tetris

Teaching TRIZ at School

TRIZ

Theory of Inventive Problem Solving
Improve your problem solving skills

Education and Culture DG

Lifelong Learning Programme

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Key to symbols

The following symbols will help you in quickly find out the relevant information you are looking for in the handbook:

Definition or key concept

Example

Instrument / tools

Self assessment / exercises

Answers to self assessment / exercises

Bibliography

Glossary

See also:
Inventive principles s 2.2.3

Links with other chapters of the handbook

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HOT TO USE TETRIS HANDBOOK

STARTING POINT

This handbook is one of the outcomes of the TETRIS Project, an initiative within the European Lifelong Learning Programme aiming at:

- identifying the educational requirements of upper-secondary schools, universities and industries from different European countries interested in the introduction of TRIZ (Theory of Inventive Problem Solving) in their curricula/training programs;
- attracting secondary school students to the study of methods and tools enhancing their creativity and supporting their problem solving skills with systematic means;
- defining an educational model suitable for addressing the heterogeneous demands of TRIZ education;
- producing and validating educational materials adaptable to heterogeneous specific situations , that can be used in a wide variety of different contexts.

The structure of the handbook has been conceived to guarantee the maximum adaptability to the heterogeneous requirements of TRIZ learners: a selected portion of the classical TRIZ Body of Knowledge has been divided into independent items, to be assembled according to specific needs and contexts of teachers, students, newcomers, practitioners.

Therefore, different readers might opt for selecting different subsets of chapters and paragraphs as described below.

The whole volume is divided into 5 main chapters related to the following topics:

1. Introduction(s)
2. Laws of Engineering Systems Evolution
3. Algorithm of Inventive Problem Solving
4. Su-Field Analysis and System of Inventive Standards
5. Tools and Principles for solving contradictions

Moreover the handbook is accompanied by an appendix with a set of exemplary inventive problems with solutions and 5 animations.

Structure of the chapters

Each chapter is related to a specific topic as detailed below; moreover, the chapters are divided into paragraphs dealing with more detailed subtopics. For example, readers interested in a general overview of the TRIZ Body of Knowledge can limit their reading to the first sections of each chapter, highlighted by means of a red bar on the side of the page. Besides, those who want to go deeper into a specific topic can study the related chapter, discarding the rest of the handbook.

Whatever is the level of detail of a topic, the related paragraph is divided into the following subsections:

- Definition: short definition of the selected Topic (hereafter referred as “T”);
- Theory: theoretical aspects related to T;
- Model: conceptual model and graphical representation of T;
- Method/Tool: operative instructions about how to use/implement T;
- Example: exemplary application of T;
- Self-Assessment: exercises to assess the reader’s level of understanding about T;
- References: further reading about T.

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Topics of the handbook chapters and related scope

Chapter 1: Introduction(s)

- The first paragraph introduces teachers and adult readers to TRIZ, explaining its rationale and expected benefits;
- The second paragraph is an introduction for students that is aimed at motivating younger readers into TRIZ study;
- The third paragraph introduces some reference concepts supporting the comprehension that can be helpful in understanding the following chapters.

Chapter 2: Laws of Engineering Systems Evolution

- The observation of the history of technical systems has demonstrated that any human artifact evolves by following repeatable patterns, despite the specific goal of such transformations. In other terms: Technical Systems evolve according to objective laws which are not dependent on the field of application or the function that the technical system is supposed to deliver. These laws govern the development of technical systems just like natural laws regulate the development of biological systems. The knowledge of genetics allows to predict the characteristics of a living organism; just like the Laws of Engineering Systems Evolution allow to anticipate future developments of technical systems.
- The second Chapter describes the 8 general Laws of Engineering Systems Evolution which can be used to analyse the level of maturity of a certain technical system and/or to guide the development of inventive solutions with an efficiently focused approach.

Chapter 3: Algorithm of Inventive Problem Solving

- System evolution implies the resolution of contradictions, i.e., conflicts between a system and its environment or between the constituting elements of the system itself. According to TRIZ research, the inventive solutions bringing a major contribution to the development of a technical system don't compromise opposite requirements. Overcoming contradictions is thus a driving force behind technology evolution and their identification is the first step of any invention process.
- The third Chapter introduces the readers to the TRIZ approach for analysing and reformulating a problem in the form of conflicting pairs of parameters (in TRIZ terms, contradictions); the step-by-step algorithm embeds the TRIZ logic and its practice progressively increases individual's problem-solving skills.

Chapter 4: Su-Field Analysis and System of Inventive Standards

- The Inventive Standard Solutions (sometimes briefly named Standards) are a system of 76 models of synthesis and transformations of technical systems in agreement with the Laws of Evolution of Engineering Systems. Together with the database of Scientific Effects and the Inventive Principles, they constitute the Classical TRIZ Knowledge Base.
- The fourth Chapter details the Substance-Field modelling approach, which is the standard TRIZ tool for modelling problematic situations; then, a selection of Inventive Standard Solutions is presented with the aim of constituting a reference list of solving techniques.

Chapter 5: Tools and Principles for solving contradictions

- Any inventive problem should be analysed according to the ARIZ logic and once that the underlying physical contradictions have been identified, and the ideal solution has been depicted, a new concept can be generated by means of the separation principles.
- The fifth Chapter describes the TRIZ principles providing the directions to overcome the contradictions of a problem modeled according to the ARIZ logic.

Appendix: Collection of examples

- The appendix contains a set of exemplary "inventive" problems with a detailed step-by-step description of the solving process until the generation of a possible solution.

Content of the animations

The TETRIS educational material also includes a set of five animations which can be used both for attracting to the study of TRIZ and to support the explanation of the main models of TRIZ (teachers can stop the animations on the appropriate frame to describe with further details the concepts behind the short stories). The content of the animations is briefly summarized below:

<u>Animation 1: History of TRIZ</u>

- The short story shows the origin of TRIZ as a theory developed through an extensive experimental activity (fig. 1), just like other well established sciences.
- The animation also introduces the existence of Laws describing the evolution of Engineering Systems.

Fig. 1: Animation 1 – History of TRIZ

<u>Animations 2-4: Nina at school/university/work</u>

- The stories represent Nina at different ages; the main goal of the stories is to show how a systematic approach to problem solving can support the generation of effective solutions in any situation, in private life as well as at school/work. All the three problems proposed in these animations are approached by means of the same inventive principles in order to show that the same model of solution can be efficiently applied to a variety of problematic situations.
- These animations also constitute a practical support to help teachers in the introduction of some TRIZ fundamentals, as detailed below.
- Animation 2 presents the concept of contradiction (fig. 2) and the importance of rejecting any compromise solution by formulating the Most Desirable Result.
- Animation 2 also introduces the Tongs model (fig. 3): to identify the underlying contradictions it is necessary to compare the most desirable result with the currently available resources. TRIZ teaches that the identification of contradictions is a crucial step to generate inventive solutions.

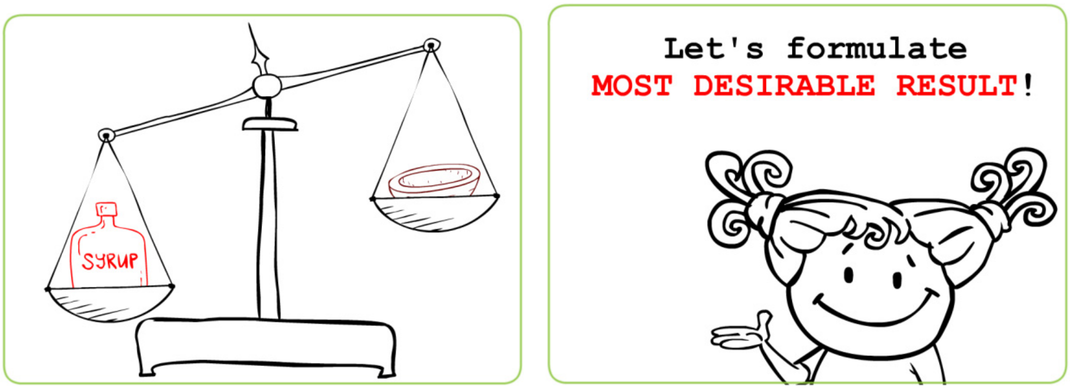


Fig. 2: Animation 2 – The concept of contradiction and the formulation of the Most Desirable Result

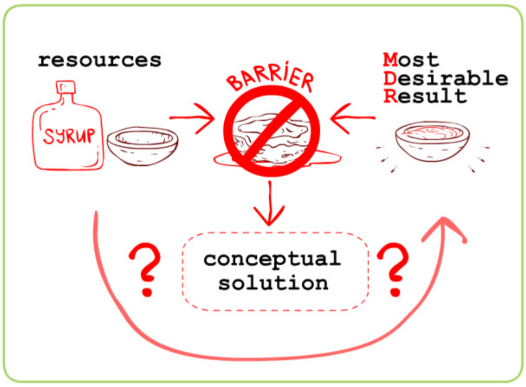


Fig. 3: Animation 2 – The Tongs model: a comparison between the current situation and the Most Desirable Result allows to identify the obstacle in the form of contradictions.

- Animation 3 adds further details to the concepts introduced in the first episode about Nina: in order to avoid the psychological inertia it is suggested to intensify the contradictions. As a consequence, radical modifications can be made as a result of adopting different perspectives (fig. 4).

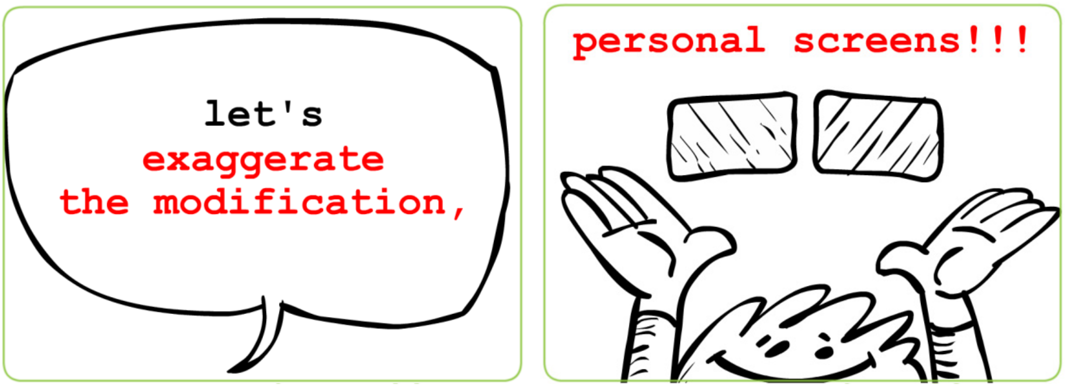


Fig. 4: Animation 3 – Exaggeration of contradictions helps overcoming psychological inertia.

- Animation 4 highlights another extremely important feature of the formulation of the Most Desirable Result: ideality suggests formulating the concept of an object of a function self-delivering the function itself, as a means to reduce the consumption of resources and to avoid harmful effects (fig. 5).
- Animation 4 provides also an extended list of products that can be associated with the Inventive Principle adopted by Nina to solve the problems described in these short stories.

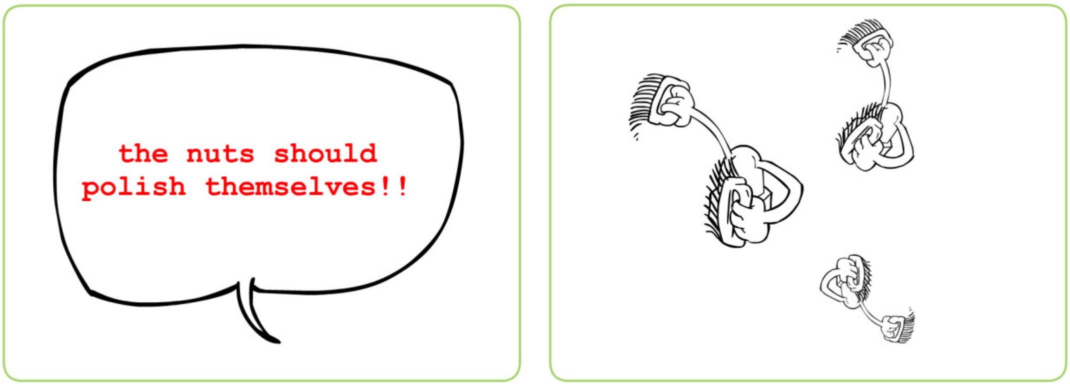


Fig. 5: Animation 4 – Ideality helps overcoming the psychological inertia and draws the attention to the cheapest and most efective solution.

Animations 5: Theory of Inventive Problem Solving

- The last animation summarises the concepts introduced in the previous ones and introduces some further elements of the TRIZ Body of Knowledge.
- The first part continues the analogy between TRIZ and other sciences proposed in the first animation; just like genetics allows to predict the evolution of a living organism, TRIZ helps anticipate the evolution of technical systems (fig. 6).
- The animation can also support teachers when introducing the System Operator (fig. 7) as well as Su-Field Modeling and Inventive Standards (fig. 8).

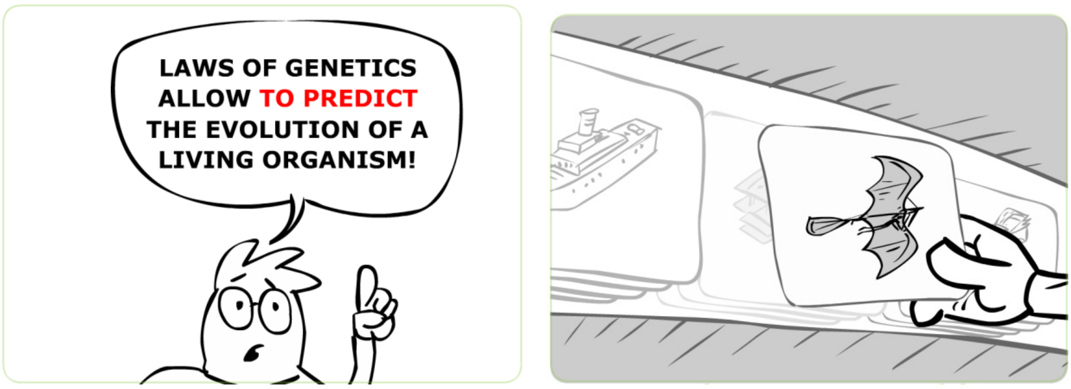


Fig. 6: Animation 5 – Ideality helps overcoming the psychological inertia and draws the attention to the cheapest and most efective solution.

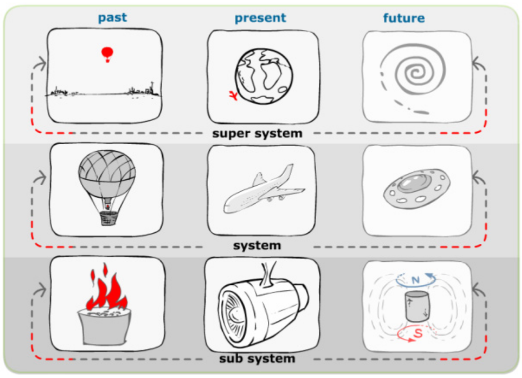


Fig. 7: Animation 5 – System operator: the TRIZ approach to system thinking.

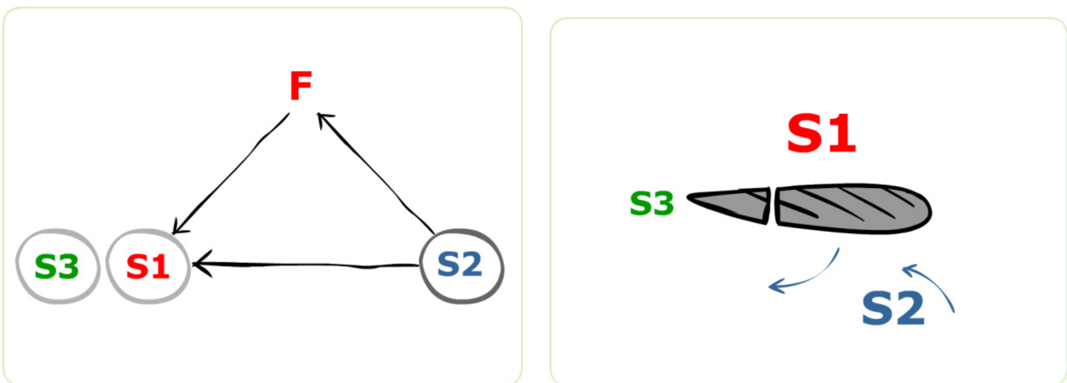


Fig. 8: Animation 5 – Su-Field modeling and Inventive Standard Solutions.

Future of TETRIS Project

The TETRIS project is the first attempt to create a unified multi-language training material to be used by teachers, students, trainers, professionals and interested readers as an alternative to multiple fragmented TRIZ education materials today available.

It is worth noting that all these materials can be freely copied and distributed provided the copyright notice remains intact. This also applies to the partial use of the handbook.

The TETRIS project team has not aimed at the development of a comprehensive set of materials to cover the whole Classical TRIZ Body of Knowledge, thus the TETRIS materials can be supplemented and improved. Those who would like to contribute to the translations into other languages, as well as to the improvement or integration of the present materials are invited to contact the project coordinator.

1 Fundamentals of Classical TRIZ

1.0 Why do we need to know the foundations of applied theories?

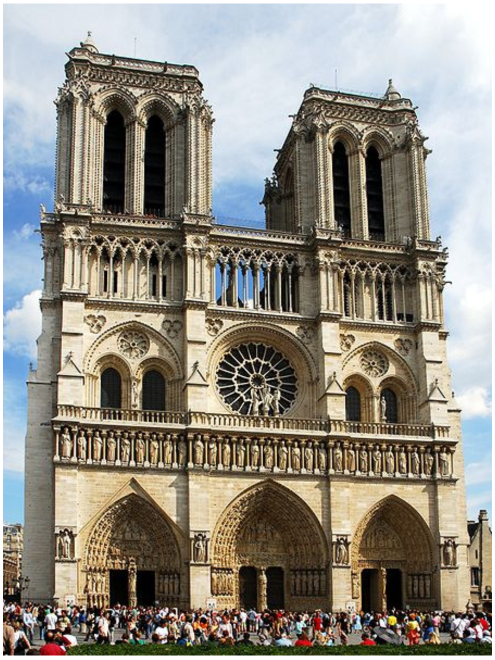
One frequently hears the following statement: “We are experts, we don’t need any theories…” This opinion is understandable in part. In relatively simple situations it is quite possible to succeed by a simple selection of the available versions and accepting those which provide satisfactory operation and help to achieve some objectives.

On the other hand, we are frequently unaware of the fact that the tools we use in our everyday professional activities are often based on certain theoretical models and assumptions. Thomas Kuhn describes many such facts in his famous book *Structure of Scientific Revolutions*. Kuhn shows that often in science history, theories and their tools have been created on the basis of not quite realized and not quite distinctly defined premises. Kuhn calls these basic theoretical premises paradigms. Realizing and correcting these premises led to serious changes in scientific notions and the creation of new, more effective tools.

One can hardly imagine that the Notre-Dame Cathedral in Paris or the Riga Dome Cathedral in Latvia could have been built on the basis of trial and error without a theory.

It is the same with cars. Imagine for a second that only “empirics” who renounce theory, mathematics, physics and accident-prevention rules work in the design-engineering departments of Mercedes and create cars by the trial-and-error method. How many years or even centuries would it take them to create a new model?

It took several centuries of research, experimentation and theoretical generalization for modern cars, aeroplanes, electronics, cinema and musical instruments to have been made possible. All that work resulted in the appearance of rules for empirics, which significantly increased the productivity of mental creative labour. It is remarkable that people using those rules often renounce the possibility of creating similar rules for inventors who create the new in any sphere of activity – technology, business, art etc.



Notre Dame Cathedral in Paris
Author Jerome Dumonteil
(www.wikipedia.org)

Even poetry, music and architecture have their rules theoretical generalizations. These rules, and typical solutions, are studied by future professionals. For example, today any schoolchild can solve quadratic equations and draw a linear perspective, whereas not long ago these things were considered very creative and not formalizable by means of rules.

In 1991, at the World Fair EXPO-91 in Plovdiv, Bulgaria, I had the chance to meet a violinist named Johann. We were demonstrating the first versions of the “Invention Machine” software product, designed to support engineering problem solving. It was the world-first TRIZ-based software created at our research lab. “Invention Machine” really helped engineers in their everyday practical work. It is just this software product that made TRIZ popular in the world.

