of problems available for solving.

Another solution can be to add to the lesson logical tasks for ingenuity, in which the answer is non-trivial, but the only one.

Example of a single-answer task for ingenuity

Continue the sequence:

1
11
21
1211
111221
....

This solution adds an important sense of confidence to the lesson, but it does not help in evaluating solutions to open-ended problems.

How else can you solve this contradiction? Share your experiences!

4. Conclusions

Open-ended problems have many advantages: they teach students to think, to look for solutions in a situation of uncertainty, to analyze their ideas; they form the habit of seeing problems as challenges and prepare kids for solving life problems.

However, when solving them regularly with students, various problems arise in terms of evaluating ideas and attitudes toward a pre-known answer:

- How do you evaluate solutions to open-ended problems that can't be tested?
- Are there wrong answers to a creative problem?
- How to motivate children to look for other solutions rather than strive to find only the existing answer?
- How to name a solution to a problem that is already known?
- How to give a sense of confidence in one's solution, a sense of completion?

Share your ideas on how to solve the above pedagogical challenges!

Available Answers to the Problems Used in this Article

Not up, but down

That's how the Tinker Bell fairy got her pixie dust.

The problem we described was solved by James Barry, the author of the Peter Pan books. When he found out about the trauma of children who imitated Wendy and her brothers taking off from their beds, he realized that something had to change. And he came up with a prerequisite for flying that no real child could fulfill: pixie dust.

Too Realistic

This problem has no existing implemented answer. But I think solutions like this are strong:

- Coating Jesus' cape with a transparent compound that glows in the dark. This would only reinforce the idea of a divine origin. The “light” resource could be used in other ways: brightly illuminate the bench, add contour lighting, add a glowing crown of thorns, place a lantern (only visible at night) in the hood, etc.

- Raise the bench to a pedestal.

Some Lemon?

It's not an easy issue with lemon. Especially because it is not exactly known whether it was nature or man-made selection that made the lemon so sour.

Let's assume that it is nature. What is the reason? There are two answers.

1. Perhaps the lemon just doesn't want to be eaten. It creates a heavy fruit, which, when it falls to the ground, will roll away from the trunk. And there it will begin to rot, releasing the seeds. Its juicy pulp will provide the seeds with moisture and nutrients for the first time, and its sour taste will deter animals.
2. The second hypothesis is more interesting and is formulated after observing many sour fruits, such as berries. It turns out that both animals and birds are not at all squeamish about sour fruits when they run out of sweet ones. They eat lemons, cranberries, wild gooseberries, and many other sour fruits. So, what happens to the seeds next, after they are eaten? They enter the stomach with hydrochloric acid! This adventure is not for the faint of heart (that is, not for the thin-skinned). Herein lies the clue: sour pulp reduces the production of hydrochloric acid, as the nerves responsible for its secretion respond to the overall acidity in the stomach. And the seeds have a chance to come out after traveling through the gastrointestinal tract without damage. That's why the lemon, with its soft seed peel, just needs sour fruit.

Unexpected Care

In 1763 General Jeffrey Amherst ordered blankets contaminated with smallpox to be sent to the Indians. The outbreak wiped out thousands of Indians, for whom the unprecedented infection was far more dangerous than for the Europeans who had long lived side by side with it.

Continue the Sequence

Each successive line describes the preceding one:

One digit 1 (1)

One digit 1 (11)

Two digits 1 (21)

etc.

A line to add should be 312211

References

1. The source of all the open-ended problems in this article is the "And to Think?" Stream www.podumat.ru

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CASE-STUDY: USING TRIZ TOOLS TO STREAMLINE LESSON PLANNING AND PREPARATION AND SAVE TEACHER'S TIME AND EFFORT

Maria Dunaeva

Abstract

For many English language teachers lesson preparation is normally a lengthy process often taking up more time than the lesson itself. Modern coursebooks that are abundant in material do not solve the problem, but only make matters worse. This work will focus on several practical examples of how the use of some TRIZ tools can simplify and accelerate some aspects of lesson planning while increasing the quality of teaching and students' engagement.

Keywords: lesson planning and preparation, private teacher, multi-screen diagram, resources, low-prep, save time and effort

1. Introduction - What Is Streamlining?

At the beginning of my teaching career, lesson planning was quite a time-consuming process for me. In extreme cases, I spent more time getting ready for the lessons than running them. So looking for ways to make this part of my professional life easier, I found some of the TRIZ tools useful.

According to Cambridge English Dictionary, when something is being streamlined it becomes more simple and effective at the same time. Therefore, my goal was to minimise the lesson planning stage without sacrificing my students' results in the process.

2. Main Body

2.1. Where to Find Resources

As teaching is a 'contact sport', in my search for solutions, I turned to

- 1) the learner as one side of the process
- 2) myself (the teacher) as the other side of the process
- 3) and what was going on between N1 and N2, i.e. the teaching/learning process

2.2. Focus on the Learner

Why is it important?

- 1) I am sure that the success of a teacher is measured by how far their students get. So my ultimate goal as a teacher is to enable my students to communicate in those situations that are important to them.
- 2) Students are people with their own goals and plans, needs and expectations, their own cognitive abilities, mindset and background etc. that serve as natural limitations to English language teaching, on one hand, and resources, on the other.

Applying a Multi-Sreen Diagram

It did not take me long to realise that a multi-screen diagram offers a holistic approach to learners' needs analysis. So with my goal in mind, I wrote a list of questions about the factors that can help or hinder learning.

<p>What supersystems was the learner a part of in the past that influenced their learning?</p> <ul style="list-style-type: none"> - Where and how they learned the language? - Where they used the language and what was easy/what was difficult? - What were their relations with the teacher: productive or unproductive, was there a lot of teacher engagement or was the student quite independent? 	<p>What supersystems is the learner part of?</p> <p>Are they supportive or un-supportive to language acquisition/learning?</p> <p>If they are supportive, to what extent can they be used?</p> <p>Is the student the only beneficiary of his skills (or is there anyone else involved: parents/teachers)</p>	<p>What supersystems will the learner be a part of in the future when they have reached their goal?</p> <p>What will they do there?</p> <p>Who and where will they use a language?</p>
<p>The learner at a younger age.</p>	<p>The learner: How old is he?</p>	<p>The learner in his point of destination</p>
<p>The subsystems in the past that influenced his learning style:</p> <ul style="list-style-type: none"> - what were his likes/dislikes in terms of activities - any habits developed then (a way to work with words to remember them) - expectations from the learning process and the teacher 	<p>What subsystems are important for learning?</p> <p>the starting point (point A): where is the learner now compared to where he wants to be? cognitive abilities cognitive constraints, if any learning style agency interests and hobbies dislikes what truly motivates the learner mindset about learning the sensitivity area does he prefer working alone or in a group</p>	<p>What subsystems are important to get there?</p> <ul style="list-style-type: none"> - the skills that the learner will need to develop - the lexical topics that he will need to cover - some additional dreams and wishes they have (in addition to the main aim and even distant from them)

Some of these questions can be answered before the start of the lessons, which saves a lot of time and effort and makes the learning process more comfortable for a learner straight away. I use a questionnaire in Google.forms, which I send to candidates or their parents, or ask those questions in a telephone conversation when someone applies for the lessons. Yet, it is worth noting that some questions (of a psychological nature) can only be covered accurately after a certain amount of classroom observation. So it is good to approach learner needs analysis as a continuous process rather than a one-off event.

Such thorough analysis helps avoid a lot of trial and error and keep a focus on the student as an individual, building on strengths and helping to overcome or minimise weaknesses. In the case of teaching ESP (English for special purposes), this saves a lot of time, effort and money as students can reach their goals faster if they are open to collaboration.

2.3 Focus On What Happens Between a Teacher and a Learner

As a result of learner needs analysis, I get an understanding of what I am going to teach and how I am going to do this. I choose the teaching approach (whether I would regard the language as a grammaticalised lexis or lexical grammar, which I often link to the learner's expectations and cognitive abilities).

For example, with AD(H)D learners, that have very short attention slots and find it hard to concentrate for too long, I would prefer using the lexical approach and teaching the language in chunks as in this way it is easier for them to memorise the new target language. At the same time, with older learners who went to Soviet schools, I would rather start with 'grammar+words=production' approach as that is what they are biased towards.

Within 'what you teach' and 'how you do it' there is a wide variety of room for simplifying the work of the teacher. Below is one example of a low-prep way to teach vocabulary to low-level students:

When we teach vocabulary to low levels, we have to make learners deal with the same set of words (for example six words on one topic) for quite a while. The problem is that after I have introduced the meaning of the words, I need my students to look at the same set of words, listen to the same set of words and repeat them many times without getting bored and disconnecting so that they can retain the target vocabulary in their memory. So how can a teacher get a low-prep variety of activities out of the same set of words in a low-prep way?

It comes from focusing on the different aspects of the target vocabulary (meaning; pronunciation and form) + using Wordwall online teaching tools:

Step 1: A fun and engaging focus on meaning comes from a Memo (Pelmanism) game. It makes students look at the words many times and memorise them. The game contains a set of target words (for example nouns that we use to name things inside the house) and a set of pictures representing each of these words.

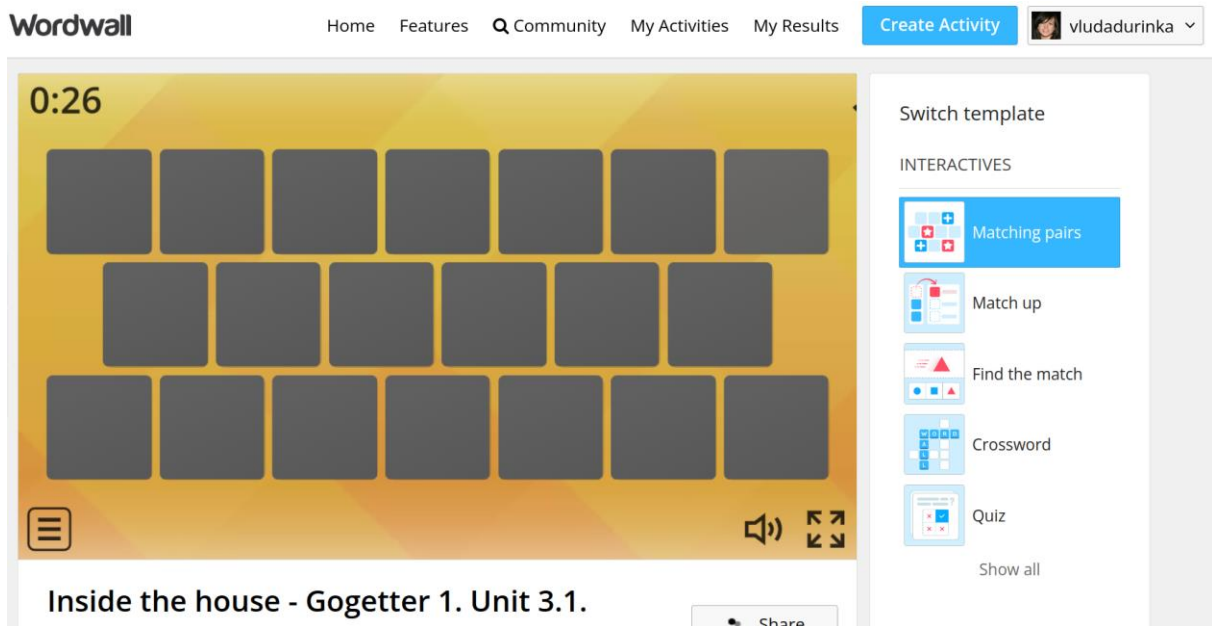


Fig. 1. Activity screenshot from Wordwall

How to play: Each student needs to flip over two cards at a time. If they match, he keeps them and gets a point. If the cards belong to a different set, they are flipped back automatically and other players can flip over any one of them if they want to. The game is played until there are no cards left. The winner is the player with most of the cards.

It can be used with students in a group, competing against each other, in one-to-one lessons when a student competes against the teacher or when student plays alone against the time.

In Step 2 the words (and cards) are still the same. This time, however, the focus is on pronunciation via a game of “Stop (or Freeze)”.