An attractive guy approached our exhibition stand and asked why our company was called the “Invention Machine Laboratory”. During our conversation it became clear that Johann was a specialist not only in music but also in artificial intelligence and that he had done the same work in music as that done by G.S. Altshuller in technology. Johann had identified and clearly defined the principles of creating music of one or another genre, integrated them into a system and developed a software program that allowed anyone to enter a sequence of several notes, indicate the parameters of a desired piece of music to a computer, which, after having performed the routine work, played the created music. As the computer's co-author, one could listen to the obtained piece of music and improve it to your taste. Johann had invented a simple language which allowed even those who could not play a musical instrument and could not read music to use that system.

Johann's company was called the "Computer Music Laboratory" and his software was called "Composer". He gave me a cassette with recorded pieces of music created by different people using his software product. It included variations on popular musical themes in different genres as well as new melodies. I used to listen to this music with delight until I lost the cassette during one of my numberless trips. It is remarkable that many of my friends, including some professional musicians, also enjoyed that music.

Later I read about experiments where computer-composed and man-composed pieces of music were compared. An auditorium of musicologists was asked to listen to pieces of music and guess whether they had been composed by a computer or by a person. Professional musicians failed to pick out the computer-composed pieces.

We can draw one important conclusion from these episodes and examples. Creative activity is not something unmodifiable or stagnant. What yesterday seemed creative work looks as routine today. And what yesterday seemed an unachievable dream requiring a huge creative effort is being done today by the new generation of creators employing new professional technologies.

1. 0.1 The notion of creation is akin to the notion of Horizon

Today, that tree on the horizon seems to be at the uppermost point of the Earth. Tomorrow, after we have got to that tree and sat in it its shade, we will see that the horizon (the uppermost point of the Earth) has moved away and a new, even more beautiful landscape has opened up before us.

The same is happening to creative work. Today, many musicians and composers are already using software products like that created many years ago by the violinist Johann from Bulgaria, just as many engineers are using some TRIZ tools in their practical work and are solving problems which remained unsolved for years in machine building, nanotechnology or microelectronics.

An interesting tendency showed itself in the example of the large number of people engaged in professional study of Classical TRIZ. Initially, they attended TRIZ courses for creating inventions necessary for protecting their dissertations or for solving complicated problems within projects in which they took part. With time, some of them began to teach TRIZ it their organizations, which increased their TRIZ competence. Problems which had previously seemed creative were beginning to look routine. Very often their objectives were becoming more and more complicated. Their creative energy found a way out though attaining those objectives.

At present, traditional advertising specialists meet with competition from colleagues armed with the knowledge of TRIZ application in advertising. Creating an advertising product which would help to significantly increase the sales of products and services of your clients is not at all a simple creative job. Competition is particularly strong in advertising and results are easy to check: a growing sales volume means that the advertising campaign has been properly designed and conducted.

Igor Vikentiev , one of my advanced TRIZ colleagues engaged in the development of Advertising Theory and creating effective methods for practical application, wrote a book entitled *Advertising Principles*. The book has been republished many times and today it is a desk book for many advertising specialists.

It is natural that the book is actively criticized by competitors – traditional ad-makers who insist that creating an advertising product by some methods is impossible and that an ad-maker must always be in the throes of composition to produce a new, original advertising product. However, the desired result is not always achieved. That is why the new generation of ad-makers and advanced professionals buy the book and attend I.V. Vikentiev's workshops. The thing is that his approaches significantly increase the probability of obtaining a positive result, which means a higher probability of conducting a highly effective advertising campaign within a scheduled time frame. Using the TRIZ-based method of conducting advertising campaigns ensures the sustainable production of good results and helps to win in the competition with those who do not admit that TRIZ is a very practical and effective theory.

Elena Novitskaya is a professional graphic designer. She has inventively revised the 40 TRIZ principles and is using them extensively in her work. She has a wide choice of customers. It is necessary to say that Altshuller's 40 principles are the most popular TRIZ tool in the world, but few people know that in 1986, G.S. Altshuller expressed regret concerning the years he spent revealing and integrating those principles and removed them from the arsenal of TRIZ tools.

High competence in TRIZ means that a specialist knows the theoretical foundations and can use them as an applied tool; this helps his company to obtain a steady profit and high results in the field of innovation and increases the chances of success for his company or organization under keen competition.

Why am I so interested in the examples concerning my colleagues from the advertising sphere dealing with the application of TRIZ elements in non-technical fields?

Igor Vikentiev is not an advertising specialist by education. When the USSR economy collapsed and many engineers lost their jobs, those who knew TRIZ began to use its tools for solving problems related to the organization of advertising business and in those niches of products and services where a new labour market was emerging.

In-depth knowledge of the fundamental principles if Classical TRIZ not only ensures the effective application of its tools, but also allows new tools, adapted to specific needs, to be created as necessary.

If experts, creating their tools by the trial-and-error method and without any theoretical generalization, face a situation when their tool does not work, they need to make a fresh start.

If, on the contrary, theoretical generalization has been made, it often, though not always, strongly facilitates the creation of new tools for new applications and the correction of existing theoretical principles. Classical TRIZ and its tools have been created in the same manner by studying the experience accumulated by many generations of inventors.

Thus, we can draw the conclusion that applied scientific theories significantly increase the probability of obtaining a desirable result at a lower cost and at a better quality of an obtained product or service. These theories may serve as the basis for the creation of new tools for everyday practical application. These tools are studied by future specialists in the course of their professional training.

The trouble is that all professionals, future competitors, learn about much the same tools during their professional training. This considerably reduces the competitive advantages of specialists and companies. At present, to win a competitive struggle, one needs to develop and improve the skill of increasing the effectiveness of work while solving so-called creative problems. All professionals are taught to solve problems by standard methods. By far, not all of them can work with non-standard problems. It is, however, just an effective method aimed at defining and solving non-standard problems that offers a tangible competitive advantage. And it is where a deep knowledge of Classical TRIZ comes to the rescue.

Using a good applied theory we do not seek a solution to a problem by the trial-and-error method, but do it systematically, creating, step by step, a solution to a respective specific situation.

The knowledge of theory for building various tools increases the level of professional training and facilitates the effective modification of existing tools or the creation of new ones as and when necessary. That is why more and more universities all over the world are considering a possibility of introducing serious Classical TRIZ and OTSM courses into their academic curricula. A good applied theory turns the solving of complicated, non-standard, so-called creative problems into routine, thereby opening up new vistas for higher-order creative work and for work on more complicated problems. The creation horizons are being expanded, offering new opportunities for efficient creative work.

The notion of creation is akin to that of the horizon and applied theories are cars which allow us to reach new horizons much faster than we could do on foot, and to move to new, still more interesting creation horizons.

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1.1 Introduction for teachers and companies

We live in a rapidly changing world. The speed of changes and the appearance of novelties are growing abruptly. It is not easy to orientate oneself in this world. Knowledge quickly gets out of date and new knowledge appears. The situation in the world and in the regions of the countries around us is also changing, as well as economic conditions. Cultures are integrating. Today, it is not enough, as it was previously, to master one specialty, learn typical professional solutions and use them all through one's life…

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TRIZ has been evoking much discussion since the moment it appeared in 1946–1949. First, it arose as an invention-creating METHOD. At that time, creating such a method was believed to be impossible. At that time, the ability to invent was considered a gift of nature. You can either invent if you are endowed with such a gift, or not if you have no such gift. Nevertheless, in 1949 the method was created and tested on very complicated problems. The solutions obtained through the use of this method won a grand-prix at an inventors' competition. In addition, the method was also tested on other problems and yielded steady results. The authors of the method – Genrikh Altshuller and Raphael Shapiro – wrote a letter to Stalin reporting the achieved results. Instead of encouragement, they were arrested and sentenced to 25 years of Gulag punishment. Genrikh Altshuller served his term of imprisonment in the Arctic Circle, working in the Vorkuta pits, while Raphael Shapiro was sent to the south of Central Asia, near Karaganda.

Shortly after Stalin's death they were given their liberty. Raphael Shapiro withdrew from development and research while Genrikh Altshuller continued his work on the method and began spreading it among engineers. The method was being gradually improved and turned into a clear ALGORITHM, which, over the course of time, was given the name the Algorithm of Inventive Problem Solving (ARIZ).

By that time, public opinion of the invention METHOD had started to change for the better. The method proved its effectiveness. It began to be studied and used by different people who, just as Altshuller, obtained excellent results. Skeptics changed their opinion and began to admit that a method of inventing the new could exist, but that referring to it as an ALGORITHM was too strong!

Nevertheless, ARIZ continued to develop and training courses for those wishing to master it began to be organized more and more often. That promoted a more active ARIZ development. The participants of ARIZ workshops kept in touch with the Altshuller and sent him difficult-to-solve problems. Altshuller applied ARIZ to problems analyzed by his followers, revealed the weak points in the algorithm and created new ARIZ versions. As a result, there appeared two figures in the ARIZ name which denoted the year of issue of a given version: ARIZ-64, ARIZ-74, ARIZ-77, etc. Workshops were becoming more and more popular and new ARIZ versions were being produced more and more often, sometimes several versions a year. As a result, letters denoting the version number were introduced into ARIZ names in addition to the figures.

For example, in 1982 several versions were created: ARIZ-82 A, ARIZ-82 B, ARIZ-82 C, ARIZ-82 D.
Each new version had been checked on test problems before Altshuller distributed it. The collection of test problems was permanently growing; it included problems which were impossible to solve using previous ARIZ versions.
There began to emerge schools of inventors, where ARIZ was taught not only by Altshuller, but also by people who had received training from him. By the mid 80s there existed about 300 invention schools where training was organized on different levels and with different frequency.

As time went on, the hypotheses proposed by G.S. Altshuller and Raphael Shapiro in their very first article, dedicated to the foundations of the invention method's creation written shortly after their liberation from the labour camps and published in 1956, found confirmation. Over 30 years were spent verifying the ideas described in the article, during which time new ideas were obtained as well as theoretical foundations underlying ARIZ. All those achievements were integrated into a single theory and tools for use in the everyday engineers' practice. In the mid 70s, the theory acquired the name of the Theory of Inventive Problem Solving (TRIZ).

By that time, public opinion had already accepted the idea of the possibility of creating an invention ALGORITHM, but had begun to deny the possibility of creating an articulate invention theory. It is necessary to say that in the late 80s and early 90s, the possibility of creating an Invention Theory was beginning to be recognized, but TRIZ was denied as a theory. G.S. Altshuller's and I.M. Vertkin's research into the history of innovation implementation by people who changed the world proved that the delay in recognizing innovations is characteristic of all cases regarding the introduction of weighty innovations: aviation, the railway, space travel and many more had to follow the same path to recognition. Today, the recognition of TRIZ as a well-knit and practically effective system is prevented by many factors, the main one being the lack of reliable information from primary sources created by G.S. Altshuller himself.
Popularity is being gained for the simplified and abridged versions of the simplest tools of Classical TRIZ. At workshops, neither the theoretical foundations of Altshuller's Theory nor its most important and basic tool – ARIZ – are considered. The information about Classical TRIZ is diluted with numerous "improved" versions of the "modern TRIZ". Many of these TRIZ versions are far from what could be called an applied invention theory. Judgements about TRIZ are very often based on these compilations rather than on primary sources. It is interesting that as early as 1985, at the first presentation of the research into the history of innovation implementation by creative people of the past and present, Altshuller himself predicted that the events would take this course after his death. That research proved that there exist steady regularities of events which accompany the introduction of new ideas, whether it be within the limits of a separate company or organization or on the scale of humanity scale.

Meanwhile, a new stage of TRIZ development and dissemination started in the mid 80s. TRIZ development logically resulted in new ideas. For example, it became clear that further development of TRIZ required the creation of a strong foundation underlying three new theories.

The first theory should deal with the evolution of those systems that the improvement of which is the job of creative people and different kinds of inventors. G.S. Altshuller called it the Theory of Technical System Evolution (the Russian acronym is TRTS). Because of the historical circumstances, he narrowed the name of this theory and restricted himself to technical systems. Different people (Boris Zlotin, Alla Zusman, Igor Vikentiev, Vyacheslav Yefremov, Igor Kondakov, Yury Salamatov, Igor Vertkin, Natalya and Alexander Narbut and many others) were engaged in TRTS development. Their works formed the basis of the recent versions of the Classical TRIZ tools.

Systems are developed by people – inventors and creators – so it was necessary to understand where the people who changed the world came from and how they managed to introduce their ideas despite the resistance of their contemporaries. G.S. Altshuller and I.M. Vertkin scrutinized the biographies of about 1000 such people whose names had become the history of humanity. It emerged that the biographies of most people who lived in different historical periods of human history and in different regions of the world have certain similar features. Many of them faced similar problems while working on their inventions and ideas and while implementing them. It is important to note that similar problems occurred not only in the life of engineers, but also in the life of painters, doctors, researchers and businessmen (for example the Federal Express history). The analysis results were presented in the form of a business game: “External Circumstances versus Creative Person”. It is a kind of problem collection which describes typical problems arising in the life of Creative People irrespective of their occupation, time and place of residence. This research work formed the basis of the second theory, which needs further development. Altshuller and Vertkin called it the Theory of Creative Personality Development (the Russian acronym is TRTL).

The evolution of Classical TRIZ proved that its theory and practical tools are applicable not only to technical systems. Such a hypothesis arose at the early TRIZ creation stages. However, the practical confirmation of this hypothesis required several decades of application of TRIZ tools and theory by different people engaged in research activities in various fields, such as physics, botany, chemistry, various production and financial applications, business applications and different kinds of social problems of different scale, advertising and many others.

Many of Altshuller’s followers started applying TRIZ to various problems, including those arising in their private life. There arose a question why some people could and others could not apply TRIZ to various situations. Not only engineers but also representatives of other professions such as advertising specialists, businessmen and research workers were beginning to attend TRIZ schools. Banks, exchanges and government organizations were beginning to resort to the services of specialists. There arose another question connected with the first one: how to teach all those people to effectively use the Classical TRIZ tools in their fields of activity. While searching for answers to those questions, new ideas came to Altshuller which formed the basis of the theory named the General Theory of Powerful Thinking (OTSM). He started to develop those ideas in the mid 70s. In the mid 80s, Nikolai Khomenko was involved in OTSM development.

By the mid 80s, many more people had accepted the idea of creating an Invention Theory. However, both the idea of developing a General Theory of Powerful Thinking (OTSM), as well as the Theory of Creative Personality Development (TRTL) faced strong resistance even in the environment of TRIZ specialists.

The OTSM evolution caused further development of Altshuller’s basic ideas and gave an impetus to the creation of a comparatively articulated theory of powerful thinking. This theory formed the basis for the appearance of tools for dealing with complicated interdisciplinary problems containing tens and hundreds of sub-problems from various areas of knowledge. Examples of problems with such an amount of complexity include: managing the sustainable development of a region with hundreds of thousands or even millions ofinhabitants; setting up a company or business based on permanent and effective creation and the introduction of innovation ideas; the creation of research centres capable of changing pioneer heretical ideas into an ecologically safe and profitable business for society.

OTSM provides users with the tools for dealing with various kinds of knowledge. It helps them effectively assimilate knowledge from different areas, including new areas of human activity. That is why a group of researchers from the former Soviet Union selected OTSM as a basis for building new pedagogical tools capable of improving the effectiveness of the educational system in teaching adults and children to deal with problems. For example, one such tool was Alexander Sokol's approach to the simultaneous teaching of foreign languages and OTSM-TRIZ basics. This approach, called the Thinking Approach, is founded on the idea that language is one of the tools used for solving the vital problems of man and in order to master and make the best use of this tool it would be advantageous to know at least the basic approaches to problem solving in general.

Let us look again at the history of Classical TRIZ and see what transformations it underwent during its evolution (see Figure 1).

First, there appeared a METHOD comprising a small number of steps. Then supplementary methods started to appear. In due course, those supplementary methods began to integrate into a system – an ALGORITHM which increased their application effectiveness – ARIZ. ARIZ evolution revealed some fundamental applied theoretical statements which were presented in the form of an applied scientific THEORY – TRIZ. The evolution of the theory proved the necessity of developing several other theories which must serve as a basis for a new TRIZ.

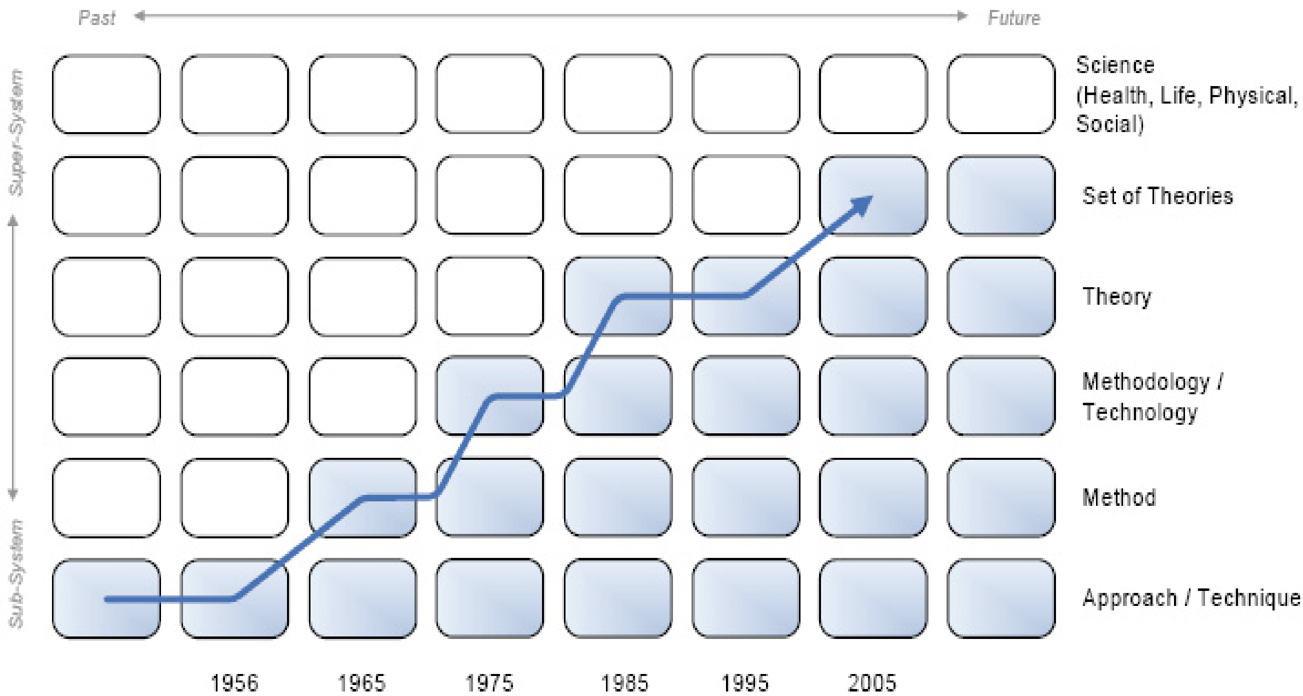

Figure 1. The evolution of Classical TRIZ

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Altshuller thought that the system of theories needed a new, more suitable name, but no new name has appeared so far. Therefore, the formed system of theories is still called Classical TRIZ, which causes some misunderstanding while talking to people interested in TRIZ but unacquainted with its history. As Classical TRIZ acquired popularity in the world, its various modifications began to appear. They are generally strongly simplified and abridged. A reverse process is likely to start – moving away from the already achieved objectives back to special methods and algorithms.

Some of the Classical TRIZ evolution branches produced interesting approaches. For example, an interesting approach and a useful method, named Directed Evolution, was created in I-TRIZ. The main authors of this approach are Boris Zlotin and Alla Zusman. Analysing this and other branches of Classical TRIZ are not within the scope of this work.

Classical TRIZ has repeatedly proved its effectiveness. TRIZ and its tools have been used for solving various problems starting with relatively simple ones (technical) and finishing with all sorts of complicated social problems.

People who come to know TRIZ sooner or later start wondering why it all works so effectively. We will try to answer this question in the next sections. For a better understanding of how and why TRIZ works, it is necessary to go thoroughly into different aspects of Classical TRIZ. Nevertheless, even the most perfunctory knowledge of TRIZ and its theoretical foundations allows people of different professions to cope with many of the problems they encounter in their professional and private life. This is just what makes Classical TRIZ and OTSM attractive to people engaged in the sphere of education.