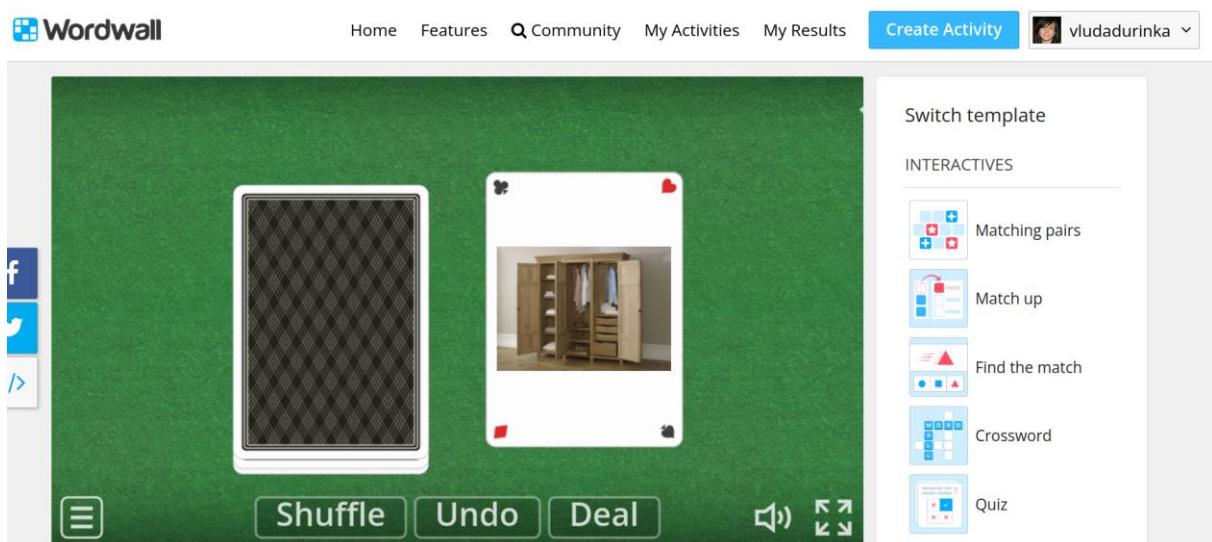


Fig. 2. Activity Screenshot from Wordwall

How to play: There is a deck of picture-only cards. The teacher flips over the cards one by one while pronouncing one of the words from the target vocabulary set. When students see the picture matching the word, they shout ‘Stop’. The players that shout “Stop” at the right time, get 1 point for it. The winner is the player with the biggest number of points.

The game makes students listen to the words many times attentively.

For stronger students, there is a variation of the game which is called “Clever Parrots”.

How to play: The teacher shuffles the cards and flips over the cards while pronouncing the words from a vocabulary set in random order - one word for each card. As clever parrots, students repeat only those words that match the picture and keep silent when a word and a picture do not match.

An additional advantage of using Wordwall for this purpose is the fact that there is no need in creating each game separately, the platform allows switching from one mode to the other, which makes these activities truly low-prep.

On a separate note, games have been a real inspiration and time saver for me. In my view, there is a lot of potential to use them to make lessons really engaging, while saving time and effort for lesson preparation if the focus is on the the mechanics and mathematical model behind the game rather than its content. There are some good games that are easily tailored to suit different students’ interests so you get a wide variety of scenarios out of one game model

2.4 Focus on the Teacher:

Why it is important:

I am sure that happy teachers, that are passionate about what they are doing and are fully aware of what they are doing and why, can better serve their students.

It saves a lot of time and effort and become a very fulfilling experience if you know yourself well enough and take the courage to build your teaching practice around your values and strengths.

To analyse my own needs and goals, I use a multi-screen diagram with the following set questions to myself. As a disclaimer, I should note that this is still work in progress and some parts of it need further development.

<p>What supersystems was I a part of in the past that influenced my teaching?</p> <ul style="list-style-type: none"> - Where did I study and what was it like like? Why it was like that? - What kind of teachers did I like? Why? - What kind of teachers did I not like? Why? 	<p>What supersystems am I part of now (work/family/other)? And how much time and effort does each of them take?</p> <p>career: Who do I teach? What do I teach?/How do I teach? Why do I teach the way I teach? Who do I feel comfortable teaching?/Who do I feel uncomfortable teaching? Who do I feel (un) comfortable to work with? Am I a part of any professional community?</p> <p>family: Who do I live with? What are my commitments? What are the opportunities and constraints related to them?</p> <p>others: What other supersystems am I part of? Why?</p>	<p>How will the future of language teaching change? Why? (the influence of AI etc.)</p> <p>What part do I want to play in the future of education? What for?</p> <p>What supersystems do I want to be part of? What for?</p> <p>Any foreseeable changes in the family situation? How would they influence my career goals?</p> <p>How much time would I like to spend on each of the supersystems?</p>
<p>Me at a younger age</p>	<p>I'm now (Point A)</p>	<p>I am at a certain date and time in the future (Point B)</p>
<p>The subsystems in the past that could have an impact on teaching:</p> <ul style="list-style-type: none"> - What was my mindset as a learner like? - What was easy or difficult in my learning experiences? - any habits developed then (both positive and negative) - my expectations from the learning process and the teacher 	<p>What subsystems are important for teaching?</p> <ul style="list-style-type: none"> - my professional skills my values my beliefs about teaching: helpful and unhelpful what I am ok with what I'm NOT ok with my cognitive abilities, constraints and needs my personal likes and dislikes interests and hobbies what brings me energy/what drains me 	<p>What subsystems are important to get there?</p> <ul style="list-style-type: none"> - skills that I need to develop - some additional dreams and wishes I have (in addition to the main aim and even distant from them) - How are my beliefs/my mindset? - my health (how do I need to take care of it to be able to do my work well)

I found it very useful to reflect on those questions, albeit it is probably a good idea not to address all of them in one sitting. Looking back on my past experience as a learner helped me to uncover my limiting beliefs and cognitive bias that impact my teaching and then take action to eliminate and replace them with the ones I need to reach my goals. Keeping an eye on the future makes me more flexible and proactive (in particular, I have learned to create ESP lessons on unfamiliar topics from scratch using AI). Finally, as I get to know myself better, it takes much less effort and time to attract those students that I am most productive with.

Conclusions

This paper is a very general attempt to bring together and outline three very big areas of teaching/learning as a resource for streamlining teaching via the use of TRIZ tools so there is still a lot of potential to dive deeper into each area, formulate IFRs and find more opportunities to get the best out of students, yourself and the what is happening between you. As can be seen, the three elements that have been described separately are closely interrelated. And the intersection of those is actually a place to look for new ideas. This interconnection also implies that in practice the teacher will likely need more than one multi-screen diagram for different groups of learners. What might seem as a lot of work and analysis at first sight, over time transforms into a useful habit that shapes thinking and becomes part of a professional mindset. Apart from that, such holistic approach to a teaching path helps to be proactive, see and leverage opportunities rather than fall victim to circumstance.

Acknowledgements

I am grateful to Anatoly Guin for introducing me to the world of TRIZ pedagogy, to Alla Nesterenko for her long-term program for teachers that I was a part of some years ago, and to all the colleagues with whom I have been friends and worked.

References

1. [Cambridge English Dictionary](#)
2. Dellar H., Walkley A. *“Teaching lexically. Principles and Practice”*. Delta Development Series, 2016 Delta Publishing, pp. 10-11.
3. Wordwall (www.wordwall.net), an online teaching resource
4. MATRIZ Level 1 Training Manual, 2019.
<https://matriz.org/wp-content/uploads/2019/01/Level-1-Manual-Word.pdf> . Last accessed: July 30, 2019
5. Нестеренко (Селюцкая) А. “Мастерская знаний: проблемно-ориентированное обучение на базе ОТСМ-ТРИЗ”, учебно-методическое пособие для педагогов, 2013 г. Book in File, Moscow

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USE OF METAPHORS TEACHING 6-9-YEAR-OLD KIDS TO SOLVE CREATIVE TASKS USING THE ADAPTED ALGORITHM FOR CHILDREN

Nadezhda Zhuravleva

Abstract

In my presentation I will talk about my years of experience in teaching preschool and elementary school children to solve open-ended problems.

There has been a lot of doubt if a preschooler can work according to an algorithm. A TRIZ specialist Ekaterina Pchelkina designed DARIZ, Children's Inventive Problem Solving Algorithm, that can be used starting at the age of 6. However, an educator faces with a lot of problems teaching small kids to work according to an algorithm.

My experience shows that it is crucial to find the right metaphor that could be understandable to children and motivating them to take action instead of giving up on the problem.

I am inviting you on a tour of my #NOPROBLEM Clinic, where I will tell you how it works. I will walk you through the algorithm as trainees in our Clinic.

Keywords: preschoolers, adapted algorithms, metaphor, problem-solving

1. Using Adapted Algorithms: Questions and Doubts

The modern world is inherently fragile, restless, non-linear and incomprehensible. For education, this poses the challenge of forming individuals capable of living successfully in such a world. How to do this? How to teach to solve problems, to find a way out of "hopeless" situations?

TRIZ teachers do have answers to these questions.

In this article I will dwell on my years of experience in teaching preschool and elementary school children to solve open-ended problems with the use of adapted algorithms.

When educators or parents start to teach problem-solving to kids, they apply adapted algorithms, but still have a lot of doubts and questions.

1.1 Can a preschooler work according to an algorithm?

Decades of experience show that it is possible to teach preschoolers to solve problems using adapted TRIZ algorithms, but you should work together on every step of an algorithm. In this article I will share with you my 30-year experience of teaching TRIZ to young learners.

1.2 What is the best age to start learning problem-solving?

At the age of 4 kids can start solving everyday problems that belong to their experience. For example, how to keep warm? How to get a toy from the top of the closet or a balloon stuck to the ceiling? With kids aged 5 you can start finding problems to solve in fairy tales or cartoons.

1.3 Where do we get problems to solve?

We normally draw on the kids' experience. You can pick everyday tasks and make creative problems out of them. One of the best sources of problems is a fairy tale. Why stories and fairy tales? The answer is obvious: they keep the experience of humankind. You can take lots of problems to solve from this source.

1.4 What if the child refuses?

How to make any child not only able but also willing to solve problems?

This activity should be interesting and attractive, so TRIZ teachers necessarily use a metaphor and make the course plot-based. I will talk about my metaphors later on in this article.

1.5 Should we prompt and guide to a solution?

If you want to teach how to work according to an algorithm, you have to teach each stage gradually. That is why at the first lessons children are in a hurry to give an answer at once, and usually they have few solutions and do not try to analyze them. It is necessary to study the algorithm step by step together with them, and at the same time analyze what knowledge they lack.

2. Authors of techniques for teaching TRIZ to kids

2.1 Tatiana Sidorchuk

Tatyana Sidorchuk, educator, teacher trainer, Level IV TRIZ Specialist, was my first teacher. In co-authorship with Nikolay Khomenko, developer of OTSM (TRIZ-based General Theory of Powerful Thinking) she developed technological maps for teaching problem solving to pre-schoolers. She has written over 200 manuals and articles on teaching TRIZ to young learners [1]. I started to build my work on the recommendations of Tatiana Sidorchuk and Nikolay Khomenko.

2.2 Ekaterina Pchelkina

Ekaterina Pchelkina, TRIZ Specialist and Executive Secretary of RA TRIZ (Russian Association of TRIZ) in co-authorship with Alexander Kislov designed DARIZ, Children's Inventive Problem Solving Algorithm [2]. This is the one I use in my work with preschoolers.

2.3 Alla Nesterenko

Alla Nesterenko, educator, teacher trainer Level IV TRIZ Specialist, has a well-developed methodology of teaching TRIZ to younger schoolchildren. She has a lot of works devoted to this very issue and teaches not only children, but also adults in her online school *Knowledge Workshop* (Masterskaya Znaniy) [3].

3. My First Metaphor

30 years ago I started to work with problem-solving in kindergarten. It was necessary to find the right metaphor that would be understandable to children and would motivate them to take action and embrace the problem as something positive instead of stupor from the mere word "problem". And the image of a rescue worker suited me just fine. Children liked rescuing fairy-tale characters. It is easier to solve other people's problems, so that life problems of fairy-tale heroes make problem-solving a typical task, the answers to which the children have already found.

The Rescuers worked according to the Children's Algorithm DARIZ developed by Ekaterina Pchelkina.

The work of the rescue service was organized as follows:

3.1 Warm-Up

To warm up, the children guessed the personage who needed rescue with the help of the Yes/No game. Then they received a call from the hero in trouble and formulated a problem situation.

3.2 Conflict Pair

From the problem situation they chose a conflict pair and the problem to be solved.

3.3 IFR and Resources

We worked strictly according to the algorithm, starting with the formulation of the IFR (Ideal Final Result), went through the resources and proposed solutions during brainstorming. Then we fixed everything without analyzing.

3.4 Best Solution

After that we chose the best solution, i.e. the closest to the IFR, usually the only one.

3.5 Call Back

Finally, the kids called back the hero and told him/her how best to proceed. (Fig.1)



Fig. 1. Steps of the adapted Rescue Service algorithm

The Rescue Service worked successfully for 30 years, until I turned into an online educator and got keen on plot-based courses.

It should be noted that it was not always easy to solve the problem with the help of DARIZ and to find the contradiction through the Conflict Pair. Besides, the metaphor of a Rescue Service is not always understandable to children, although it is quite attractive.

4. New Metaphor for Storytelling

For my online course I designed a new plot and a brand-new metaphor. This is how our internship at the #NOPROBLEM Clinic was successfully launched for online classes.