Research has been conducted and OTSM-TRIZ elements have been used in pedagogy and education for over 25 years so far. Individual special methods have been created as well as complex systems used in education and pedagogy. Using those methods, we are ready, right now, to start developing creative and thinking abilities in children aged 2 or 3 and guarantee a positive result. Most of the pedagogical OTSM-TRIZ tools are represented by games and various kinds of creative activity. Children who began to assimilate creative thinking methods based on OTSM-TRIZ are already grown and have children of their own. It is interesting that they themselves are beginning to work with their children using new, modern methods or creating their own methods if the need arises.

This fact is worth noting: high-quality, in-depth comprehension of OTSM-TRIZ not only improves the application efficiency of the existing tools for dealing with complicated non-standard problems, it also allows the prompt creation of needed tools if those available do not cope with a problem.

The current OTSM-TRIZ is in fact a construction set composed of various tools which are united into a required system according to respective rules. These rules constitute the theoretical foundations of OTSM-TRIZ to be mastered for a better understanding and for solving problems arising in the educational system. That is why we are starting with the theoretical foundations. You should not be afraid of the word “theoretical”, because the theoretical foundations of Classical TRIZ and OTSM are in effect applied tools of a higher generalization level. That is why they work where the existing standard tools of professionals and experts of all kinds cease to work.

We live in a rapidly changing world. The speed of changes and the appearance of the new are growing abruptly. It is not easy to orientate oneself in this world. Knowledge quickly gets out of date and new knowledge appears. The situation in the world and in the regions of the countries around us is also changing, as well as the economic conditions. Cultures are integrating. Today, it is not enough, as it was previously, to master one specialty, learn typical professional solutions and use them all through one's life. New knowledge and new tools for working with this knowledge appear even within one specialty. It is difficult to foresee how the world is going to look in several decades. It could be said that this problem is solved by life-long learning. To better outline the problem, let us use one of the Classical TRIZ tools – aggravating the problem situation to an absurd extreme. This method allows basic roots to be identified within a problem, leaving for a time the remaining particulars for subsequent analysis.

Let us imagine that we have created the best, the most advanced training course and begun teaching a group of students. Some days later, the students successfully defend their graduate papers and get diplomas. But when they leave their educational institution it becomes clear that the most advanced skills and knowledge they got while studying became hopelessly outdated during the training period. Real life changed during that time and required new skills and knowledge.

The situation is really challenging and many educators are really at a dead end! What should they teach to students in this rapidly changing world if knowledge becomes obsolete by the end of a training course?

The Third Millennium, G.S. Altshuller's unfinished novel, describes a fictitious school where not narrow specialists are trained but generalists capable of deriving the knowledge necessary for resolving vital situations.

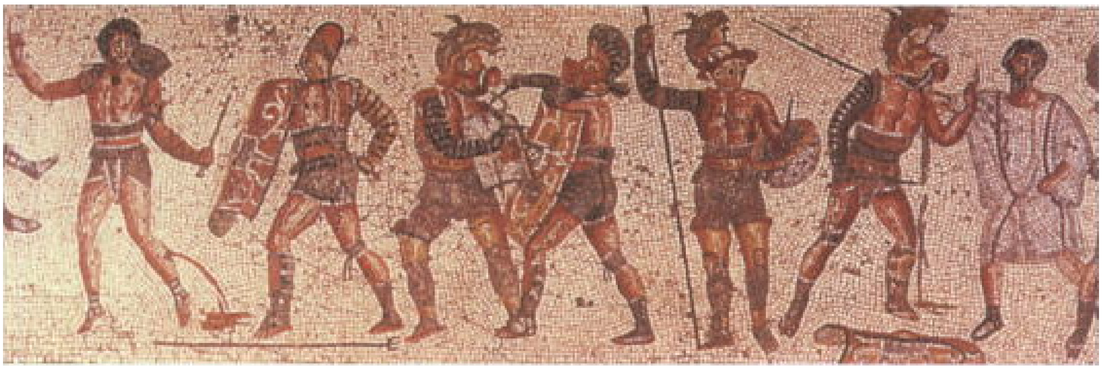
Problems are also changing. Typical professional solutions are becoming useless. What is to be done?

We think that G.S. Altshuller's ideas exposed in his fantastic novel are worth our attention. We have to teach our children about living in a world about which we ourselves know very little. Today we cannot provide our children with standard tools for solving problems which are unknown to us. What we can do is teach them to create tools for effectively solving those future, unknown problems. This is proved by the applied experience of Classical TRIZ and OTSM. Probably it is not enough. Neither Classical TRIZ nor OTSM can replace special knowledge in various subject areas. However, we think that the skill of dealing with the knowledge about problem situations is one of the fundamental subjects of the educational system of the future. And we must start creating this future right now.

1.2 Introduction to TRIZ for students

Nowadays, it is difficult to find somebody who has never played a computer game, at least once in his life. A significant number of computer games is offered, and differ from each other in their plots, graphic levels, sound quality… and in their AIMS of winning in the virtual world.
But how can these people solve a real problematic situation and become a winner in the real life?
In our electronic book we will discuss these questions. The physical and emotional feelings of gambling, astonishments which appear as a result of new discoveries, victory triumph will be familiar to you because everything begins from games and real life demands considerable efforts…

... The Roman Empire, the Rom centre, the Coliseum arena. The bright son appears over the tribunes. You have a short, fighting sword and a light, consistent shield in your hands and feel with your shoulder a shoulder of your fellow-soldier in the compact, locked file of fighters. With the slight press of the button everything goes in motion. The tribunes cry with excitement! The dozen thousands of hands are risen up. In the opposite side of the arena dust is mounted up from the furiously rushed, fight chariots of the enemy. And your team knows how to turn these hateful chariots down and to achieve a victory over the stronger enemy!



(source: The Ancient City: Life in Classical Athens and Rome di Peter Connolly e Hazel Dodge)

Of course, it is only a game …

(source NASA Photo ID: EL-1997-00146 AND Alternate ID: L96-924)

... The modern, supersonic, combustion ramjet. You have a hand wheel of this high-powered machine in your hands. The roar of the engine makes you push yourself in the seat and feel acceleration physically. The takeoff strip flashes downwards and is changed by the beautiful Earth view. The horizon is marked by tender, pastel tones and above you can see endless space darkness. You find yourself in face to face contact with this miraculous, iron bird. With the slight movement of your fingers on the control

box and you make the rocking wings move. The plane turns, drifts down and flies up again. You feel yourself like a hero. The professional pilots who operated planes throughout their service life express their admiration about such training stimulators.

Probably, it is a game as well…

Modern role playing games (RPG). You play a computer game not alone, not even with a couple of your friends… The dozen hundreds and even million of players are involved in the game! Their presence can be filled physically as a shoulder of the fellow soldier in the Coliseum arena. In addition to high-powered acoustics, nice and quick graphics and special effects the game interactivity appears. The plot development depends on the players and their actions. The play appears to be like life. The situation can change quickly and in these conditions it is necessary to take responsible and non-standard solutions. The plot roles can be different: household, travel, politics, new business development, child's upbringing, social life, economy…

Is it a game as well?

These examples are linked by the astonishing feeling of reality, the power feeling over the computer, the possibility to get new skills and also diverse levels and aims of these tools in the world experience.
And it is not necessary at all that games, plots and images which were illustrated above coincide with your favourite.
It is more necessary to understand the core of a game correctly.
We would like to emphasize the following points in these image pictures.
Our amazing, changeable and manifold world demands new knowledge about tools, modelling and management skills during its development.
In the Middle Ages only a few scientists could add, subtract, divide and multiply figures which exceeded by its amount the number of fingers in both hands:

XLIX * XLI = ?

And the reason lies not in presence or absence of intelligence, but in solution of non-standard problems. The roman system of calculations was time-consuming and uncomfortable and even more complex for difficult, untypical calculations. With the invention of Arabic figures and of the decimal system it becomes easier to study arithmetic. And nowadays, everyone can study it, if he wishes. It is even more important to find with a methodic approach the correct direction while solving inventive, i.e. non-standard problems. Nowadays, everyone can learn it, if he wishes.
The double calculation system makes even computers work more effective…

The tool and the fundamental knowledge and models where this tool is found play here a crucial role.

This book is written with the aim of sharing our knowledge about TRIZ and of learning how to use TRIZ tools in order to solve non-standard problems. In the following two pages we give an overview of some basic questions.

What?

This book is about TRIZ – a theory of solution of non-standard tasks. This theory gives the basis for the creation and the appliance of solving tools for complex, non-standard problems. It differs from other theories by its universality – this approach is applied in any subject areas, though it does not substitute special knowledge. At the same time it is instrumental because it suggests using concrete rules during a problem solution.

What is a Non-standard problem?

For example, the following task which was posed 50 years ago was solved with the help of TRIZ by its inventor, G.S. Altshuller:

It is necessary to develop a fire resistant, heat-protective suit. It must provide safety protection from high temperatures (100 ^{0} C) in a fire point and also have a self-contained breathing system to survive poisonous gas produced by combustion. Materials capable to resist to high temperatures have been already invented. And the systems of self-contained breathing have been also found. What causes then a problem?
The case is that it is almost impossible to work in this heat-protective suit because it is equipped with two systems: the self-contained breathing system and the system of heat protection. And one should bear in mind that it is also necessary to carry tools and sometimes to evacuate injured people…
The question is how to decrease the weight of the heat-protective equipment?

(fonte: Photo Contest Entry, color, Mar. 1981, "Air Force Fire Fighters" VANDENBERG AIR FORCE BASE, CALIFORNIA (CA) UNITED STATES OF AMERICA (USA), autore AIRMAN MELODY A. WEISS

If reformulate this problem in accordance with one of TRIZ tools, one can guess how we can solve this problem:
If the self-contained breathing system will be excluded, then the heat-protective device will be easier, but it will be impossible to work because the breathing system is not provided. If the system of heat protection is excluded, then it will be possible to locate the self-contained breathing system. But how we can provide heat protection?
It is necessary to create the heat-protective suit which will provide a fireman with air and gives him necessary heat protection, using the accessible technologies and materials.

The task remains non-standard, until the method of solution is unknown.
One of TRIZ tools was applied in order to solve this problem: **it was necessary to change and to combine systems so that its advantages remained and its disadvantages disappeared.**

Applying this general rule to the concrete problem with the heat-protective suit, we can give the general description of the problem solution: it is necessary to combine two subsystems in one system in order to provide breathing and heat protection.

According to one of TRIZ tools the formulation of this problem gives a concrete direction how to solve this problem: we should think about the connection of two subsystems in one main system in order to decrease the weight of the heat-protective suit.

It was suggested to use liquid oxygen for the system of heat insulation and cooling at a temperature of minus 183°C. Liquid oxygen which vaporizes and transfers into gas cools the heat-protective suit. It takes heat from this suit and when liquid oxygen is heated, it can be also used for the breathing system. As a result, not only the weight of the heat-protective suit will be reduced, but also firemen can stay longer in the dangerous zone and the comfort during their work is also improved. As a result of this invention extra benefits appear: such a heat-protective suit could give a fireman the possibility to do his work up to a temperature of 500 ° C.

It is the best possible solution, isn't it?

The main idea of TRIZ refers to the observation that our world evolves according to objective laws, which can be explored and implemented in practice. And the creative processes are not exceptions because we have some rules for them as well.

As a reader, you can briefly make an acquaintance with TRIZ, when you read this introduction. You can see the animations which reflect the core and the history of this theory and go deeper into reading and studying this training aids. It is up to you to decide.
Your knowledge will be turned into skills and attainments, when you will feel the effectiveness of this method with the tip of your fingers. You will realize the effectiveness of TRIZ firstly during the solution of some training tasks and the lectures of your teachers and then, in real-life experiences. And from your efforts not only the course of the game will be changed as in the above described plots, but also the course of life will be changed. And you will feel yourself like a winner not only in a game, but also in real life.

Who?

Whatever is your age or profession, for sure you have already realized in your life that we live in a world of problems and we spend a lot of time trying to overcome them.
The book is written with the help of the programme *Lifelong Learning* and is intended for people of different ages and professions. You can read it by yourself or with the help if the lectures of your teacher; hopefully, this will be just the starting point of a deeper study of TRIZ and its powerful instruments.

Where?

The printed form of this book will appear in the countries of all the project partners in several different languages: English, French, German, Italian and Latvian. You can print this book or read it on this website. Here you can find information about conferences, seminars, books, magazines and forums. It does not matter with what you begin your acquaintance with TRIZ. The more important is the result, which you can achieve. At least, the part of the result which some companies achieved as a result of its appliance of TRIZ in practice: *ABB, Ford, Boeing, General Motors, Samsung, Chrysler, LG, Eastman Kodak, Peugeot-Citroen, Exxon, Siemens, Procter & Gamble, Digital Equipment, Xerox, Hewlett Packard, Motorola and many others…*

When?

If you do not have five spare minutes for the beginning of your acquaintance with TRIZ, then you can read about it during your lectures and conferences, travels on public transport and waiting for a doctor's appointment. You can suggest solving an interesting task during a party with your friends. That will animate your party and explain how the chaotic search for a proper variant differs from the meaningful solution which you will be able to acquire to that time to a certain degree.

Why?

In order to improve the quality of Your life: to achieve a professional success, improve one's social position and to increase material benefits.
In order to become special: to see the world from another side, do not scare an unknown and to find solutions which you can find in comparison with others who are not capable of obtaining any solution.
In order to gain satisfaction from seeing that impossible becomes possible, from helping and making somebody happy. You also feel satisfaction from acquiring skills about which you have had no notion.

We will be glad to see you in your circle- among people who not only seek for answers to difficult questions, but who find them self-confidently. Do not loose your time dear reader! We wish you success and cool solutions!

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1.3 TETRIS OTSM[1]—TRIZ glossary-solution

1.3.1 Problem.

1.3.1.1 Typical Problem.

Definition:

Typical problem is a problem that is typical for certain domain of human activity, there for in this domain typical solutions for that kind of problems are well known.

Theory:

One of Sub-Function of Altshuller's ARIZ (ARIZ 85-C) is transformation of a non typical problem description into typical one. Then we can use typical solutions of TRIZ or/and typical solutions from domain where this kind of problems are most typical and well known.

1.3.1.2 Non Typical Problem (see: Innovative (Problem) Situation).

In the border of OTSM-TRIZ Non Typical Problem

1.3.1.3 Innovative (Problem, Inventive) Situation.

Definition:

Innovative situation is a situation we would like to change but typical well known solutions could not be helpful for certain reasons.

Theory:

Some innovative situations arise due to some undesirable phenomenon that should be eliminated or decreased. More generally we consider Innovative situation as unsatisfactory situation of many kinds: we would like to change something but it is not possible for certain reasons or changes we are going to make lead us to a conflict with other shareholders participate the problem situations. Sometimes Innovative situation arise when we have to explain unknown phenomenon that appear in nature, scientific research, manufacturing and business process of an organization etc. Any kind of contradiction between a natural phenomenon and contemporary scientific knowledge could be also considered as an innovative situation: it is necessary to think on new paradigms capable to resolve contradiction between real life phenomena and actual scientific theories.

Even more generally: any kind of unhappiness with status quo we could not change within modern stereotypes and typical solutions we could consider as an Innovative Situation.

1.3.2 Solution

1.3.2.1 Typical Solution.

Definition:

A well known solution of a typical problem presented in general form. Used by many professionals who learn typical solutions during their professional education and throughout their professional experience.

General solutions should be adjusted for a specific situation. Then typical solution became implemented solution (See: Implemented Solution).

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1 At the beginning of 1980s more and more people started applying TRIZ not only to engineering problem solving but to different kinds of problem, even in their private life. That is why Altshuller started writing in his articles and manuscripts that TRIZ had to be transformed into the General Theory of Powerful Thinking. OTSM is a Russian abbreviation for the theory and at the same time the name given by Altshuller himself. As our research was provided under his supervision and he approved of our results, in July 1997 Altshuller granted N. Khomenko a permission to use the name OTSM for his research. This was done under the condition that every time the name was going to be used, its history had to be explained. That is why this comment appears here.

1.3.2.2 Non Typical Solution.

Definition:

Solution that is unknown for professionals who are working on the problem (innovative) situation. See detail: Innovative (Problem) Situation.

1.3.2.3 Line of Solutions.

Definition:

In the framework OTSM-TRIZ problem solving Process (See: OTSM-TRIZ Models of a Problem Solving Process) we distinguish several main lines of non typical problem analysis. Line of solutions show how appear implemented solution out of initial description of non typical Innovative (problem) Situation (See: Innovative (Problem) Situation).

Theory:

The Mile Stones system of several lines was developed for educational proposes, but it is also helpful for avoiding some misunderstanding between members of a problem-solving team as well as between an OTSM-TRIZ coach and his customer.

Here we deal with one line of analysis of a problem situation - that of building a solution that is used in practice here and now – in specific conditions.

These are the requirements for the Solution Line which are in our opinion the most important ones in terms of the OTSM-TRIZ problem solving process:

The Line must be coordinated with the entire complex of lines of analysis of a problem situation and synthesis of solution on the basis of the models of Classical TRIZ proposed by Altshuller [G.ALTSHULLER.: Process of Solving an Inventive Problem: Fundamental Stages and Mechanisms. April 6, 1975. (http://www.trizminsk.org/c/126002.htm)].

The Line must not depend of the used tools of problem analyzing and solving, in order to provide flexibility of its use for various tools of problem solving.

The Line must not depend on those areas of knowledge to which the problem pertains, in order to be universal and subject-independent.

The Line must be simple and understandable by experts in the problem area even without a specific knowledge of the problem solving technologies, in order to use a team of experts-specialists in narrow fields and to communicate in one conceptual language.

Model:

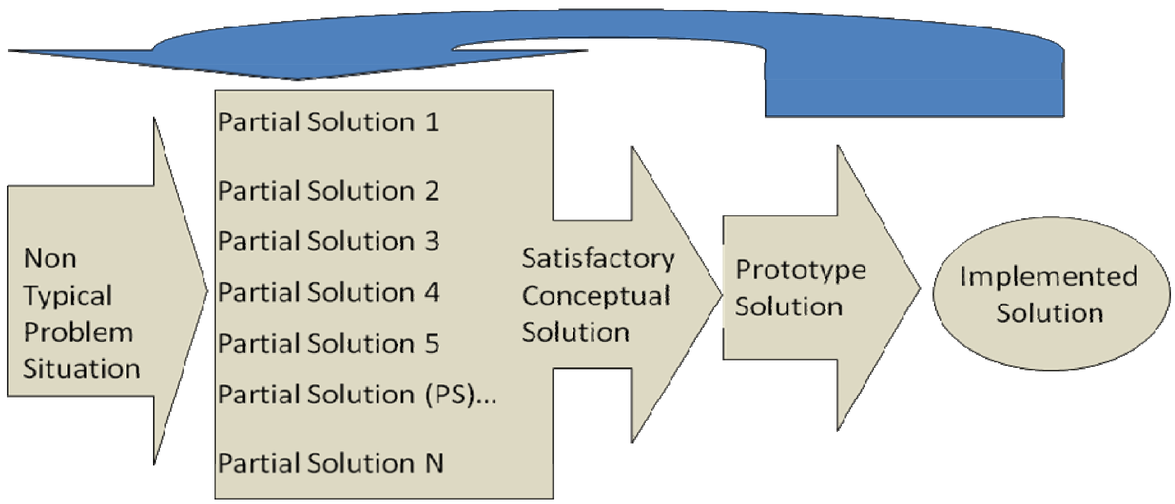

Figure 1. OTSM-TRIZ Line of a Solution.