Let me tell you how it works. I will walk you through the trainee problem-solver's path to familiarize you with the problem-solving algorithm. The main tool of our clinic is still the Children's Inventive Problem Solving Algorithm (DARIZ). You can see it in the picture below. (Fig. 2)

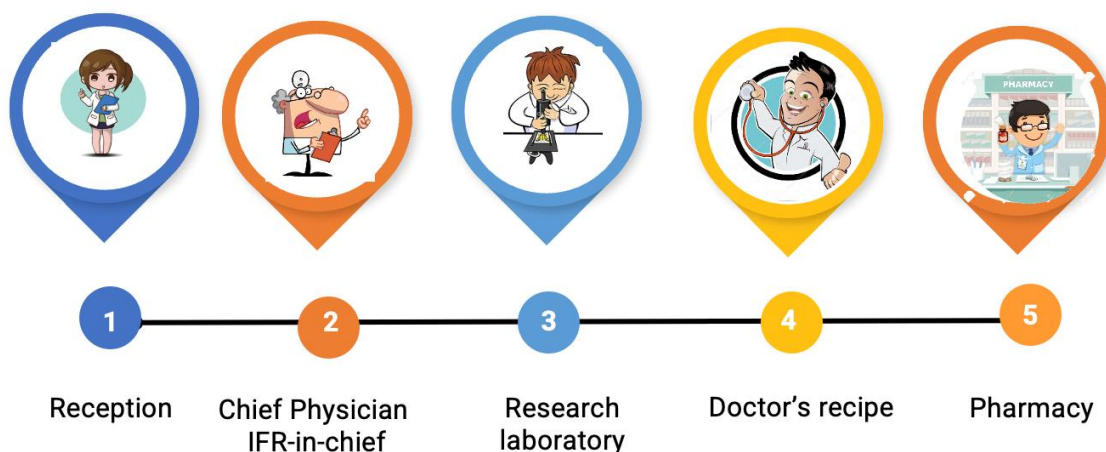


Fig. 2. Steps of the adapted algorithm at the #NOPROBLEM Clinic

The robot assistant offers the children a trainee card, on which you see the adapted steps of the same algorithm.

4.1 Conflict Pair

At the Reception, the children figure out the Conflict Pair (CP), or "sour couple," as Ekaterina Pchelkina calls it.

4.2 IFR

At the Chief Physician's office, the IFR-in-chief issues an order that everything should happen all by itself, that is, he formulates the Ideal Final Result, which will direct us to the desirable solution.

4.3 Research

In the research lab, each member of the Conflict Pair is described, and we select the attributes that need to be changed to solve the problem.

4.4 Resources and Solutions

Doctors and trainees think how to change these attributes, that is, look for the resources of the Conflict Pair and consider the resources of the environment to prescribe the right medicine, that is, to propose a solution.

4.5 Evaluation

But before we go to the pharmacy, we have to evaluate each proposed medicine (i.e. solution) with certain criteria. See the picture below.



Fig. 3. Evaluation criteria

This is what a trainee's card, or roadmap, looks like. Kids easily memorize it and recall the steps without any difficulties (Fig.4)

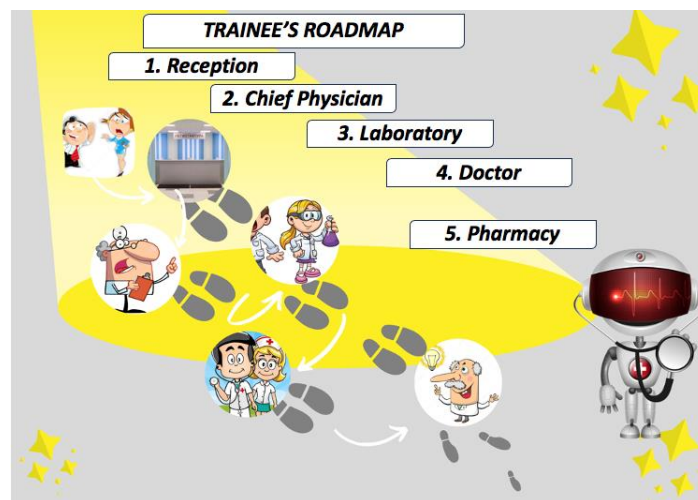


Fig. 4. Trainee's Card

After completing the internship, children receive a "Certificate of Problem Eliminator" and are invited to the "Agency for Problem Elimination", where they will get practical experience in solving not only everyday, but also fantastic open problems.

Productive activities are always used at the end of each lesson. Children are asked to draw their best solution or the one that the whole group has chosen as the most effective. Drawing makes children think through the details of implementing their idea, sometimes helping them to change it to a cheaper and more effective one.

5. Examples of Children's Work

Let me show you some solutions that the kids proposed during our online classes. I will give you two examples of different open-ended tasks.

5.1 Fairy Tale

"In hot Africa, on a desert island, there lived a Lion Cub and his wise friend the Tortoise.

One day the Lion Cub built a slide out of sand, filled it with water so it wouldn't collapse, but he couldn't go for a ride. Why?

Help the Lion Cub ride down the sand slide. Or guess what the wise Tortoise advised him."

Solving this problem, the children suggested:

- Sprinkle the slide with dry sand
- Ride on something hard and smooth (palm leaf, shell of a large coconut, basin, etc.)
- Ask the Tortoise to roll over on its shell and ride together
- Use slippery jellyfish that have been washed ashore after a storm

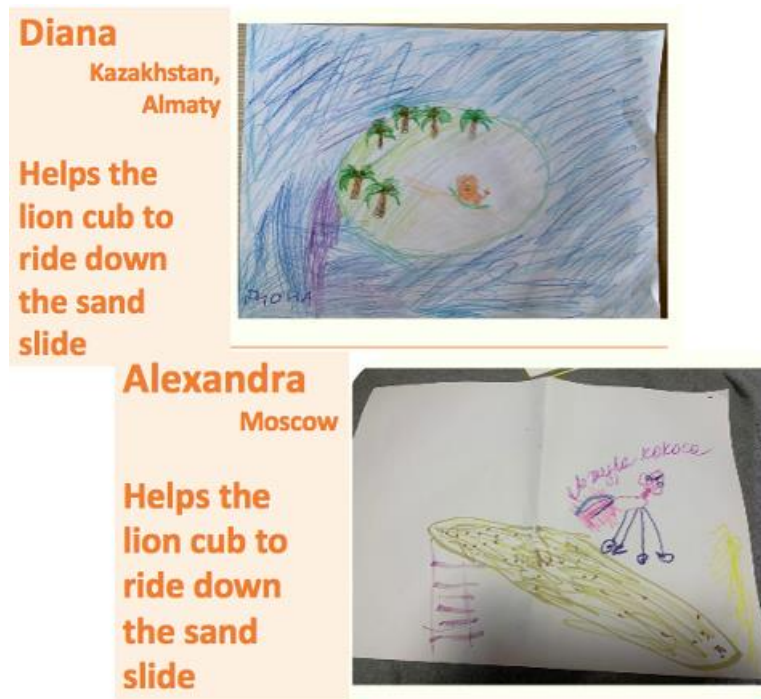


Fig. 5. Kids' solutions

5.2 Real Life

"Alexander had a small turtle living in his house. It was very curious and liked to crawl around the apartment, hide under furniture, in corners, but it was not always able to get out of hiding places. Alexander was very worried when he did not find the turtle. He does not want to put it into the cage and lets it crawl freely. Help the boy. Think of a way to quickly locate the turtle."