Theory:
During OTSM-TRIZ problem solving process we use typical solutions of a certain specific domain of knowledge or TRIZ typical solutions and techniques to obtain Partial Conceptual Solutions (PS) or Partial Solutions (See: Partial Conceptual Solutions). Each Partial Solution could be presented as a hypothetical system. Those hypothetical systems (PS) could be converged according TRIZ rules of system convergence and produce new partial solutions. As soon as we obtain Satisfactory Solution (See: Satisfactory Solution) we can switch from conceptual solutions stage to implementation stage and developed Prototype and Implemented Solutions (See: Prototype Solution and Implemented Solution).
During implementation of a satisfactory conceptual solution (Stages of Prototype and Implemented solutions) some new problem situations could arise. In order to correct satisfactory conceptual solutions with respect to those newly born problems OTSM-TRIZ problem solving process could be applied. These iterations should be used until corrected satisfactory conceptual solution will be implemented with appropriate quality.
Most specialists who encountered a problem situation have a strong conviction that the more solution concepts (ideas) are developed in the course of problem analysis, the better for the project. At the same time here and now – in specific conditions – one solution is being used. We consider this solution, embodied here and now - specific material objects; specific actions performed by people or a method and theory that are being used in practice – a final goal of problem-solving and call it Implemented Solution
In other terms generating a high number of conceptual solutions is to be considered a waste of time end efforts and should be avoided in order to increase the efficiency of the innovation process.
An exteriorly obvious idea is often seen as a novelty even in the environment of professional problem solvers. At the same time, those who regularly deal with problem analysis and problem solving know that while analyzing, one often comes across multiple solution ideas. Those ideas are often indistinct, are not filled with specific knowledge. Often and often those ideas have numerous disadvantages, having at the same time something positive in the context of solving a specific problem. Such ideas, described in the form of a set of their positive and negative properties within the framework of OTMS-TRIZ, are called Partial Conceptual Solution or Partial Solutions (PS).
Nevertheless, in the course of the work on a problem, these Partial Solutions gradually concretize, integrate with one another forming a more concrete outline of a further Implemented Solution. This kind of solutions, forming a system of Partial Conceptual Solutions, is called Converged Conceptual Solution (CCS).
The difference between Converged Conceptual Solution and Partial Conceptual Solution consists in that:

- Converged Conceptual Solutions are more concrete and are close to reality unlike very indistinct Partial Conceptual Solutions, which are rather fragments of fairytales than solutions to be used in real life.
- Converged Conceptual Solutions are created in such a way that positive properties of different PCS are summed up and multiplied producing a synergetic effect, while the negative properties of the same PCS decrease and eliminate one another.
- Converged Conceptual Solutions are now evaluated not only by their positive properties, but also by the disadvantages inherent in them and by the negative effects they may cause when realized. To reveal these negative, undesirable effects, mental experiments and computer and full-scale simulation of individual CCS are carried out.
- Converged Conceptual Solution includes Partial Conceptual Solutions as constituent elements. Moreover, other CCS may figure in the capacity of CCS elements.

As a result of CCS integration with one another and with PCS, there appear CCS which may have undesirable properties and effects, but the summary level of their negative, undesirable properties and effects is much lower than the produced positive properties and effects. Such solutions look quite acceptable. This testifies to the fact that we have obtained a new type of solution, which we call Satisfactory Conceptual Solution.

The distinctive features of Satisfactory Conceptual Solution as compared with Converged Conceptual Solution are:

First of all it is the fact that the desirable integral – positive - effect considerably exceeds the negative - undesirable – effect, which is so small that in some specific conditions of a specific situation it is quite possible to reconcile oneself to it.

While there may be dozens of PS and CCS, the number of Satisfactory Conceptual Solution rarely exceeds 5 or 6 (it may amount to 10-20 together with variants.).

Description of Satisfactory Conceptual Solution is more specific and concrete than PS and CCS. It is concrete to such an extent that it is possible to pass to the selection of necessary materials and components and to start development and manufacture of prototypes.

All so far described processes occur in the heads of problem solvers. The obtained ideas are checked with the aid of mental experiments, tracing and sketching, and computer simulation. Sometimes, in order to check some PCS and ICS, full-scale experiments are carried out before selecting or rejecting the obtained ideas for manufacturing a prototype or experimentally checking its efficiency. The selected Satisfactory Conceptual Solutions embodied in a prototype and tested experimentally with a positive mark are called Prototyped Solution.

After passing to work on Prototyped Solution, the situation changes basically. So far, we have dealt mainly with mental simulation and mental experiments. Now a full-scale experiment with physically existing models is of first importance. At this stage, a transition to idea realization, to its embodiment in specific forms starts: mechanisms, constructions for engineering systems; organization, groups of people, organizing various events, law provision of various formalities, etc. are for problems from the business sphere.

Though at the implementation stage we are dealing mostly with material embodiment of ideas, we, nevertheless, encounter some problems, the solution of which requires mental experiments, analysis and generation of additional Conceptual solutions. In other words, we need the same mechanism of problem solving which helped us obtain Conceptual solutions accepted for prototyping.

After the tests have been carried out, the problems have been solved and a decision to pass from a prototype to implementation stage has been taken, we face once again the situation, when it is necessary to solve the arising problems. And we can use once again the mechanism of obtaining a Conceptual solution, which we used in order to obtain solutions suitable for prototyping. In a general case, prototyping of some additional conceptual ideas may be needed.

Thus we can describe in a general form the process of work on a problem from an initial situation till a solution introduced in practice. It will comprise three stages:

Mental simulation of a problem situation in order to obtain a conceptual solution.

Full-scale simulation or experimental check of conceptual solutions obtained at the stage of mental simulation in order to obtain a well-tested material prototype of the conceptual solution.

Implementation of a finalized prototype and its wide use in real life situation for which it is designed.

This is just one of the most general schemes of OTSM-TRIZ presenting different approaches to the process of transformation of Initial Problem Situation Description to a concrete production of Implemented Solution (material or non-material) or actions in accordance with some plan.

We call this scheme Line of Solution:

- Initial Problem Situation Description, - without an acceptable solution.
- Conceptual Solution (Partial, Converged and Satisfactory conceptual solutions), - description of a solution, accepted for prototyping or implementation.
- Prototyped Solution, - tested prototype accepted for implementation.
- Implemented Solution, - Desirable result performed and accepted.

Initial Problem Situation Description is usually indistinct. It is not always clear what are the aims and what means are allowed to use. There is only a description of some disadvantage – some Undesirable Effect, of something to be eliminated or changed.

Implemented Solution is a specific product that eliminates the initial problem situation. This problem may be of various kinds:

- Material, for instance, some electronic devices, mechanical machines or buildings.
- Nonmaterial, for instance, theories and methods, some feelings of a spectator examining a picture or other work of art.
- Actions already performed in accordance with a certain plan in order to achieve some aim or actions, which achieved that aim.
- Combination of the above-mentioned products.

OTSM-TRIZ approach is aimed at providing a transition from the Initial Problem Situation Description to a Conceptual Solution. This is the main designation of this approach and its niche in the problem solving process. At the same time, since certain problems occur often enough both in passing to Prototyped Solution and in passing to Implemented Solution, one can say that the OTSM-TRIZ approach is applicable to all stages of problem solving – from Initial Innovative (Problem) Situation Description to Implemented Solution. Just like mathematics is used for estimating and evaluating concepts, for calculations necessary for creating a prototype, and for calculations needed in transition from a prototype to Implemented Solution. Just as in case with mathematics, the OTSM-TRIZ approach may be used in all sorts of specific problems arising due to some undesirable phenomenon or unsatisfactory situation in order to obtain conceptual ideas on how phenomenon could be decreased (eliminated) or undesirable situation could be changed.

Classification of the main types of solutions used within the framework of OTSM-TRIZ approach to the problem situation analysis:

1. **Initial Problem Situation Description -** description of something undesirable without an acceptable solution how to eliminate it.

2. **Conceptual Solution -** description of a solution accepted for prototyping or implementation.
2.1. **Partial Conceptual Solutions** – appears as a result of the analysis stage of a problem solving process.
2.2. **Converged Conceptual Solution -** appears as a result of the synthesis stage of a problem solving process
2.3. **Satisfactory Conceptual Solution** or just **Conceptual Solution – Converged Solution** that passed test of mental experiments or computer simulation and was accepted for prototyping or implementation.

3. **Prototype Solution -** tested prototype accepted for implementation.

4. **Implemented Solution -** result of problem solving that is performed and accepted.

1.3.3 Models for representation of Elements of Innovative (Problem) Situations

1.3.3.1 ENV Model

Theory:

OTSM based ENV model is one of the two most important models for understanding both theories and their instruments for efficient problem solving: Classical TRIZ and OTSM.
So what is an ENV model? What for it was introduced and how this theoretical model could be used for everyday life practical needs?

Definition:

ENV means: Element – Name of a property – Value of the property, or for the shorter - ENV.

Theory:

The ENV model is dedicated to formalize description of elements of a problem situation to be analyzed. This is one of functions of Classical TRIZ System Operator (SO) (see: System Operator) as well as Advanced System Operator (ASO) developed in the course of transition from Classical TRIZ to OTSM. System Operator of Classical TRIZ became a component of an Advanced System Operator and ASO in turn included into OTSM ENV model as one of its component.
The use of the ENV model could simplify the understanding of many nuances of Classical TRIZ and how practical instruments work. Moreover, it makes the educational process more logical and transparent. All classifications we apply in the context of OTSM-TRIZ based problem solving process is based on the ENV model, as well as all instruments of Classical TRIZ and OTSM are underlying by this model. This is helpful also when needs arise to integrate some particular Instrument of Classical TRIZ or OTSM with some other instruments for intellectual work, such as Six Sigma, Taguchi method, QFD, various tools for strategic planning and project management, Knowledge management and various computer system for knowledge processing, Neurolinguistic Programming (NLP) and many others. This is one more reason why this model Appear in OTSM-TRIZ: Simplification of integration OTSM-TRIZ with various complementary instruments for intellectual activity of a human and computer support for human thinking.
Three main functions of OTSM ENV model:

- Formalize descriptions of elements involved into innovative situation.
- Simplify education by making transparent links between all theoretical models and practical instruments of OTSM-TRIZ.
- Simplify integration of Classical TRIZ and their instruments with other complementary instruments were created to support intellectual activities of human and computer.

Three main components of ENV model:

- Element.
- Parameter.
- Value.

Example:

In the context of our everyday life we use just simplified version of the ENV model (Figure 2: Model "Element-Feature".). When we describe an "apple" to someone who has never seen an apple before or when we explain to foreigners the meaning of the word "apple", we say that it is a fruit; hard enough; that could be green, yellow or red; usually sweet enough but not too much; round or oval; it grows on trees etc. for many common cases it is enough and convenient for communication on any other subject we have in reality or in our imagination. This is a model Element- Property.

Model:

Name of an element and list of its features.

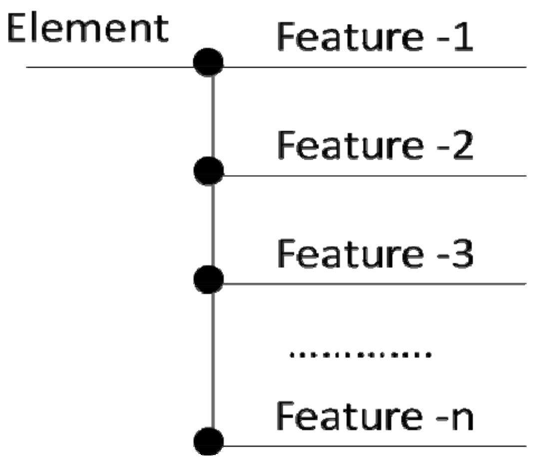

Figure 2: Model "Element-Feature".

Theory:
However, to overcome mental inertia and resolve problem (innovative) situation efficiently it is better to use a more detailed model where feature is split into Name of a property and Value of the property presented as a name of a parameter and value of the parameter.
Please, pay attention that in the context of OTSM-TRIZ we consider feature as a synonym for: parameter, variable, property, characteristic, etc. In other words everything that we use to describe certain Element and that could be presented as a Name and set of its Values.

Model:

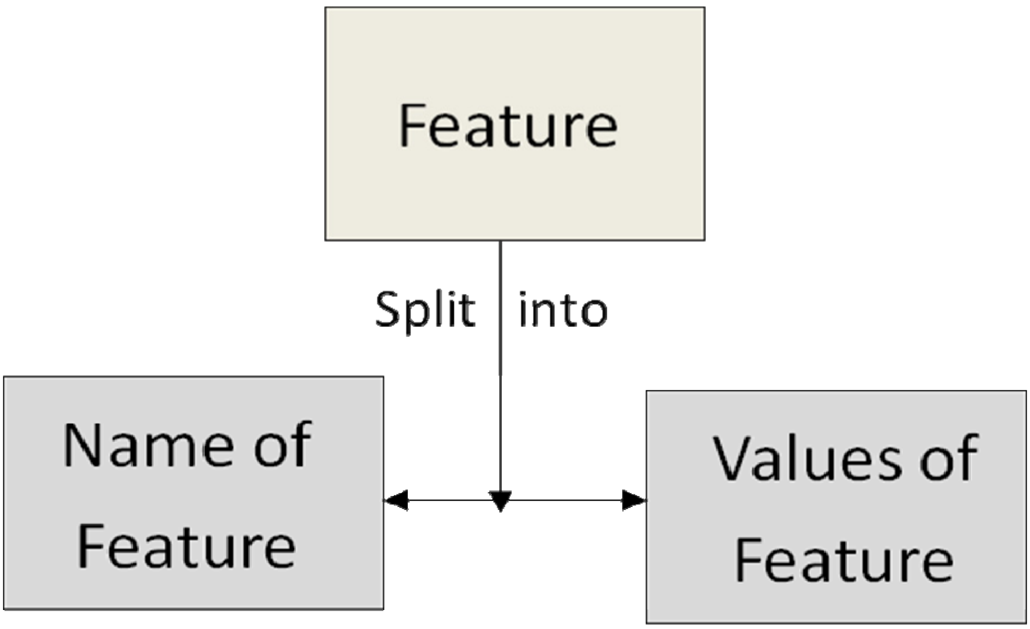

Figure 3: Feature Split into Name of a Feature and Value of the Feature

Example:
Element: Apple - could be viewed as a set of important parameters: Kind of Plants; hardness; color; level of sweetness; shape; kind of plant it growing on etc.
Each of these parameters could have a specific value: Kind of Plan has value – Fruit; hardness has value – hard enough; color could have several values - Green, Yellow; Red; level of sweetness has a value – Sweet enough but not too much; parameter shape has a value – Round or Oval; plant were it grows – Tree.

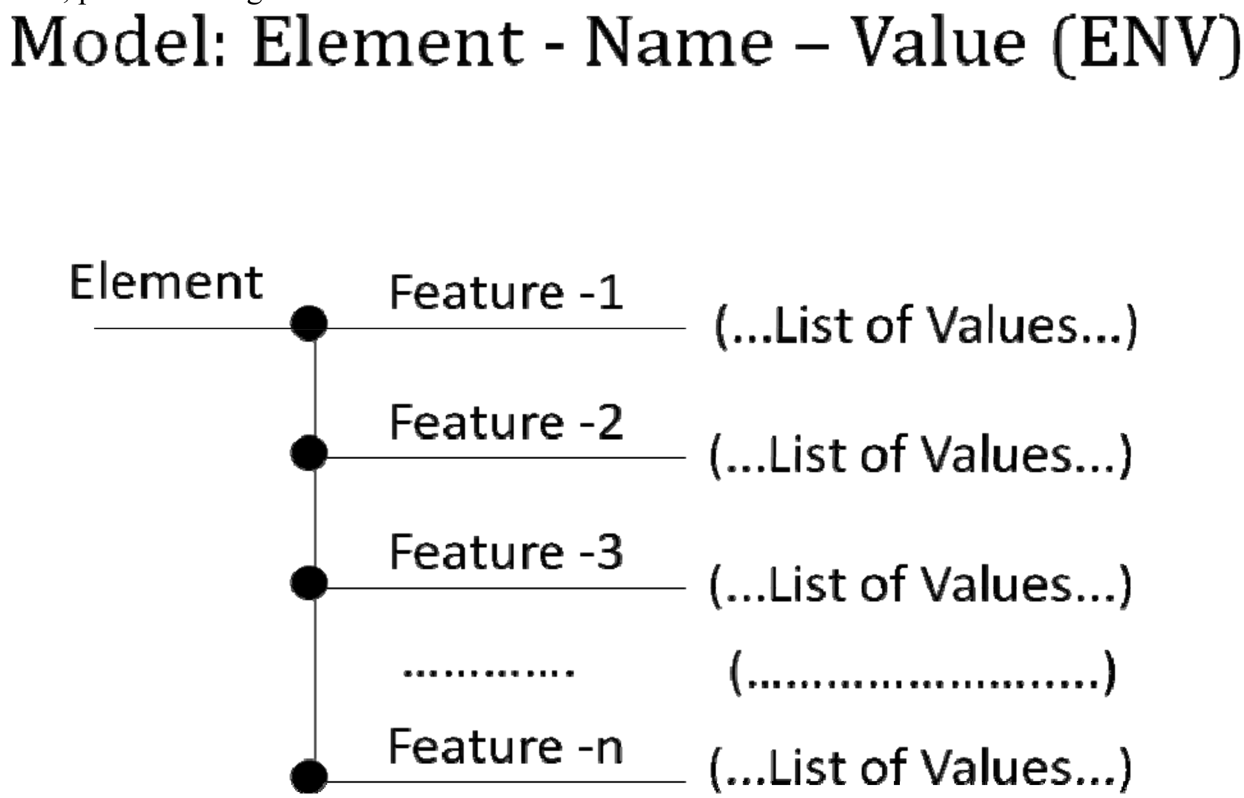

Figure 4: General Model: "Element-Name-Value" (ENV)

Theory:
In order to be meaningful, each of the parameters used to describe a certain object must have other possible values in some other elements of the world. In other words when we say that the property "color" of an "apple" can assume the values "red, yellow and green", we provide an useful information if other objects in the world can assume different colors (e.g. purple, orange, blue etc).
ENV model should be viewed as a multidimensional space of parameters. This perception of ENV model brings many advantages that help increasing the level of formalization in the course of work on solving complex interdisciplinary problems.
The Classical TRIZ concept of Contradiction shows us exactly what parameters of what elements must change their values, and Convergence Rules introduced into Classical TRIZ by Igor Vertkin [Igor Vertkin. Механизмы свертывания технических систем.] could help us transfer those features to other component of a system and increase ideality of initially given system.
Using the ENV model for teaching Classical TRIZ in order to describe various elements (components) supports the clarity of the explanations, helps understanding what those elements have in common and how we can distinguish those elements (components) from each other.
Last but not least. Notion of Element as well as Parameter and Value are not something absolute but relative. In some specific case Red color could be treated as an element to be improved

in term of its property: dissemination on the colored surface (possible values: uniform; spots; lines, circles) or in a saturation of the red color (possible values: High saturation, medium saturation, low level of saturation, saturation as a sunset sky or saturation as a dark red rose etc.). This relativism is based on the Specific Situation Axiom of Classical TRIZ and helps implement this theoretical axiom as a very practical instrument to destroy mental inertia and develop satisfactory conceptual solutions.
For Classical TRIZ simplified ENV model described above is perfectly suite. However for most advanced applications and complex problems it is necessary to study Fractal Structure of an ENV model.

1.3.3.2Element (component)

(See also: ENV model)

Definition:
In the context of OTSM-TRIZ we consider as an Element everything we can think of. It does not matter if it is substantial or non substantial, if we could not touch or feel by our sensors directly or indirectly as well as any of imaginary things we can find in fairy tales and fiction stories and novels.

Example:
Examples of real world elements: Trees, grass, human, animals, technical systems.
Example of models which have been used or are still in use in scientific representations of the World: Phlogiston, Relativity Theory, Objective Laws of nature, Mathematics etc.

1.3.3.3 Parameter (variable, synonyms: property, feature, characteristic, etc.)

(See also ENV model.)

Definition:
In the context of OTSM-TRIZ a parameter always belongs to a certain Element and has at least two different values.

Examples:
Element: Color
Parameter: Saturation
The parameter can assume different values: red as a Summer Sunset, or red as a dark red rose, or red as a tomato, or red as Flamingo.

Element: Statement
Parameter: Truth
The parameter can assume two values: True and False.

At the same time, Truth as an element can be characterized by a set of parameters. For instance: parameter Level of truth: Completely True, partially True, absolutely Not True. Parameter Time when something could be true or not: existing of Phlogiston was considered as a truth before Thermodynamics Theory was initiated, and today Phlogiston is considered as Not True.

1.3.3.4 Value

(See also: ENV model)

Theory:

Each Parameter (variable) that belongs to a certain Element can assume a limited set of values among the possible values which can be associated to that Parameter (starting at least from two different values to an infinite set of values).

1.3.3.5 System Operator (multi screen schema of powerful thinking)

Theory:

System Operator (SO) or, as Genrich Altshuller named it, Multi-screen Schema of Powerful thinking, shows the model of powerful thinking in the course of problem solving process (Figure 5: System Operator or Classical TRIZ Multi-screen Schema of Powerful Thinking.). Learning this model and develop appropriate skills to use it in practice is a core of Altshuller's educational program. For this purpose ARIZ was created. Altshuller often mentioned that ARIZ is a multi screen schema of powerful thinking presented in the form of line of analysis of a problem situation. It means that ultimate goal of ARIZ education is learning the most efficient way to use System operator for problem solving.

Model:

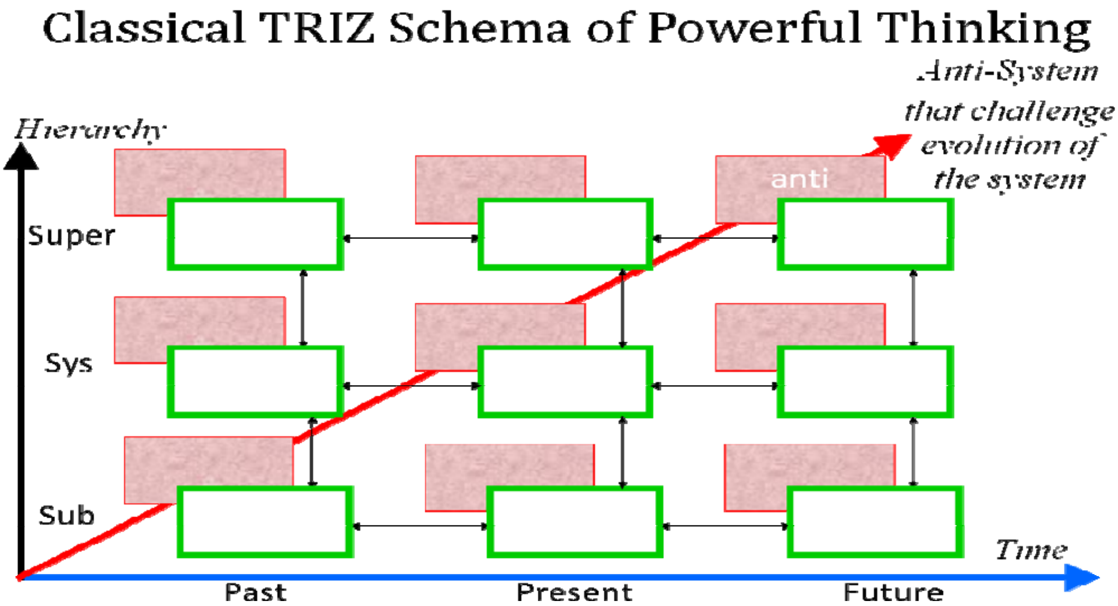

Figure 5: System Operator or Classical TRIZ Multi-screen Schema of Powerful Thinking.

Theory:

System operator could be seen as a three-dimensional parametrical space:

Dimension of Hierarchical level of System: Whatever is the element we are taking into account (System), it is always possible to consider its constituting parts (Subsystems) as well as the environment it belongs to (Supersystem);

Dimension of Time: whatever is the time interval taken into consideration for a certain analysis or description (Present), it must be considered as a phase of a sequence, therefore with a Past and a Future;

Dimension of Anti-Systems: whatever is the property of an element taken into consideration, this dimension suggests looking to the opposite values of the same property (anti-property); similarly, a combination of anti-properties characterizes an anti-system.

For practical needs it is useful to treat each of these three dimensions as a composition of several dimensions. For instance, in practice we often faced with a situation that one Element be-

longs to several hierarchies of systems. Live bag in the car belong to dashboard or doors or steering wheel and at the same time its belong to a safeties system of the car.
Another example: depending on the specific situation we can consider Time dimension as a historical time (if we study evolution of certain systems), as a process time (while analyzing a chain of events, even with their cause-effect relationships), as a life cycle of an element of a system or in terms of speed and acceleration if these variables are relevant for the specific situation.
The System operator can be used as a tool by itself with different functions within the problem solving process. For example, during the preliminary stages of the problem solving process, while looking for roundabout problems whose solution allows to obtain the same overall goal, a multi-screen view helps orienting the thought from cause prevention to effects compensation or mitigation, as well as a means to change the scale of the solution space in order to avoid psychological inertia. Besides, while looking for resources, the System Operator helps focusing the attention on every relevant aspect of the system and its environment, by analyzing any time stage at any detail level with a systematic approach.
Using ARIZ helps understanding what kind of time dimension of Classical TRIZ Multi-screen schema of Powerful Thinking is most suitable. While using System Operator directly, for instance for Resource Analysis on step 2.3. Of ARIZ-85-C or for understanding initial innovative situation, it is necessary to distinguish clearly System operator for Element and System operator for System. What is a difference?
In order to use SO in the System context we have to clearly formulate function of a system to be considered. As soon as the Function is identified we automatically identify product of the system. Based on Product and Function we can identify subsystems: Tool, Transmission, Engine and Control Unit for technical systems.
In the course of Classical TRIZ evolution Altshuller came up with the conclusions that some more dimensions should be introduced to a classical SO. However he did not find a graphical representation to present several more dimensions in the Classical SO.

1.3.3.6 OTSM-TRIZ Models of Problem solving process.

Introduction:

The OTSM-TRIZ problem solving approach can be represented by a number of models which clarify its structure and peculiarities.
Together with the ENV model, the following models constitute the essence underlying all the instruments of Classical TRIZ and OTSM-TRIZ as well.
One of the very first idea on improving problem solving process was about change the fundamental stereotype that was and still is very popular and underlying all Creative Problem Solving Methods: it is necessary to generate as more various unusual ideas as possible and then select the right ones which could solve our specific problem. Until now this stereotype (paradigm) dominate in the domain of problem solving. Genrich Altshuller formulated and exaggerated a contradiction that this paradigm arises: the more various solutions we generate the more time we will need to spend for evaluating satisfactory solutions that suit our specific inventive (problem) situation. Out of this contradiction there appears the Ultimate Goal for Classical TRIZ: create a problem solving method that will generate just one solution but this solution will be a satisfactory solution for a specific problem (innovative) situation.
We should mention that all models described below were dedicated to get orientation in order to develop more precise instruments based on those models. However all of those models could be used as instruments for practical needs.

1.3.3.7 "Funnel" Model of a TRIZ based problem solving process.

Theory:

Out of the Ultimate Goal of a method capable to generate just one solution as an outcome of the process, the first general idea about problem solving process appears: the "Funnel" model. Large input at the beginning of a problem solving process to observe and analyze initial problem (inventive) situation and narrow output in the end of a problem solving process that shows us satisfactory solution. Problem solving process should be located inside this "Funnel" and prevent a problem solver from useless trials and errors. We should say that this model still has not been accomplished at 100% but great achievements on this way were done by Altshuller and his followers. In the course of Classical TRIZ evolution and its transition to OTSM "Funnel" model appears in this form (See: Figure 6: "Funnel" model of a Problem Solving Process.)

Model:

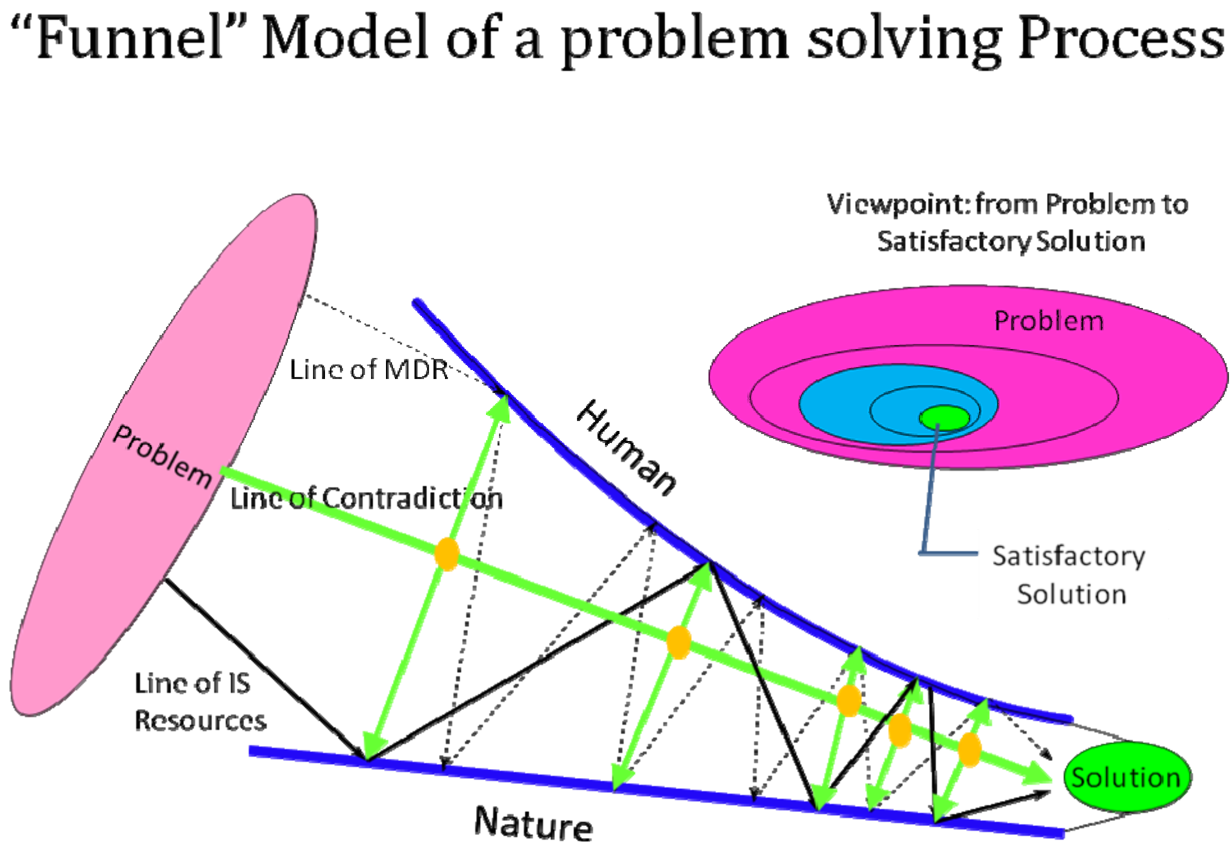

Figure 6: "Funnel" model of a Problem Solving Process

"Funnel" models is used today mostly for educational purposes to explain in general what is happening in the mind of professional OTSM-TRIZ expert in the course of a problem solving process.

We could say that each stage of the process and each specific instrument pushes a problem solver through the Funnel tunnel with his problem in very particular way.

So when you will learn TRIZ, you should pay specific attention to the question: "In which way the instrument I'm using follows the Funnel Model? How could we narrow the area of analysis in order to avoid useless trial and errors but obtain satisfactory solution by discovering the deep root of a certain problem and eliminate it?

In other terms the problem solving process should be intended as the construction of the identikit of the solution: each step is finalized to the definition of suitable Values of the relevant Properties of the system elements constituting the solution to the inventive problem we are dealing with. It also means that the problem solver should avoid "guessing" the solution while the process is still in progress: all the clues should be collected systematically in order to restrict the domain of possible solutions.

1.3.3.8 "Tongs" Model of modern OTSM-TRIZ

Theory:
Historically this was the first practical model of the problem solving process proposed and implemented at the very beginning of TRIZ evolution (See: Figure 7: Simplified "Tongs" Model of TRIZ based Problem Solving Process).
The tongs model suggest avoiding the generation of possible solutions starting directly from the Initial Situation. Besides, the first step should be to identify and describe precisely the Most Desirable Result (MDR); then, a comparison between the actual situation with the available resources and the MDR brings to the identification of the barriers preventing from the achievement of the MDR itself. According to the TRIZ theory, any barrier can be described and modeled in terms contradictions. The conceptual solution must be thus generated as the way to overcome the contradictions underlying the current system.

Model:
Ovals on the Line of Contradictions could be viewed as "Tongs" Models at the Figure 6: "Funnel" model of a Problem Solving Process. Same for the "Hill" Model – ovals on the left slope of the "hill" (See: Figure 9: "Hill" Model of a TRIZ based Problem Solving Process.)

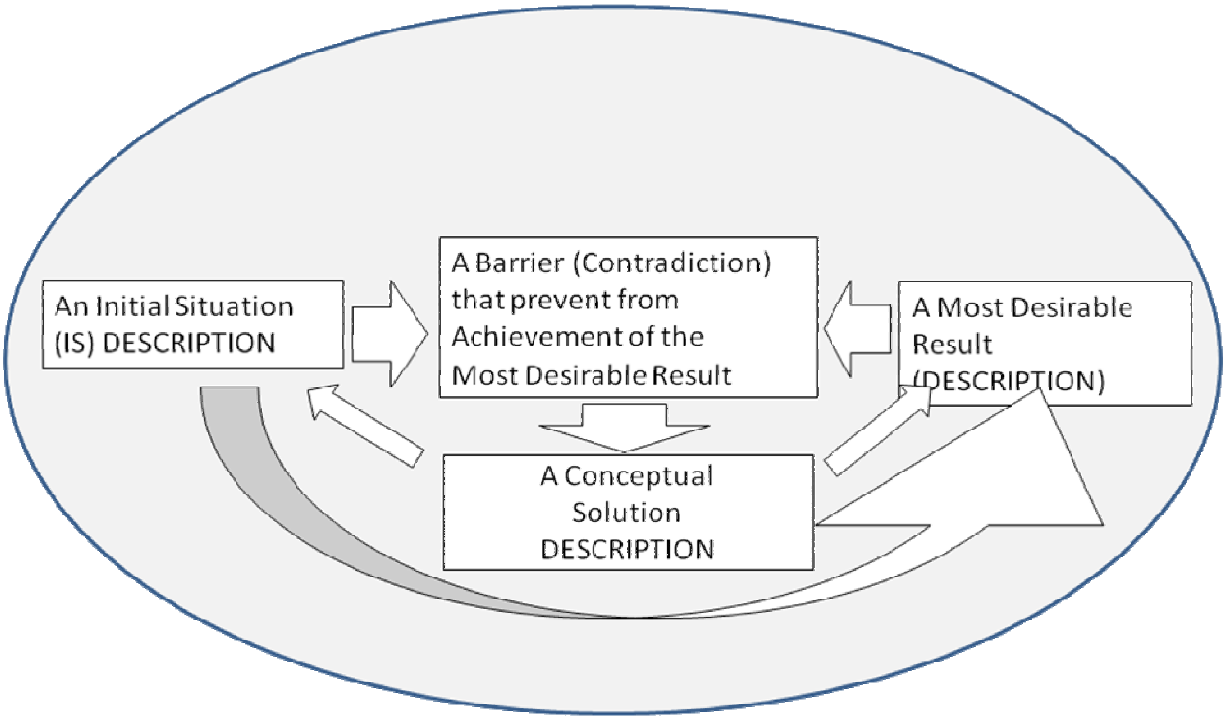

Figure 7: Simplified "Tongs" Model of TRIZ based Problem Solving Process

1.3.3.9 "Hill "model of Classical TRIZ

Introduction:
In the middle of the 70s a new model of the problem solving process was proposed by Genrich Altshuller. This next model is underlying all the following ARIZ modifications until ARIZ-85-C. Eventually this model got the name of "Hill" Model of a problem solving process. "Tongs" model appear in the "Hill" model on the left slope of the "Hill" as one of its component.

Theory:
The Hill model states that the first part of the problem solving process consists in a generalization of the problem through an abstraction process with the aim of transforming a non typical problem into a standard model of a problem. Two are the main types of problem models according to the TRIZ theory: an unsatisfactory interaction between two elements of our system (i.e. an insufficient or a harmful function identified through a Su-Field model) or a contradiction
After building a general model of a problem, TRIZ instruments bring to the identification of candidate models of solution to be finally contextualized in the specific situation according to the available resources (right part of the hill).
Hill model not only help use "Tongs" model more efficiently, but also to introduce one more important novelty in the problem solving process: the transition between different levels of generalization. In the beginning of problem solving process we reformulate the problem several times according to the rules of the "Tongs" model, but every time we increase the level of generalization. This abstraction process leads us to a more general description of a problem and as a result of this generalization it is easier to find a direct analogy between problems that look very different.

Example:
For instance two famous problems that is very popular in the modern TRIZ world are problems on Hydrofoil that is destroyed by capitation effect in the water and a problem on preventing oranges from eating by apes. At the beginning this two situations looks absolutely different. But after using "Hill" model and generalizations we obtain the same model of problem for both initial innovative situations: Two objects and harmful interaction between them. Altshuller's System of standard inventive solutions proposed in this case use mediator that is modification of one of the substances or mixture of both. This was one of main functions of ARIZ modifications before ARIZ 85-C: Generalize initial situation description and use TRIZ typical solutions or any other available for you. In other word it means transformation of non typical problem into one of well known typical problems. This dramatically increases efficiency of instruments based on Classical TRIZ. However new classes of problems appear very quickly: problems that could not be transformed into typical problems. What should be an efficient model of problem solving process for these complicated problems? As an answer to the question ARIZ-85-C appeared. This version of ARIZ starts new S-curve of Classical TRIZ based instruments for problem solving and eventually lead us to a new model of problem solving process that appears in the course of Transition from Classical TRIZ to OTSM: Problem Flow model of OTSM.

Author: de Bentzer Ulbrahe (source: www.wikipedia.org)

Model:

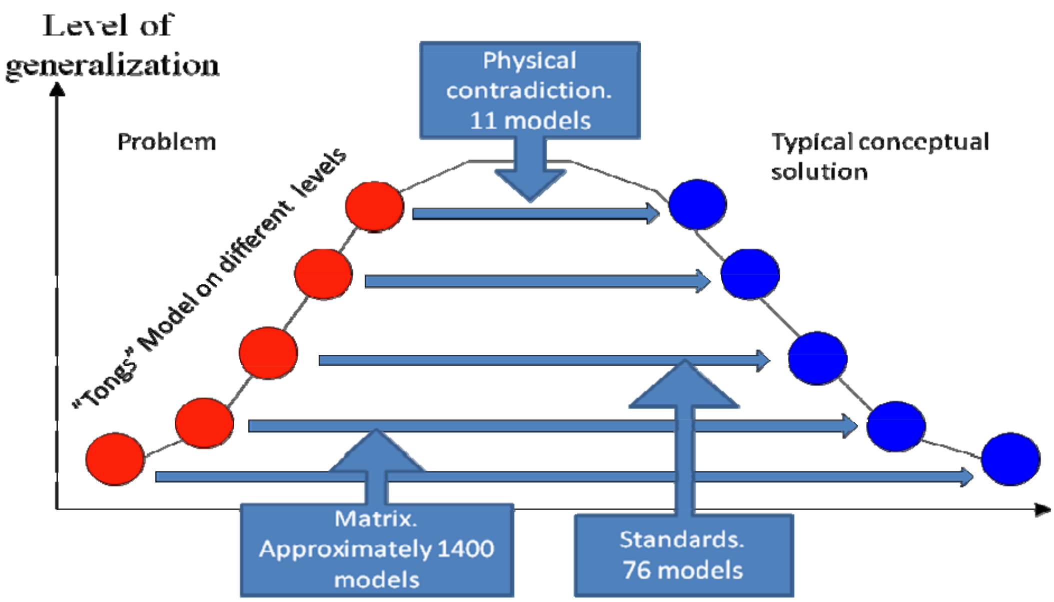

Figure 9: "Hill" Model of a TRIZ based Problem Solving Process.

1.3.3.10 "Contradiction" model

Introduction:

Consider now a set of design problems, the requirements of which concern two evaluation parameters denoted EPI and EPII. A point in figure *10 left* represents a solution of these problems. These solutions are mapped with a set of technical alternatives the elements of which are known by the designers. These solutions are described by a set of design parameters. Evaluation parameters are functions of design parameters. Let's call EPI-dp and EPII-dp the set of parameters that influence the values of EPI and EPII respectively. EPI-dp and EPII-dp are defined by the set of technical alternatives.