The children suggested:

- Put boxes or rags in the passageways under the furniture, to make them inaccessible
- Enlarge the turtle's shell by attaching an empty plastic bottle
- Attach a bell to the turtle to hear where it is crawling
- Attach a brightly colored balloon or ribbon to the shell
- Listen for rustles, search under furniture with a flashlight
- Take pictures of inaccessible spaces with a cell phone and selfie stick
- Bait with food
- Lure with warmth
- Attach a TV remote that detects itself



Fig. 6. Kids' solutions

And, finally, do we have to teach to choose only one but best solution?

I believe we do. Choosing the decision that is the closest to the order of the IFR-in-chief, is a key skill. It is formed gradually through training.

6. Conclusions

To conclude, I would like to state the advantages of this type of work.

The image of a rescuer or a doctor is attractive and motivating. The use of fairy tales stimulates the kids' interest. We have to choose problems that are close to real-life situations and the kids' experience. After solving these problems similar tasks stop being new and become typical problems kids are familiar with and able to cope with.

At the same time, we should bear in mind the following aspects:

- To be able to work with adapted algorithms the teacher has to be familiar with ARIZ
- Kids are able to apply this tool only if you train on a regular basis
- The quality of solutions totally depends on the number of TRIZ models kids can use

References

1. Tatiana Sidorchuk, Nikolai Khomenko "Thoughtivity for Kids: Developing Creativity, Imagination, Problem Solving and Language in Ages 3-8; Through Triz and Other Innovation Methods", Goal Q P C
<https://www.amazon.com/Thoughtivity-Kids-Developing-Creativity-Imagination/dp/1576810828>
2. Ekaterina Pchelkina "DARIZ. Children's Algorithm for Inventive Problem Solving. For Parents and Educators." (Original title: "DARIZ. Detskiy algoritm resheniya izovretatelskih zadach. Dlya roditeley i pedagogov") Galaktica. Moscow, 2018 (in Russian)
3. Alla Nesterenko "Hooray! We've Got Problems!" (Original title: "Ura! U nas problemy!") e-book, Trizbook, 2014 (in Russian)
<https://trizbox.ru/catalog/ebook/ura-u-nas-problemy>

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TRIZ IN EDUCATION: CONTRADICTION OR INTEGRATION

Olga Krasheninnikova

Abstract

This paper dwells on the question whether TRIZ can be complementary to modern curricula and contribute to developing learners' higher-order thinking skills. I briefly describe modern approaches to teaching TRIZ to kids as well as ways of bringing TRIZ into classroom and then give examples of integration of TRIZ and another modern teaching approach, namely CLIL.

Keywords: TRIZ, TRIZ Pedagogy, OTSM-TRIZ, approaches, cognition

1. TRIZ for Kids: Preconditions

TRIZ is considered to start when the first working algorithm (ARIZ) was designed by Genrikh Altshuller in 1956. In the 80-s with the explosive growth of the TRIZ community, TRIZ specialists realized that the system works not only for solving technical problems, but it can be applicable in many other spheres of human activity.

Moreover, a person who is familiar with TRIZ develops a special mindset that can be characterized by the following traits.

- Need for creativity, predisposition to search for and solve creative problems in different fields.
- Ability to apply creative methods and models in different spheres of human activity. For example, a person who has been trained to use TRIZ to solve technical problems, can apply creative methods to solve problems of relationships, management, etc.
- Development of a new type of intuition based on Evolution Trends.
- High learning ability, that is the ability to master knowledge in new areas very quickly and systematically [1].

Naturally, a question arose if it is possible to develop such mindset in kids if we start teaching TRIZ at early age. Thus, in late 80-s TRIZ Pedagogy was born.

TRIZ pedagogy aimed to form productive thinking and educate a creative person prepared to solve complex problems in various fields of activity. Its difference from the known means of problem-based learning is the use of techniques and algorithms developed within the framework of TRIZ. They have been revised and adapted to the goals of pedagogy [2].

2. TRIZ Teaching Approaches

In the course of adaptation of TRIZ tools to the needs of young learners, various approaches to teaching TRIZ have formed. They can be roughly described as Classical, Popular and Technological [3].

2.1 Classical Approach

Based on classical technical TRIZ, it boasts a well-developed system of TRIZ tools adapted for kids and integration with other modern teaching approaches: neuropedagogy, eidetics, etc.

One of the most prominent authors is Ekaterina Pchelkina, Executive Secretary of RA TRIZ (Russian TRIZ Association, Saint-Petersburg). She adapted ARIZ for kids and came up with a system of adapted problem-solving algorithms for young learners that are called DARIZ (Children's ARIZ) and are used by the majority of TRIZ teachers.

The approach focuses on developing kids' thinking skills, creativity and problem-solving. The majority of courses within this approach are for extracurricular classes, although teachers apply it as thinking models for their subject classes or introduce problem-solving activities motivating children to apply subject knowledge to solve inventive problems.

RA TRIZ organizes TRIZ Olympics for young learners and teachers as well as other contests, encourages kids' inventions and research projects.

2.2 Popular Approach

This approach has succeeded in popularizing TRIZ Pedagogy on a large scale. The term "TRIZ Pedagogy" itself is used by the teachers and authors belonging to this approach.

It can boast a large database of TRIZ games, brain-boosting activities and pedagogical methods. Bright examples of this approach are *Creatime* project, Evgenia Hin's *A Podumat* (Let Us Think) project.

There is a big number of courses for kids of different ages, mainly extracurricular. However, they are expanding the method to private schools and regular classes.

The approach focuses on creativity and cognition development introducing open-ended and inventive tasks to subject lessons and TRIZ classes. The teachers have collected a rich database of open-ended problems in different subject areas.