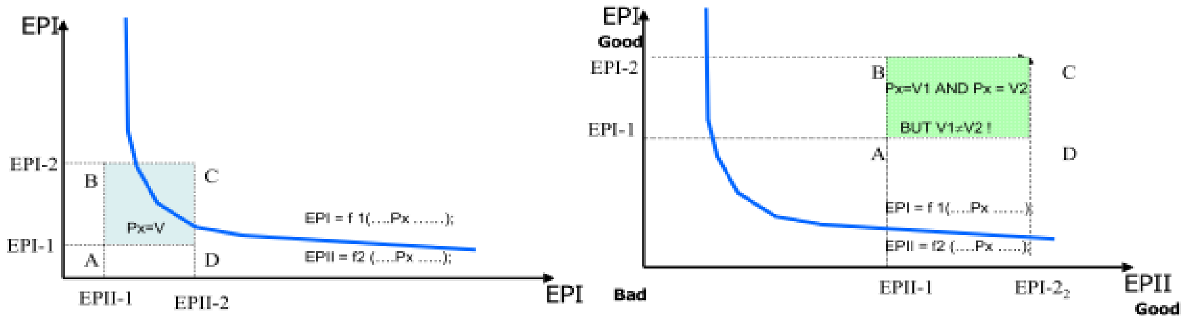

Figure 10: left "Optimization situation", right "Innovation situation"

In the first situation the requirements targets EPI and EPII values to be within the range [EPI-1, EPI-2], [EPII-1, EPII-2] respectively. Thus a solution fits the objectives when EPI and EPII define a point inside the rectangle ABCD in figure 10 left. If there are no common design parameters between the evaluation parameters (i.e.: EPI-dp∩EPII-dp=Ø), they are independent and there is no problem to reach any point in the rectangle ABCD. But when at least one design parameter influences both evaluation parameters EPI and EPII, they are dependent. This dependence relation constraints the area of feasible solutions in the evaluation space; it is represented by a curve in figure 10 left. When the situation of the relation between the parameters overlaps the requirements area like in figure 10 left, finding a solution can be considered as an

optimization problem. On this example the common parameter is called Px and each value V of Px defines a point of the curve. The problem is then to find the values of Px that allows the evaluation parameters EPI and EPII to fit jointly the requirements. We can then enter a decision process by adding preferences about the pairs of evaluation parameters.
Let us now consider a second situation as summarized in figure 10 right: the only difference with the previous situation is that the targeted area for the evaluation parameters is not overlapping the area of possible solutions defined by the design parameters. The relation between the evaluation parameters due to the technical known solutions and natural law or laws that drive links between parameters remains the same. Thus there is no way to get a solution by using this model of relation between the evaluation parameters and a new paradigm is required in which the relation between them overlaps the requirements. Two main approaches, which can be performed in synergy, may be used to perform this overlapping. The first attitude consists in changing our values about the preferences and keeping both the set of technical alternatives and the structure of the system. The second method consist in changing the set of technical alternatives and the structure of the system by expanding knowledge and inventing what is called in TRIZ language non typical solutions. As an output of this process new curves between the evaluation parameters are generated. If they overlap the preference area we come back to an optimization situation.

Theory:
The previous examples concerning the relation between Evaluation Parameters can be generalized and stated the following way: the fact that two evaluation parameters are linked means that at least one common parameter both of them depend on does exist. These common parameters have to be disclosed in order to develop new technical alternatives and finally new structure of the system. Thus in our example the fact that EPI and EPII are linked means that at least one common parameter Px the evaluation parameters (EPI and EPII) depend on does exist. The reason why it is impossible for the evaluation parameters to fit the requirements in the framework of existing models is the following: in order to fit jointly a pair (EPI, EPII) of the evaluation requirements Px should take two mutually exclusive values; let's call them V1 and V2. Moreover once taking into account partial elements of the preference structure the situation can be described at least by three dilemmas. Let's illustrate this point through the previous example. We assume that the preferences elements are:
in the range [EPI-1, EPI-2], the higher EPI value the better
in the range [EPII-1, EPII-2] the higher EPII value the better.
The three resulting dilemmas TC1, TC2 and PC become:
TC1: when EPII value is good from the requirements point of view then EPI is bad.
TC2: when EPI is good from the requirements points of view then EPII is bad.
PC: when Px value equals V1 then TC1 holds whereas when Px value is V2 then TC2 holds.
The PC dilemma concerns a choice between two mutual exclusive values of a parameter that leads to two options TC1 and TC2 that are unfavorable from the requirements points of view.
Classical TRIZ system of contradictions has just 3 types of contradictions (administrative, technical and physical): TC1 and TC2 are named *technical contradictions* (a contradiction between two evaluation parameters of a system) whereas the underlying contradiction PC corresponds to the concept of *physical contradiction*.

Model:

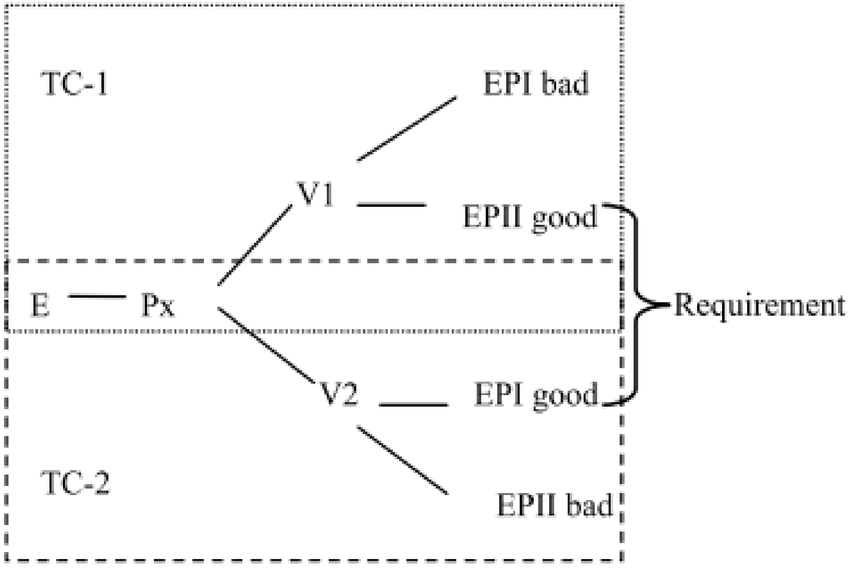

Figure 11: OTSM-TRIZ basic's system of contradictions

2 Laws of Engineering System Evolution

2.0 Introduction

Do you know why people sometimes solve their problematic situations in the wrong way?
Not only schoolboys and students, but also designers and engineers, directors and writers, presidents and even Kings can solve their problems in the wrong way? Probably, you can recollect some examples of wrong solutions, as well as some examples of creative solutions.
To find the answer to this tricky question, we will offer you a short 33-seconds travel in the company of Antoine de Saint Exupéry and the Little Prince to an asteroid № 325 in order to visit the King...
The king ruled over all – his small planet, the other planets and all the stars... And all surroundings obeyed him. The Little Prince has been admired by such power! And he has also asked the King to order the Sun to set because he liked very much to admire a sunset.

-«I will order the Sun to go down», – answered the King, «but, at first, I will wait for favorable conditions because the wisdom of a king includes careful consideration. »

«And when conditions will be favorable? » – asked the Little Prince.

- "Hum! Hum!" replied the king; and before saying anything else he consulted a bulky almanac. "Hum! Hum! That will be about--about--that will be this evening about twenty minutes to eight. And you will see how well I am obeyed!"

You should not doubt, the Sun went down exactly at 07:40 p.m. because it is one of the laws of Nature. And the King was really wise because he behaves in accordance with the laws of nature and did not break these laws.
Our world consists of paradoxes. And the most surprising of them deals with the fact that people at all times looked for the connection of various processes and phenomena. Even there, where there is no connection! However, it is not the case because a new researcher comes and detects this connection.
Laws, i.e. interrelations of processes and phenomena in nature form the basis of knowledge about the world which surrounds us and which is important not only in diverse sciences, but also in our daily, ordinary life. A simple example illustrates this. Any driver knows if a road is wet after the rain, the length of the break path increases.
For what purpose do we need knowledge about the laws of nature? It is necessary for a person to look constantly in the future for the purposeful and intelligent activity. At least, to look one step forward. Recollect, even simply walking in a park you unconsciously look for space on the ground for your next step. The more difficult the way is, the more attention it demands. The more difficult the system is, the greater efforts are necessary to forecast its development. And only if we have defined the laws according to which systems develop, it is possible to say with confidence about the further step of development of this or another system.

2.0.1 The role of the Laws in TRIZ

2.0.1.1 Laws in science

Any science becomes a science in a full sense only when it starts describing the world on the basis of the laws which are discovered by this science. The astronomy became the science, when it discovered the laws of movement of planets. The alchemy became chemistry, when it described the laws of interaction and transformation of substances.
TRIZ – the science which studies processes on the boundary of two objects: a person and technology. The sphere of its studying includes both thinking of a person as well as the laws of evolution of technical systems. Any theory has a fundamental character, but it also develops its

applied tools. TRIZ develops tools for solution of creative problems, ways of narrowing of a search field, methods of conscious management of unconscious processes.
One of typical mistakes of TRIZ studying and teaching consists in that TRIZ is studied as another subject: as physics, chemistry or astronomy. The center of studying in these sciences is the surrounding world, the natural phenomena, whereas in TRIZ the more attention should be given to the processes of thinking.

2.0.1.2 Laws in TRIZ

The laws of development of technical systems were firstly published by G. S. Altshuller in his book *Creativity as an Exact Science: the Theory of the Solution of Inventive Problems* in 1979:

1. The law of the completeness of parts of the system.
2. The law of "energy conductivity".
3. The law of harmonizing the rhythms of parts of the system.
4. The law of increasing of the degree of idealness of the system.
5. The law of uneven development of parts of a system.
6. The law of the transition to a super-system.
7. The law of the transition from a macro to a micro level.
8. The law of increase of the S-field involvement.

If to speak about TRIZ as about the system, it is important to mention that it is very harmonious. The tools which are included in its structure make the system work. They are interconnected, and the basis is formed by the Laws of Development of Technical Systems.
Laws are divided into 3 groups: laws of statics (1-3), laws of kinematics (4-6); laws of dynamics (7, 8). In such a division there is a certain analogy with mechanics – the section of physics. By consideration of «a life line » of development of the technical system *the S-shaped curve*, the following is observed. The Laws of statics are characteristic for the appearance stage of the technical system; laws of kinematics – for the development stage of the technical system; laws of dynamics – for the closing stage of development and transition to a subsystem. The technical system develops and changes. The model of the technical system changes as well. The new assumptions appear which are considered in accordance with a concrete situation with the aim of constructing a model.
Thus, while calculations of the flight speed of the plane from one point to another, the plane is considered to be a material point. But, while defining the minimal speed which is necessary to fly up, we shall take into consideration an absolutely different situation, other physical laws. The lifting strength will raise our attention. It effects wings of a plane and also its weight. During calculations of a maximum admissible speed for a safe landing we shall deal with absolutely different objects. It is very important to define the aim and to select an appropriate model.

2.0.1.3 The Characteristics of laws of development of the technical system at its different stages of development systems

At the appearance stage, during the creation of a new technical system the system is studied as "an object in itself". The most important processes essential to its ability to survive occur inside of the system. In this case, the assumptions are possible and the system is studied separately from another surrounding technical systems. The following questions are solved for the system: « To be or to not be? », «What kind of structure should be used? » By analogy with mechanics: in mechanics, the laws of statics study a balance condition of a material body under the influence of the applied forces.
At the development stage of the technical system evolutionary processes are studied in the technical system, but irrespective of the technical and the physical factors which define this development. The processes which define the development are still found inside of the techni-

cal system. But the main thing is not any more the survival of the technical system, but movement, development, achievement of the certain level in comparison with other technical systems. The most essential at the given stage is the achievement of the maximal values of key parameters by the technical system. These key parameters include speed of a plane; a carrying capacity of a car, a number of operations per second produced by a computer.
At the closing stage of development the laws of transition to new systems come in the foreground. Actually, resources of development of the technical system are outspent. The existing system is studied in an environment of other technical systems. The main question is « How to encourage development in an existing environment? », while it is examined under the influence of concrete, technical and physical factors.

2.0.1.4 The definition of laws of development of technical systems in the given textbook

The system of laws of development of technical systems is also developing. The works of many researchers and developers have specified and enlarged the tools of the applied laws. Let us mention the names of some researchers in this area: Altshuller G.S., Zlotin B.L., Petrov V.M., Litvin S.S., Vertkin I.M., Fey V.R., Lubomirski A.L., Salamatov Y.P., Kondrakov I.M. and many others.
There are several systems of laws of development with its characteristics, specifications and hypothesis in TRIZ. Serious research is conducted in each of these systems. There exist disputable positions in some publications, but this is the consequence of the research process and development. All of them anyhow lean on the classical system of Laws of G.S.Altshuller. That is why we study this system.
In the given material, we adhere to the classical system of Laws Engineering Systems Evolution – the system of G.S. Altshuller. Basically, such a choice is determined by the educational purposes of materials. These are 8 laws, each of which is described in a separate chapter. It is possible to begin the introductory reading from any of them. However, it is more logical and effectual to study the materials in succession starting with the first chapter.
Each chapter has following sections: Definitions, Theory, Model, Tools, and also includes questions for self-tests.
At the end of each chapter the list of the applied literature is given. We tried not to use other examples from other books and articles which deal with TRIZ in these materials. A great number of schemes, pictures and photos are used in the texts in order to illustrate the presented material.
We wish you a pleasant and effective reading and creative, royal-wise solutions!

2.1: The law of the completeness of parts of the system

Prototype of the Avion III de fr:Clément Ader. Musée des Arts et Métiers, Parigi (Source: www.wikipedia.org , Photo et photo-montage © Roby)

In Paris Museum «Arts et Métiers», in the grand staircase under the ceiling, a flying machine constructed by a French inventor, Clément Ader, soars. In 1890 this flying machine managed to make a short flight at the height of several centimetres. It may make you smile now, but it was indeed a big breakthrough at that time!
Can it be seen as an airplane? How technically viable was the construction in years of its building? Who and what country is the founder of the first aeronautic vehicle? What mistakes did the first aviators make?
Let us quote the American Professor, Samuel Langly who dealt with the theory of aviation. When he was asked why the first aviators had had failures, he answered: "Perhaps, because man came up to the issue from the end and tried to make flying machines before he learnt the laws on which flying is based on".

Before trying to answer the questions mentioned above and not only those concerning flying machines, but also any other technical systems, it is necessary to know and be able to apply the Laws of Engineering Systems Evolution.

2.1.1. Definition

"A necessary condition for the living capability in principle of technical systems is the presence and minimal functioning power of the basic parts of the system."
Altshuller, G. S. (1984). *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems* (A. Williams, Trans.): Gordon and Breach Science Publishers.), p. 223.

The consequence:
"For a technical system to be controllable it is necessary for at least one of its parts to be controllable.
"To be controllable" means changing its properties in a way required by the controller."
Altshuller, G. S. (1984). *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems* (A. Williams, Trans.): Gordon and Breach Science Publishers.), p. 224.

The law is related to the chapter "Static", to be more precise, to the laws which define the life beginning of technical systems.
However, it is important to understand that the law refers not only to such ancient technical systems as a bow, a stone axe, a catapult. Any technical system changes during its evolution. There is very often a full replacement of one or several basic parts in the technical system. At the moment of such a change of parts a new system actually appears and the law of the completeness of parts of the system is applicable to it as well as for the essentially new technical system.

2.1.2. Theory

Details

Any technical system consists of certain parts (taking a look at the technical system we can distinguish its parts). A pen consists of a case, writing bar and an end cap. We use such a description to give a more detailed description of the device of the technical system and have a better understanding of the operating principle of this technical system. This is a model of the system which is given in the components of its subsystems.
There are a lots of system models.

For instance, a picture of the airplane, a picture of the automobile, an electronic scheme of a telephone; a spoken story about what a computer is; a textual description of glasses – all this are models of different technical systems.

The model used in the given law determines the main parts of ***any*** technical system from the point of view of its functioning and evolution. The main aim of the given model is its use during a problem solution. This model is constructed with the definite aims, for example, a device photo gives the general view about its appearance or component drawings describe its integral parts. The model will become good, if it allows achieving the stated aims and gives answers to the posed questions. For example, the aerodynamic model of a car is used to solve the problem of a decrease of wind resistance.
The purpose of the given model is to generalize all technical systems and to show the most general peculiarities of the technical system.
The minimum working capacity of parts of the system is an ability of parts of the system to provide teamwork in order to perform the basic function of the technical system. The criterion of the function's performance is the change in the element's parameter values. (During the description of the function in terms of the OTSM – ENV model).
The minimum admissible change of a parameter value is caused by requirements of the consumer of the given technical system. The information about the algorithm which defines the function is described in the part of this chapter: Tools à How to determine a function of the technical system correctly.

For example, the function of a car: to change a location (N = Name of the Property) of the person (E = Element) from the house (V1 = Value 1) to the work (V2 = Value 2). If the essentially new model of the car can drive a person only some metres (to change the location of the person), it is obviously not enough for the consumer. Hardly, someone will buy such a car. But it can quite satisfy the designer at the given development stage of this car.
Differently, the given technical system possesses necessary conditions for its life capability. It contains the basic parts according to the four-element model. These parts have minimal functioning power in its structure.

The typical mistakes

Often the connection between the law and its consequence seems to be not obvious. It is important to understand the logic of a consequence about controllability and its connection with the law. The controllability is explained in more detail in the consequence of the law. Controllability is understood as the possibility to change value of a parameter or parameters of the technical system and its parts during its operational time. Each part of a technical system works in one "organism" and is used with the aim of achieving the general function. Due to, it is possible to operate the whole system by operation of one of its parts. It is fair to say the opposite. If it is not possible to operate any of the basic parts of a system, the whole system is not operational (i.e., we cannot change value of parameters of one of parts in order to change parameters of the whole system).

2.1.3. Model

A model includes the main parts of the technical system: the engine, the transmission, the tool, the control unit. (The main parts of the technical system are separated in the scheme by a dashed line). In a general case, the source of energy and an object do not form any part of the technical system. For instance, the water stream in a river that brings the mill wheel into motion or the wind that makes blades of a wind electrical power station rotate. However, *Source of energy*, «batteries» of the technical system, «flashlight» are included into the technical system. The engine and energy source are often the same, but not always. Further on, we consider the example of four elements model in more detail. First of all, we will begin with the function definition of the technical system.

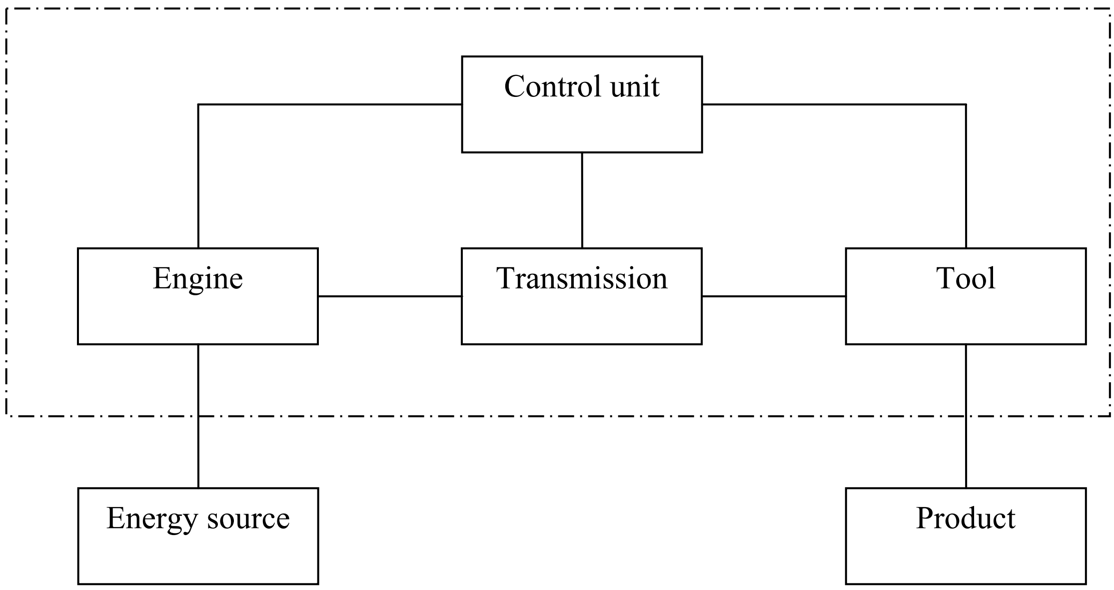

Fig. 1.3. The main parts of the technical system

2.1.4. Tools (how to use)

2.1.4.1. How to determine the function of the technical system correctly

The function of the technical system should be defined before we can use the law of the completeness of parts of the system in practice. It is a very important moment.

The function is found in the aim of the system existence, to be more precise, with what aim we will use the system. When we have no distinct idea about a function, we can not define the composition of the system in accordance with a four element model. To talk about a system in this case does not make any sense.