The approach is based on the following principles:

2.2.1 Integral Picture of the World

Everything in the world is interconnected. Teaching across subjects will help the kids develop an integral picture of the world.

2.2.2 Knowledge Through Creativity

Solid knowledge and skills are developed through creative activity.

2.2.3 Creativity as Basis

In the modern world creativity is the most important part of personality.

2.2.4 Student Subjectivity

Contemporary education should regard a learner as a subject of education making his or her own choice [2].

2.3 Technological Approach

I call this name the OTSM-TRIZ based approach. OTSM stands for General Theory of Powerful Thinking. This approach was developed by TRIZ Master Nikolay Khomenko and its goal was a system of tools to work with complex non-standard problems in any context or field of human activity.

The OTSM-TRIZ approach to teaching has more specific tools than any other TRIZ approach. Its aim is to develop the ability to detect and solve problems in any field of knowledge including the unknown. It means that a student has to be prepared for life learning and ready and able to get the necessary knowledge all by him/herself. That is why a lot of specific tools developed within this approach are dedicated to dealing with information: a learner when confronted with a problem should be able to collect the necessary data, categorize them, make a model of the problem, a model of its solution and finally come up with a concrete solution [4].

The ability to make your own models, that is to move from the concrete to the abstract and vice versa is considered key competence for effective problem-solving. The tools OTSM offers are general enough to be easily transferred to any subject-specific area.

In the author's opinion, OTSM is the only TRIZ based teaching approach that perfectly fits in any curriculum enriching teachers' tools to develop their learners' cognitive skills and creativity in any class within any subject area.

Some of the most prominent authors are Alla Nesterenko, who developed a methodology for problem-based teaching in primary and secondary school, Tatiana Sidorchuk, author of methodology for preschool education. Among European educators it is worth highlighting Alexander Sokol's Thinking Approach (Latvia).

3. Different Yet Similar

Despite the differences in particular tools and key methods, all the TRIZ-based approaches agree upon the core values of TRIZ education or TRIZ for education: to foster creativity, which is no longer considered an intrinsic characteristic of few geniuses; to bring up a new generation of people able to adapt easily to the everchanging world: proactive problem-solvers, life-long learners, innovators able to generate new ideas in line with sustainability values.

4. TRIZ and Modern Education

TRIZ has outgrown the times when it contradicted the educational systems that 30 or 40 years ago were mainly concerned about solid knowledge and offered good tools for reproductive learning where the students' initiative was rather unnecessary than welcome.

Nowadays all the curricula highlight the importance of active learning, problem-oriented education, autonomous inquiry and research, creativity and the ability to use general methods of dealing with information rather than memorizing exact facts.

But when it comes to implementing all these principles, teachers still have a lot of trouble designing a syllabus or a lesson that would meet all the above-mentioned requirements.

This is the exact point where TRIZ and curricula meet. Whereas educators lack a well-designed system of trainings, tasks, models to stimulate cognition and foster problem-solving and creativity, the TRIZ approach becomes a source of such tools.

5. TRIZ and CLIL Integration

In Lenguateca schools, both online and offline we integrate CLIL and TRIZ to ensure the students' better results.

CLIL stands for Content and Language Integrated Learning. It was created by David Marsh in 1994. The term CLIL describes an evolving approach to teaching and learning where subjects are taught and studied through the medium of a non-native language [5].

If we represent different approaches to CLIL on a cline, we will see that ideally teaching a subject and a language at the same time should be well-balanced, with 50% of subject and 50% of language learning. But the approach is quite flexible. Teachers can focus more on subject teaching or the language. That is why it can be combined well with TRIZ (Fig.1).

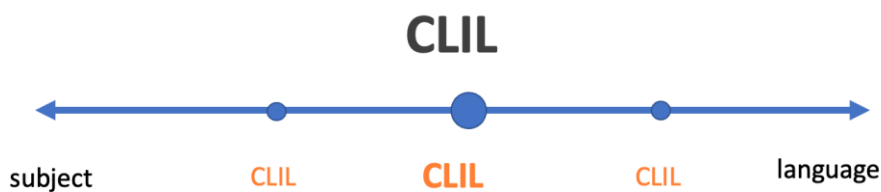


Fig. 1. Graphical Representation of CLIL

5.1 CLIL Basic Principles

A CLIL teacher should always bear in mind the three dimensions of a lesson or a course: subject, language, thinking skills or cognition, as well as stick to the 4 Cs (Fig. 2).

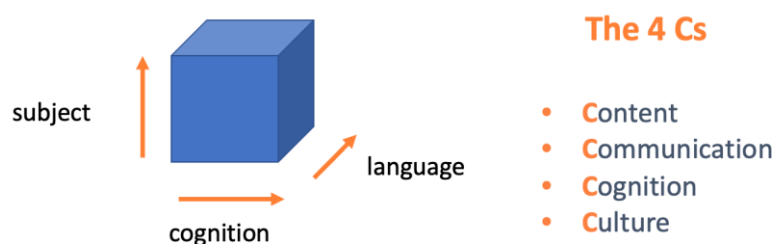


Fig. 2. CLIL Core Principles

The 4 Cs framework was described in 2000 by Marsh and other researchers and it refers to four aspects of CLIL teaching: content, communication, cognition and culture.

CONTENT refers to the subject content, though it is not only subject knowledge, but the accompanying learning skills, such as the ability to create a presentation or record a video or to conclude your work.

COMMUNICATION refers to the receptive and productive language the learners will need to understand the content and to express their understanding of it. The language is used in a functional context, that is the teacher has to pick the words and constructions the learners will really need to communicate in this context.

COGNITION refers to thinking skills, that is, the learners should explore the content, process the information and construct their own meaning.

CULTURE refers to exploration of other cultures, but not only that. It can also refer to the “way of thinking” specific to each subject.

5.2 Why CLIL

We mainly work with multilingual kids who are normally children of Russian expats. CLIL is an extremely beneficial approach to stick to with such learners.

Such kids normally possess good basic communication skills but have difficulty expressing themselves on topics different from their family use. CLIL answers the question how exactly we can enrich their vocabulary. First, by introducing different content, and second, by working at their academic language proficiency. It needs scaffolding, that is, good support from the teacher, and CLIL approach provides step by step instructions on how to organize linguistic support.

5.3 Where CLIL and TRIZ meet

CLIL pays a lot of attention to developing higher-order thinking skills (HOTs) and it uses Bloom’s taxonomy as a basis.

According to it, tasks that are at the bottom of the pyramid, namely remembering, understanding and applying refer to the so-called LOTs, that is lower-level thinking skills, and the ones at the top of the pyramid represent higher-order thinking skills (Fig.3).

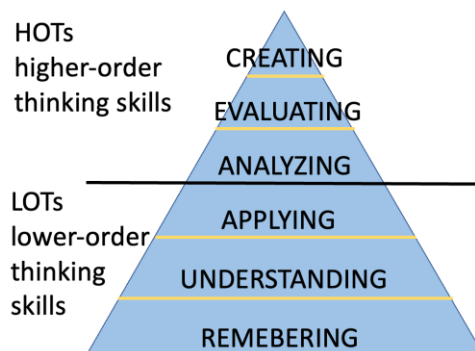


Fig. 3. Bloom's Taxonomy

However, CLIL does not provide clear answers to some of the questions such as:

- How exactly do we develop HOTs?
- Is it enough just to provide challenging materials?
- How exactly do we extend thinking beyond simply understanding and applying the content in similar situations?
- Is it enough just to provide questions? Are we sure the kids will know how to find answers? And if we extend the questions further than what you can google?
- And finally, how do we teach creativity?

Everything CLIL offers is a set of tasks like “compare”, “state the difference”, “say it another way”, “design a booklet or a mind map” with reference to different levels of Bloom’s taxonomy.

And this is exactly the point where TRIZ tools, especially the ones based on OTSM-TRIZ, provide a system of games and techniques to scaffold cognition.

In TRIZ we avoid reproductive teaching and help the learners autonomously come to the understanding of content through specially organized research and analysis. It means that we focus mainly on the higher-order thinking skills.

Every task can be represented as a problem, or a challenge. Moreover, the learner is provided with general, not only subject-specific tools to solve the problem. Thus, kids acquire general problem-solving competencies, which is of course one of the goals of contemporary education.

6. TRIZ and CLIL: Examples from Classroom

6.1 Problems and Storylines

In our school every course has its storyline and its personages. Let us call them “challenge-makers”. Every day they face with new problems that kids help them to solve.

For example, an ex-pirate Joe lives on a lost island and has problems with his memory, so he decides to write notes not to forget things. And as we solve this problem, we understand why we need spaces between words, full stops and capital letters. Then we learn how we can cypher information.

With smaller kids we have a Sound Bunny who likes listening to sounds, and a letter-eating Monster who shows how to convert sounds into letters. The same personages face with different problems that do not only deal with language matters. Thus, they help us introduce other content into the class.

There are also some advisors, like Muffin the dog, who can show some steps to take in order to solve the problem.

6.2 Research

Let us look closer at the life of the ex-pirate Joe. He has a very strange pet. We try to understand what is so weird about it and start to explore the animals we know. We play with a collection of pictures and as a result find out the basic parameters by which they differ – that is, we come to the classification of vertebrates. Finally, we come to the conclusion that this strange creature is a mixture of two classes: a mammal and an amphibia and find a name for it (Fig 4).



Fig. 4. Joe's Pet [6]

There are different ways to conduct a class using this situation. It depends on the teacher's aim.

You can go further and find advantages and difficulties of such a creature, and you might use a multi-screen model to analyze it.

You can go deeper into classification and explain why this creature cannot exist in real life.

As a result of this research kids can design a flowchart with classification or a “passport” of a mammal. “Passports” are part of the OTSM-TRIZ technology. They help us differentiate between different classes of objects.

6.3 Creativity

Every topic must have a creative outcome. In the case of the strange animal it is a good opportunity to study one of the CIA (Creative Imagination Development) tools for generating new ideas, namely Hybridization.

A creative task can be “Create your own strange pet” but make it a combination of different classes of animals. Then describe this animal and explain how it lives, what it can do and what it is difficult for it to do. This task has a high cognitive load and at the same time implies motivated use of the language. Without preparatory work such as research, study of CIA tools it would have poor results among the majority of the class.

7. Course Design

Designing an integrated TRIZ-CLIL course one should always bear in mind multiple goals, such as:

- CONTENT, that is the subject to study.
- COGNITION or TRIZ tools or thinking models one is going to teach on the basis of this content
- LANGUAGE PROFICIENCY – the grammar and vocabulary the students will need to study and to speak about this content and how exactly they will develop the four linguistic competencies: listening, speaking, reading and writing.
- CREATIVITY in a wide sense: problem solving, creative tasks related to the content, evaluation of the results.

These aspects can be mixed from class to class. Sometimes a teacher can focus more on the language, sometimes on the creativity, but in any case, it is crucial to keep in mind these multiple goals. That is why a course can look like a web with different knots or like a mixing console, but in any case, it is not a straight and well-paved road (Fig. 5).

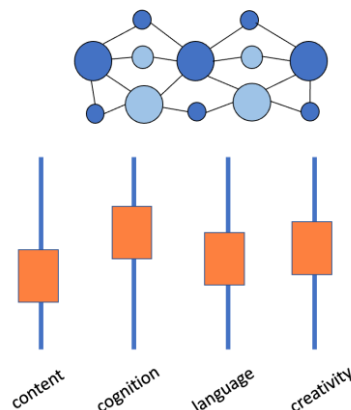


Fig. 5. Course Design

8. Conclusions

TRIZ should be considered not only a system of tools for innovation but also a teaching approach that can contribute to developing the learners' higher-order thinking skills and bring creativity and problem-solving in classroom to a new level of systematic, well-scaffolded activity based on clear principles and techniques.

Schools that apply this approach note that the students show better academic results, better adaptation to new circumstances and collaboration skills, high creative potential and are not afraid of hardship.

References

1. Zusman A.V. "Creative Pedagogy" (Original title: "Tvorcheskaya Pedagogika"), Article (draft). (in Russian)
2. Guin A. "TRIZ Pedagogy: Teaching to Think Creatively" (Original title: "TRIZ Pedagogika: Uchim Kreativno Myslit"), Moscow, VITA-PRESS, 2016. (in Russian)
3. Nesterenko A.A., Terekhova G.V "Contemporary State of TRIZ Education: Analysis and Development Prospects. Monograph" (Original title: "Sovremennoe Sostoyanie TRIZ Obrazovania: Analiz I Perspektivy Razvitiya. Monografia"), 2012. (in Russian)
4. Nesterenko A.A. "Knowledge Workshop" (Original title: "Masterskaya Znaniy"), e-book, Moscow, 2013
5. McLoughlin A. "How To Write CLIL Materials". ELT Teacher 2 Writer, 2021
6. <https://www.freepik.com/ai/image-generator>

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