Some preliminary notes

*) this technical system could be represented by diverse models with the aim of fulfilling diverse functions.

**) it should be noted that the analogical situation can occur during the analysis of the multi-screen scheme. If the function is not defined, we will come to nonsense during the analysis. Not determining the function of the technical system it is not possible to discuss the structure of the system according to the OTSM-TRIZ theory.

The structure of the system

It should be noted what we understand under the structure of the system. It is the composition of its components in the system and the complex of interconnections in the system, as a result of which the quality appears, which we also call « the function», with the help of which we reach the formulated aim. All that functions in order to improve the quality are the components of the system. But other phenomena, which do not function, do not define the components of the system, even if these elements are located in the system. On the other hand, the elements, which are located far away from the system and do not have any relation to it, often form a part of the system, if the function is defined. To be more precise, if we define the function correctly, we often form the new vision of the technical system and discover previously unnoticed inter-connections. It is one of the main goals of the analysis. To be more precise, we form the model of the minimal system with the defined function.

The algorithm of the definable function consists of three steps.

(Common language model of Function). A person explains with his words what he wants to get from this system. In the process of studying students come quickly to the second step. But there are also cases as well, when it is not easy to reach an agreement about the oral description of the function. In order to come to the agreement, we need the second step.

1. (Verb-Noun model – Value Analysis model). It is the model of *Universal Semantic Code (USC),* and the model of Value Analysis. In practice several verbs often appear during the analysis of the function of the technical system. It is especially characteristic for the complicated systems. A noun usually describes a product, which will be changed. And a verb characterizes the way the product changes. This approach is good for the functional analysis, it is much better to use this approach than to apply the oral model using the universal language. But the following problems may appear: the existence of verbs-synonyms. Each of them causes its own association and the psychological inertia appears which prevents from solving a problem. Our experience show that in many cases this model (Verb-Noun model – Value Analysis model) leads to the deadlock or can lead into the false direction.
2. Four verbs ENV Model – OTSM ENV model of Functional Description. ENV Model allows performing a deeper analysis and describing a function of the technical system in more detail. There are also possibilities to develop and to improve this model and it is better than the Verb-Noun model. We should use four verbs and describe the function using the terms of the OTSM – ENV Model.

3.1. First of all, we should define the „Element". During the second step we defined the verb and the noun. The noun is an element, to be more precise, the product. If we need another element during the transition to the third step, it means that we have defined it in a wrong way. In this case it is necessary to return back to the second step and to concretise the Verb-Noun model.
A verb describes the change of something, while the function is the change of something. There are four types of verbs, four types of changing something: «to change», «to decrease», «to increase» (these are the varieties of change, but sometimes it is important to concretise the change) and the fourth verbal type– «to keep». When we talk about management/control, we need to «change», to be more precise, we use the dual change – to decrease and to increase.

3.2. What do we change particularly? What does it mean «to change the element E»? We change the certain parameter of this element – N, "Name of the parameter".

3.3. How do we change this parameter? We change the meaning of the parameter:

“Value of the parameter”. During the description of the model we should indicate: «the change of the value of the parameter N of the element E with the value V1 to the value V2». For example, the change of the value of the half-finished product, raw material changes the value of the product. We have at least one parameter.

Notes:
*) Actually, it is necessary to mention that one function performs the change of one parameter. If we have several parameters, it means that we have several functions, and it lead to the conclusion that we have several folded systems.

That is why, except three listed verbs there is also the fourth: „to keep“– to keep, not to change. Actually, it is a purely psychological trick in the course of training. It is often easier for a student to say the verb «to keep» instead of «not to change». A typical example which we use in the course of training - what is the function of a bottle? To keep water. According to the definition, the function always represents some kind of the change. If we have faced with the verb «to keep», it means that we have faced with the psychological inertia. The verb “to keep” serves as an indicator for some deep processes, which we should understand. If we say «to keep», we should think over the following step, what we should change in order «to keep». (To prevent undesirable changes and «to keep» the current state).
Let us illustrate one of the typical examples in order to define the function of the technical system and to understand **what should be changed**. In order to understand it better, within the limits of the concrete, described situation, one should do a mental experiment – take away an object. There is a bottle with water on a table. Our aim is to define the function of the bottle. Mentally, we will take away the bottle (but not water!). What will happen? Water will flow... Why? Since gravitation forces exert influence on this process. Therefore, the function of the bottle is to compensate, to change and to correct the influence forces of gravitation. Its function is to prevent and to change water flow.
This algorithm allows performing the deeper analysis, to formulate the function more precisely and to define the parts of the system.

The example
Let us consider the traditional application of the car which transports people and cargoes.

The first step (Common language model of Function)

Cars are usually used to transport people and cargoes from one place to another. We will not consider now other functions of the car, for example: it can serve as a shelter from a rain, to measure distance between two points. It can serve as a warehouse for old things and it has many other functions (this topic is more appropriate for the course of developments of creative imagination)

The second step
An object, a product: a person. The function: to remove a person, to transport him.

The third step
E – an element: a person; N – the name of the parameter: the location of a person; V the value of the parameter: V1– from a house; V2 – to work.
The function of the car: to change the location (N) of a person (E) from home (V1) to work (V2).
ENV Model: E – “Element”; N – “Name of the parameter”; V – “Value of the parameter”.

2.1.4.2. How to determine the parts of the technical system correctly

Some preliminary notes

*) The typical mistake is that before the definition of functions of the system, we try to define

its main parts in accordance with a four elements model. That is why in this case, the analysis of the technical system which defines its main parts represents the subjective point of view: "It seems to me so, I see it in such a way."

The Product

When we define the function, we will define the Product automatically. It is defined as the change in the process of the function fulfilment. The tool is the part of the system which interacts with the product. A cutter of the lathe tool, not the lathe tool itself, a knife edge, not a knife itself. We need energy of some special type in order to fulfil the function (the change of the material object). That is why we need an engine. The engine is the part of the system which transforms the accessible energy type into the necessary form for a tool to fulfil the function. Transmission includes parts of the system which transforms the accessible energy type to the Tool from the Engine.

*) We use the concept «product» with the meaning of a product, an object which is ready to be used in our every day life. From the common point of view, raw vegetables which are cooked in boiled water for some time are ready products which can be eaten. The more effective models suggested in OTSM-TRIZ are used for the situation analysis with the aim of solving a problem. The thing which we call the Product is not an end product, but the Transformation of the half-finished product (Product 1) into the product which is ready to be used (Product2) in another system or to be applied by people. In this particular case, we examine the Product in terms of the multi-screen scheme, along the time axis. The product 1 shows its qualities before the change and product 2 after the change.

So, we have the Product 1 during the initial moment. Under the influence of the Tool, we receive another Product during the completion of the Function. And as a result of the process, we receive the Product 2 which is ready to be used. So, there are at least three screens on time axis in the multi-screen scheme. All three screens are included into «Product» which aim is to fulfill the function. During the function fulfilment the intermediate product step by step transforms into the product which is ready to be used in another system or to be applied by people.

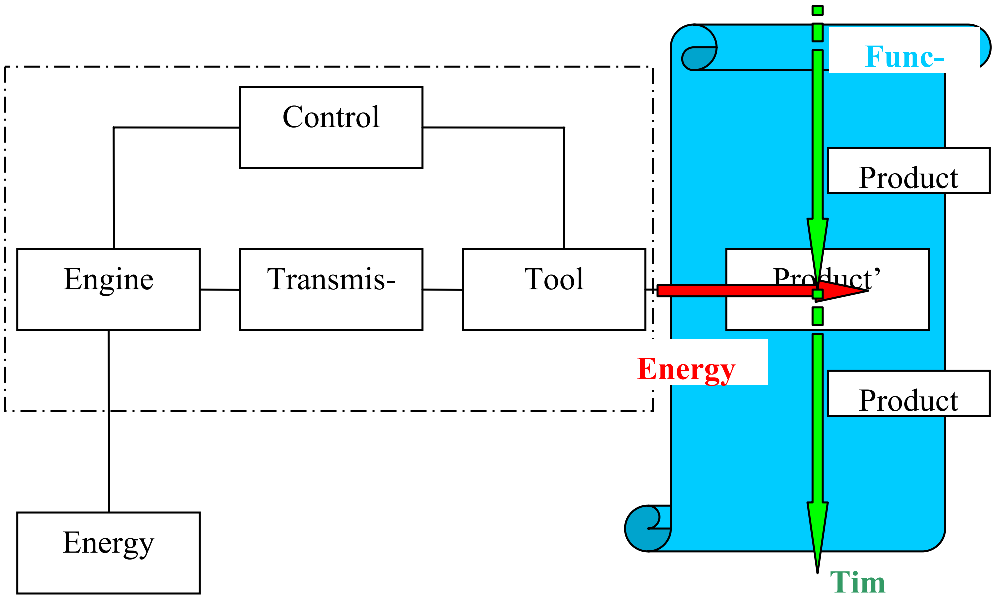

Fig. 1.4. Transformation of Product 1 into Product 2.

The typical mistake

Usually, all can give the definition of the multi-screen scheme. But in practice, when we discuss the Product, it is difficult to understand, because it is necessary to see all in development, in movement.

The Tool

Further on, if it is necessary to change something, at least one parameter will change the value. If we have the material system, we should usually change a material object in order to change the value of a parameter. Even if we change the location of an object, energy is demanded. There is something that makes this change. We call it the Tool. The Tool is something that co-operates directly with the Product.

In the example with the car: the Product is a person. It is necessary to change the location of the Product. What change the location of a person? Not a car, but that part which cooperates with Product directly. It is the seat.

Altshuller, G. S. gives the classical example: the Tool is not the lathe, but a cutter of the lathe tool. In case, when you cut an apple with a knife, the Tool is not the knife, but the knife edge.

It is very important nuance.

The Engine

As soon as we have defined the Tool, we return to the question about energy. We need to spend energy in order to change any parameter of a material object. Accordingly, it is necessary to understand what kind of energy we should spend. (What kind of energy is involved during the completion of the function?).

Let us consider not only the presence of through pass of energy, but also a chain of transformations of various kinds of energy.

In the example with the car:

It is necessary to transport a person from one point to another, this is linear movement. If we spend kinetic energy for this purpose, we should receive it from somewhere. We need linear kinetic energy in order to transport. We should find a place, where linear kinetic energy appears in a car and how it reaches the Tool. It is necessary for us to define the engine, (not the physical engine of a car, but to define «Engine» in accordance with the classification of four elements model).

*)

Let us notice that the engine of a car can be: the steam-engine, the internal combustion engine, the diesel engine-motor, the engine of String, the mechanical converter on the basis of a spring or rubber; the jet stream of a liquid or a gas; the untwisted flywheel (as in children toys) and many other things...

**)

In the previous paragraph we discussed the part of a car which we call an engine in our everyday life. What can be an engine in a traditional car in terms of four-element model taking into account diverse situations? It is not necessarily a car motor. For example, barrels filled with air, the so called «pontoons» can be «engine» as well which are used to perform the function «to raise the sunken car from the river bed to the surface.

When we talk about «Engine» within the frame the OTSM-approach of a problem solution, we talk about the last converter of energy from some form (primary energy of«Energy source»), which is accessible to the given system. This energy is transformed during one or several steps of transformation to that kind of energy, which is necessary for the «Tool». There is a chain of transformations and we choose the last transformation, as a result of which we receive energy, which is necessary to fulfill the function. The boundary of the minimal technical system is there, where the energy transmission takes place from one type into another one which is necessary for the Tool in order to fulfil the function. This moment is of special importance for the situation analysis, when it is necessary to find an explanation for unclear and undesirable effects.

The Transmission
Transmission includes all elements (subsystems) of the whole technical system through which energy is transformed without any change of its type. Energy is transformed from the engine to the tool. It is necessary to mention that this process is of special importance during the research of causes of unclear effects.
The schematic algorithm which defines the components of the minimal technical system is represented below:

1. Function. OTSM-algorithm.
2. Product.
3. Tool.
4. Engine.
5. Transmission.

2.1.4.3. How to estimate the working capacity of parts of the technical system

1. Presence of four parts in a system.
2. Working capacity of each part out of a system
3. Working capacity of each part as a part of a system
4. Estimation in accordance with other developed laws of technical **systems.**

2.1.4.4. How to estimate the operation of parts of the technical system

1. Control presence – Do we have such a controlled part in a system?
2. What is the degree of controllability of other three elements? (To estimate: do they cope with the task good or badly).
3. What management parameters do we have?

2.1.5. Example (Problem-Solution)

Example The conditions of «Engine» incapacity.
Let us consider the following function of a car on the basis of a combustion engine: "To move itself from one place into another".
Let us put a question: Under what conditions the car will not fulfill its function, will not move and transport itself and cargoes?

It is possible, in the case, when one of its parts of four elements model is absent: «Engine», «Transmission», «Tool», «Control Unit». What does it mean?
If «Engine» is absent or incapable: for example, on the Moon. The matter is that air oxygen, which is not present on the Moon, is necessary for functioning of the internal combustion engine. The cause of incapacity of «Engine» - absence of one of parts of «Energy source»: petroleum + air oxygen.
We will illustrate one more example. We need not pure petroleum for the engine, but a mixture of petroleum with air oxygen in a certain proportion. Very small drops of petroleum in air – a petrol fog which prepares one of the units of «Engine» - the carburettor.
Notes:
It is very important to analyze the whole chain of energy transformations, functioning of the technical system and its structure in detail in order to analyze the technical system and to solve a problem.
The engine will not function, if we fill in petroleum in the cylinder. If we change the quality of fuel in such a way that fog can not be formed, as a result, fuel can not be burned down and the engine can not transform the chemical energy of fuel into the mechanical energy of moving pistons. In one detective film the hero pours ordinary sugar in a petrol tank in order to elimi-

nate the chance of his persecutors to drive the car and to catch him. The received «petrol syrup» has other properties, for example, its viscosity. In this case, the necessary fuel for combustion is not available– a fog will not be formed, the engine will not start, the car will not be driven. (We do not recommend repeating this experience, because it can destroy the whole engine).

Example

The car can not fulfill the formulated function, for example, in case of absence or incapacity of «Transmission». «Transmission» - a part of the technical system, which transform energy in the form of its «Engine» transformation with the aim of supplying it to «Tool», in this case, mechanical energy (rotations). As a result of fuel combustion in cylinders there is a back and forth motions of pistons in the traditional internal combustion engine. If simply to transfer this movement (as movement of a swing: «forward-backward») on wheels, the car will not move. It is necessary that the transformation of one kind of mechanical energy into another takes place and as a consequence, the movement of pistons will lead to wheel rotation. For this purpose, there is the number of transfer mechanisms in a car. These are drive shaft, gear wheels, couplings…

Example

The car can not perform the formulated function («To move itself from one place into another») for example, if the «Tool» is absent or is broken. The wheel pushes the car from a road surface. For example, a wheel can not make a start on the absolutely slippery road. The friction, a coupling of a wheel with a road is necessary in order to bring the car into movement. The standard car, which is capable to float on water, cannot move along a river or lake. In this case, we need another operating device, for example, special wheels with blades or the water propeller like on the ship.

In the photo below, "Amphicar" is illustrated. Its Tools during its movement on water (according to the classification of four element model) are two middle-sized propellers.

Example

The car also can not normally perform the function, if the «Control System» is absent or broken. «Control System» usually includes steering, brakes, a rearview mirror. But firstly, it is necessary to provide the operative work of «Engine». It is not enough to fill in «a petrol fog» in cylinders, it should be transported in the definite moment, not earlier and not later on; It is necessary to ignite it, to be more precise, to ignite a spark in that moment, when «a petrol fog» is supplied in a cylinder. It is necessary to release the formed exhaust gases from the cylinder. In most cases, it is «programmed» in the operational system of an engine; a driver himself can control some operations.

Example

And as a final example we illustrate a humoristic view of the car of the Stone Age. How did it look in the past? There are wheels and the engine, the case and the cabin for a driver…But this car will never be able to fulfill the characteristic function of cars: «to transport people or cargoes from one place to another». This can not move itself. Any of its parts is not able to operate separately or as a part of a system.

2.1.6. Self Assessment - Questions, tasks

1. What difference do we have between the technical system and other technical objects?
2. What parts are included in the composition of four element model of the technical system?
3. How can you define «the law of the completeness of parts of a system»?
4. What condition is necessary for the existence of the controlled technical system?

Summary.

We can imagine any technical system as a model which consists of four main parts – Engine, Transmission, Tool and Control Unit.

The technical system will be operative, if it includes the mentioned, minimum-operative parts.

The Basic definitions.

Technical system; function of the technical system; Model; sub-system; evolution; engine; transmission; Tool; Control unit; Product; S-curve.

2.1.7 References

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2.2 The law of ‘energy conductivity’ of a system

According to the German traffic rules a bicyclist should have a headlight and a tail light behind during movement at night. And, the basic energy source for these devices **should be necessarily a dynamo-car**, instead of batteries, accumulators or, especially, solar batteries according to rules. Why? We will notice that many rules and laws as some lawyers say «are written by blood». To be more precise, a wide experience of many people is concentrated in them, both negative experience, and ways of overcoming of problematic situations. To say it differently, objective laws, recommendations about their performance and a payment for possible errors are described in them.
Let’s return to a bicycle. To be more precise, to the system of the signaling and the illumination.

The device of illumination of road on a bicycle is the most important at night during movement. An energy source for a bicycle is muscular force of the person. During movement of a bicycle there always appears a source of mechanical energy which the dynamo-car will transform to the electric energy. This source is more reliable than batteries or accumulators and it does not depend on forgetfulness of the bicyclist. (Without a doubt, this technical system has some lacks. We will dwell upon them and on ways of solving these problems in detail during consideration of other sections.)

2.2.1. Definition

“The law of “energy conductivity” of the system: A necessary condition for the life capability in principle of a technical system is the unhindered passage of energy through all parts of the system”.
Altshuller, G. S. (1984). *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems* (A. Williams, Trans.): Gordon and Breach Science Publishers.), p. 225.

“The corollary of Law 2 is also significant: It is necessary to ensure conductivity of energy between this part and the controlling organs in order to control the part of the technical system.”
Altshuller, G. S. (1984). *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems* (A. Williams, Trans.): Gordon and Breach Science Publishers.), p. 226-227.

The law refers to the section “Static”, to be more precise, to the laws which define the beginning of life of technical systems.

2.2.2. Theory

2.2.2.1. Through pass of energy as an estimated parameter of the technical system

The first condition of viability of the technical system is described by the Law of completeness of parts of a system – presence and the minimum working capacity of the basic parts of system (Engine, Transmission, Tool and Control Unit).

Viability is considered to be the qualitative characteristic which includes a number of estimated parameters.

The ability of the technical system to perform the function, to be operated, to coexist, to cooperate, and also to compete with other technical systems depends on many evaluated parameters: (defined for each technical system) – speed, reliability, cost, range of use, etc..... In process of development of the concrete technical system the definition of „viability” extends. It is supplemented with the new evaluated parameters.

Thus, the additional criteria, evaluated parameters, are necessary in order to increase viability of the technical system in process of increase of requirements of people to parameters of the performed function, development of the technical system, toughening of a competitive environment. … (The note: but in this case we speak about the estimated parameters for the model of the technical system.

Coming back to the illustrated example at the beginning of the chapter, we will draw conclusions on its basis. What meaning does the statement has: « for maintenance of the minimum working capacity of the technical system through pass of energy through all parts of the technical system» is necessary besides the presence of the basic parts of the technical system: Engine, Transmission, and Tool?

For the considered technical system of illumination “Engine” - batteries is alien from the point of view of passage and transformation of mechanical energy. (........) Batteries, accumulators can be used as an additional “source” and “an engine” of this technical system.

The through pass of energy is produced of the energy source – muscular force of the person which come through the Engine, is transmitted to the Tool and further – to the Product (sense organs of the person, an eye).

2.2.2.2. The typical mistakes

In order to understand and comprehend the essence of the law, it is necessary to read attentively some definitions, the theory, examples. Do not hurry. New ideas are hardly recognized not only in our society and in the world, but as well in our head.
The through pass of energy is important at first not for the technical system, but for the user of this technical system. Pay attention to the words in the definition – «the condition of basic life capability». To be more precise, the ability of the technical system is described here which is able to fulfil the function.

2.2.2.3. Example 2. 1. Red thread. (Explanation of the theory)

Since 1776 following the order of Admiralty factory workers had started to intertwine ropes with a red thread making ropes for military fleet at the factories. The thread was intertwined so that it could not be removed even from a small piece of a rope. What aims do they pursue?
Two important problems were solved thereby. First, in process of use, ropes were used up and their further application became dangerous at the definite thickness. The red thread was intertwined so that at reduction of a thickness of a rope by certain size it was possible to signal about it. The second problem dealt with the larceny of ropes from factories for their personal use. There was a red thread in any piece of a rope and it was easy to expose the criminal.

This example serves as a good vision of the Law «Power conductivity». For maintenance of the minimum viability of the technical system energy should pass like «a red thread» through all parts of the technical system.

2.2.3. Model

2.2.3.1. The four- element scheme

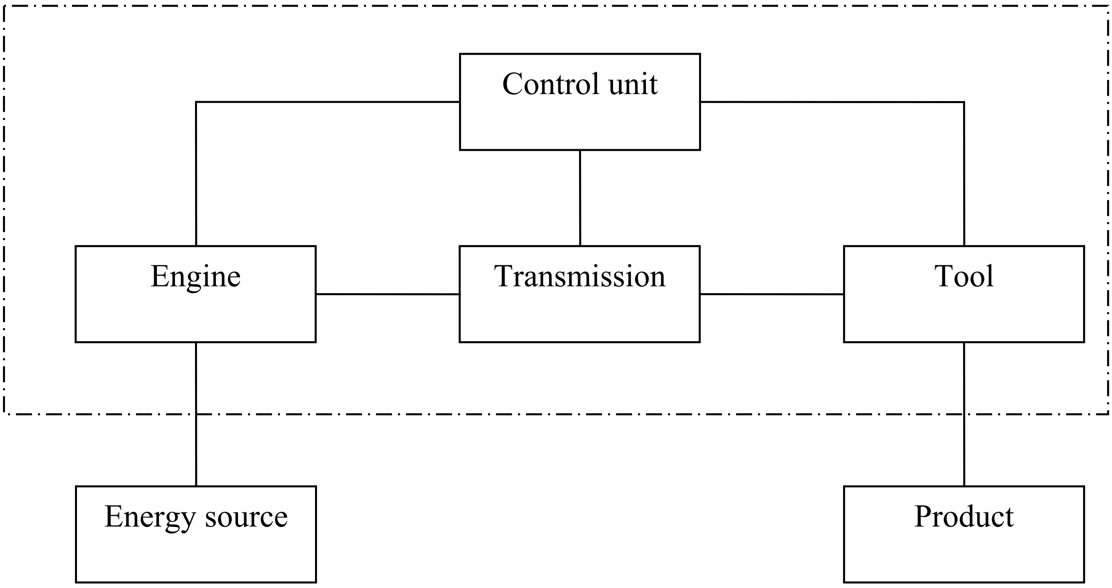

Fig. 2.1. The main parts of the technical system.

2.2.3.2. Example 2.2 (Sokolov’s loudspeaker) – a thorough pass of energy

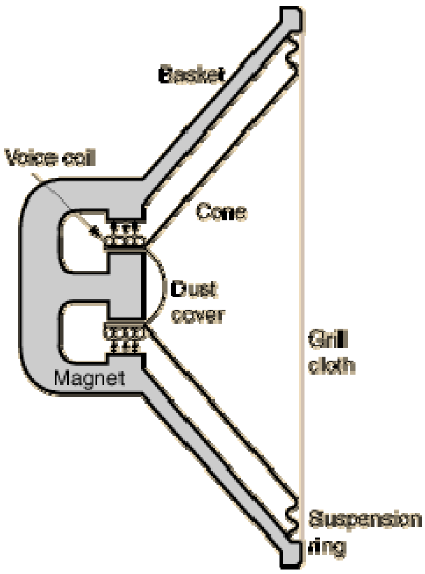

Figure 2.2. Cross section of a loudspeaker

For the coil of the loudspeaker the copper wire, which has been reeled up in one layer, is usually used. But in the first years of development and mass application of loudspeakers magnets did not possess sufficient magnetic force for creation of necessary sound pressure on a loudspeaker exit. (The note: sound pressure depends on current strength in a conductor and forces of a magnetic field. A human ear perceives sound pressure as loudness of a sound; however, this dependence has the difficult character).

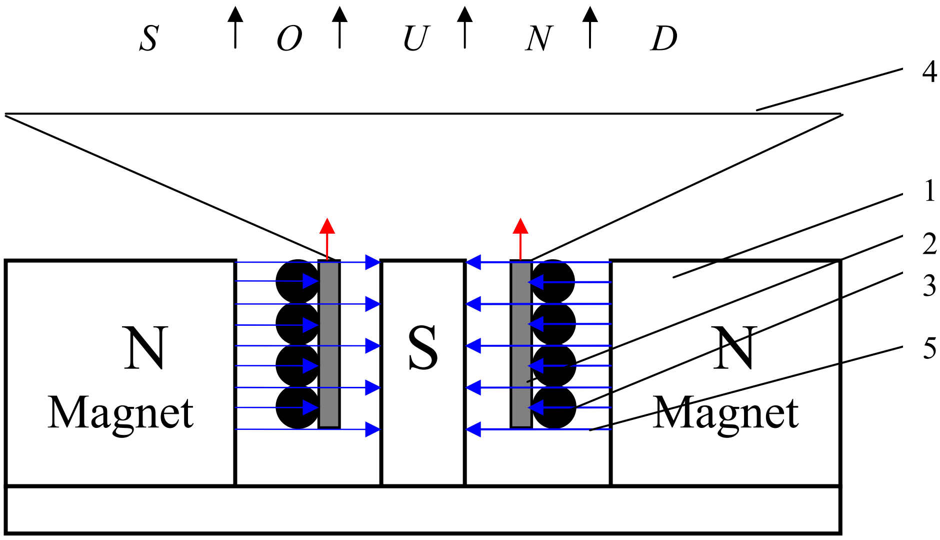

Figure 2.3. The cross section of a magnetic chain of a loudspeaker

The Figure includes:
1 – magnet
2 – coil assembly
3 – coil laps (waps)
4 – diffuser
5 – line of fource of a magnetic field
There are only three obstacles for power lines of a magnetic field which are located between two poles of a magnet and which weaken a magnetic field. These obstacles are an air interval; a carcass of the isolated material for the coil; and a copper wire. The less air interval is and thinner a coil carcass is, the fewer losses will appear in a magnetic chain. And the magnetic field will be stronger. That means that sound pressure and loudness of a sound will be stronger.

A copper conductor causes losses in a magnetic field.

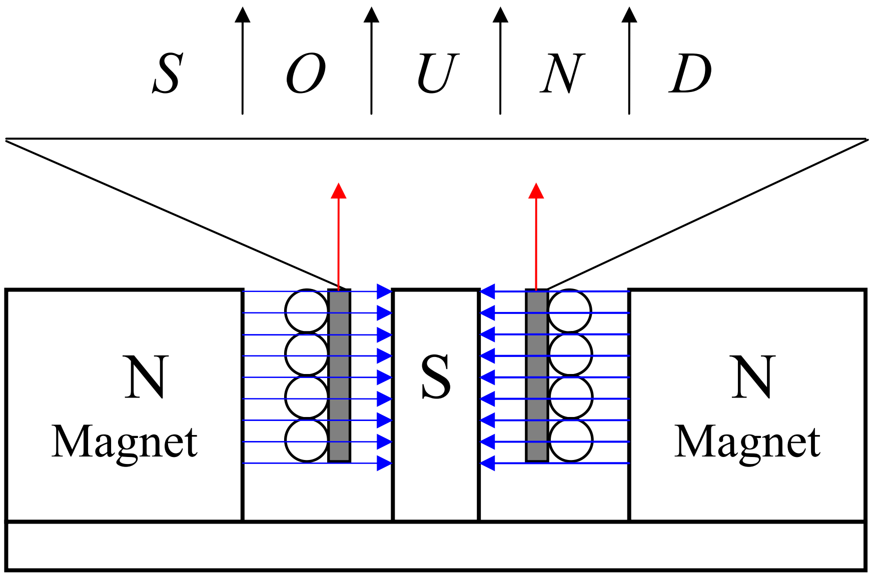

Figure. 2.4. The cross section of a magnetic chain of a loudspeaker

The figure illustrates the changes: instead of a copper wire the wire from a ferromagnetic material, for example, the steel is used.
The inventor, the Sokolov, has patented a loudspeaker in 1936 in which the winding part is executed from a ferromagnetic material for the purpose of increasing its efficiency. The ferromagnetic material conducts well a magnetic field, without bringing losses in a magnetic chain.

2.2.3.3. Power conductivity of the four elements model

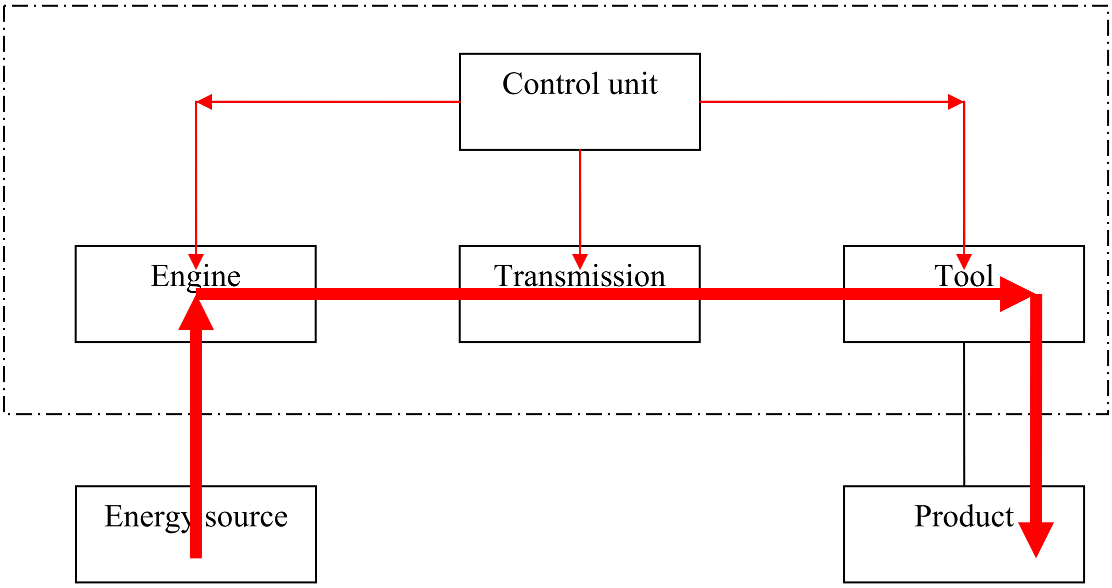

Figure. 2.5. Power conductivity of the four elements model

The consequence of controllability

« In order the part of a technical system was operated, it is necessary to provide power conductivity between this part and the control unit». What does it mean? How should we work with it?

1. It is necessary to construct four element model of the technical system.
2. To analyse whether there is a through pass of energy in parts the technical system.
3. To analyse whether there is energetic conductivity between parts of the technical system and a control unit.
4. To establish what fields are used for management and to analyse necessity and possibility of replacement of badly operated field by well operated in accordance with following order: gravitational – mechanical - thermal - magnetic - electric - electromagnetic.

The inverse problem – to break power conductivity

During the solution of some problems inverse action is required. It is necessary not to admit a through pass of energy in order to prevent harmful influence of the technical system on a product. In this case it is necessary to define at first the function.

2.2.3.4. Example 2.3. A safe switch of a press.

Press machines (a piece of equipment used to put weight on something in order to make it flat or to force liquid out of it) or mechanical hand-operated scissors are used at some factories. The worker delivers manually a half-finished material to a zone of processing, and then, turns on the press. Danger emerges because the hand of the worker can appear in a dangerous zone at the moment when the press is switched on. How to prevent the on-switch of the press in case of hand hit in a dangerous zone?

We will represent on the scheme of the technical system which harmful action should be prevented (fig 2.6).

It is necessary to improve controllability of a press: the press should not be switched on, when a hand emerges in a dangerous zone. Thus, the function of the new technical system will be «to switch a press on only in that case, if any of hands of the worker are not in a dangerous zone».

The operation of a press is completed in this case in such a way that if a hand of the worker appears in a dangerous zone it is not allowed switching the press on. To say it differently, the mechanism is uncontrollable in the described problem: the mechanism works in the case, when one, at least one hand is in a dangerous zone. On the scheme (fig 2.7), there are no power communications – red arrows – in an operative chain between the Control unit and other parts of a system. Uniqueness of this situation is explained by the fact that there are some dangerous moments, when the first worker delivers an intermediate product to a processing zone using one hand, and the second worker switches a press on. It is necessary to destroy, to break off a through pass of energy in any part of a chain in case, when a hand appears in a dangerous zone.

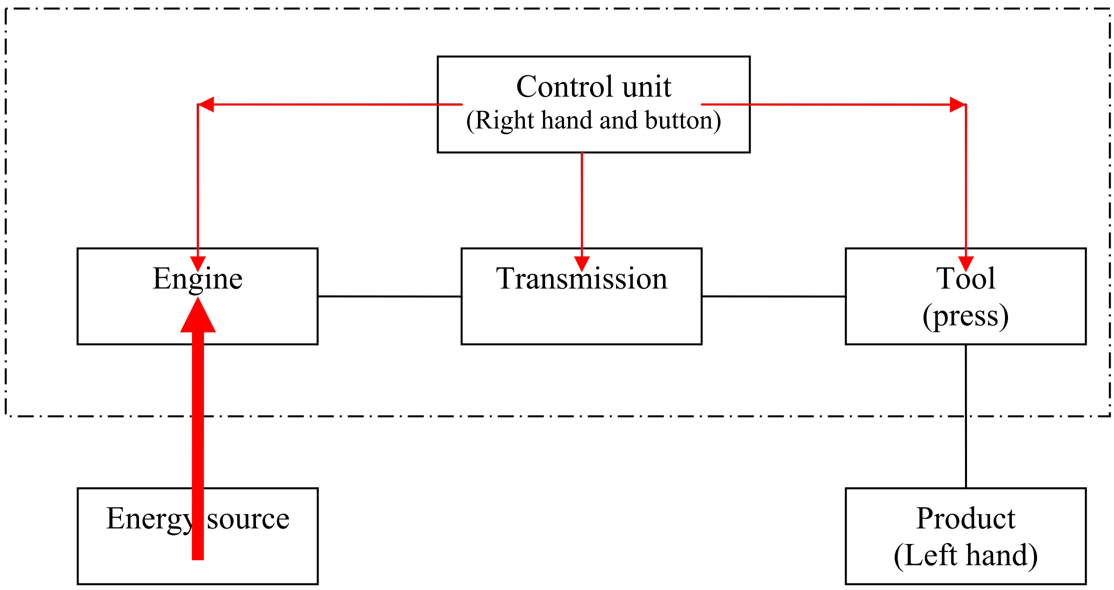

Figure 2.7

The changes are reflected in the following scheme according to the decision to operate a press by two hands. The control device switches a press on only when two buttons are pressed simultaneously by two hands. A through pass of energy through a system and further to a product is interrupted (in a case when a hand together with a processed product appears in a dangerous zone).

Energy source → | → →Left hand → | Engine→ → Tool (press) →Product (+hand)

Energy source → Engine | → Right hand → Left hand → | →→Tool (press) → Product

Example 2.4. (Protection against electronic scanning)

We will demonstrate one more example in order to illustrate that case, when it is necessary to break off power conductivity of a system.
The beautiful and attractive exterior of buildings and of windows of modern banks and of a casino influences very essentially their business.
But the electronic equipment is established in these establishments, which activity (various codes, passwords, etc.) can be easily scanned, read out using radiated radio signals. The premise should be impenetrable for electromagnetic waves in order to avoid these problems taking into account safety conditions. But to close all windows using metal boards is not beautiful for an exterior. What should be done?
It is often possible to see graceful curtains on windows in bank premises. They are made of metal chains. (The photo 2.8.; 2.9.) For what purpose are they used?

Fig. 2.8.
The photo illustrates the window of a known casino in Europe.

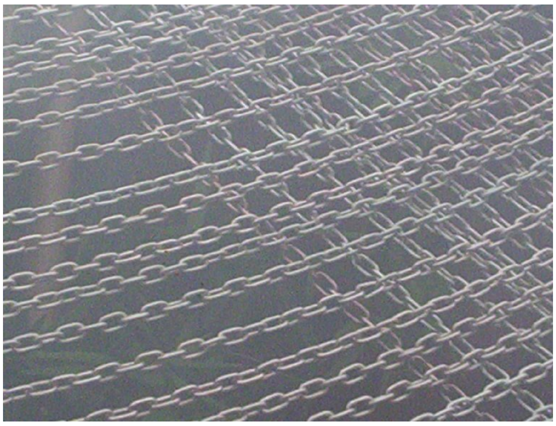

Fig. 2.9.
The photo illustrates the curtain structure (the image is increased)

The model of the "Harmful" machine

The model «Harmful machine» is used in order to solve similar problems. The matter is that there is often an imposing on the useful effect (efficiency) of the harmful element while dealing with practical problems. A model of "the harmful machine » is created in order to define the parts of a system correctly, which causes this harmful influence, and leads to the selection of a changeable element.
The construction logic of the harmful machine is the same as of the ordinary technical system. We begin the analysis with the formulation of the harmful function which disturbs us. The "Harmful" Function is to accept and to write down signals from the electronic equipment which is located indoors.

Product: a signal.
Tool: a scanner-device
Transmission: airspace indoors and outdoors, a building, a window which is located between electrical equipment and a scanner.
Engine: Electrical equipment.

The useful, technical system.
The Function. To make a good impression of a firm (of a casino, of a bank) with the own appearance.
The Product. An eye of a person.
The Tool. Electromagnetic waves of visible diapason.
The Transmission. The **internal volume of a building**, a window, curtains. And **the air environment which emerges from a window and reaches an eye of the observer.**
The Engine. Reflexion of sunlight or artificial light of internal walls and of surfaces of objects indoors.
The energy source. Sunlight or artificial illumination.

The harmful technical system.
The Function. To read out the data of the electronic equipment located indoors.
The Product. Radiation of the electronic equipment.
The Tool. A scanner outside.
The Transmission. **Internal volume of a premise, of a wall,** a window, curtains. And **the air environment from a window to the scanner.**
The Engine. The electrical equipment.
The Source energy. An electrical network.

If two models of technical systems, useful and harmful , are represented graphically, it is easy to see that the general part of transmissions coincide in the useful and harmful systems.

2.2.4. Instruments (how to use)

For what purposes can we apply the instruments? For:

- Solution of practical problems: creation of «the useful machine»;
- Solution of practical problems: destruction of «the harmful machine»;
- The analysis of the technical system in accordance with the Law – an estimation of competitive advantages of the technical system; estimation of weak places of the technical system;

an element constituent which forecasts development of the technical system: what part of the technical system or what parameters of the technical system cause the greatest difficulties during the operation?

How to use?

1. energetic conductivity– Examples: 2.2, 2.5, 2.6.
2. about control – Examples: 2.5, 2.6.
3. a brake of energetic connection – Examples: a press; curtains 2.4, 2.5.

2.2.5. Example (Problem-Solution)

Example (The prognosis for car «control»)

Imagine that you live in 1901 and work for the known firm “Mercedes”. It is necessary for you to make the prognosis concerning the world demand of cars for 25 years. For the prognosis, it is necessary to define correctly factors which limit growth of consumption of a product.
What do you think, what was one of deterrents of increase in release and in sale of cars from the point of view of a level of development of the technical system “car”?

- Car Cost?
- Speed of the car?
- Economy of the engine?
- Level of pollution in exhaust gases?
- Complexity of driving?

Yes, driving was difficult and even dangerous. The first cars involved only sportsmen-fans. Many automobile owners hired drivers.

The driver had to train long in driving.

Imagine that to you are offered to go for a drive with the speed of 50 km/h in the unstable car without lateral walls, a windscreen, a screen wiper, with set of mechanisms, with weak brakes and unreliable tyres. The workplace of the driver has been equipped by so many handles and control levers that ability to use them quickly came not at once. There were along three brake levers: on a transmission shaft, on back wheels and on so-called «a drop-type sprag» — a peaked core which was lowered on a road during lifting movement while brakes on a bias did not keep the car (a prototype of a modern hand brake). The designer did not bother whether it is possible to reach the lever and whether it is convenient to use it. The lever was installed there where it was demanded by a design, thereby demanding from the driver to demonstrate improbable acrobatic abilities.

How to apply the law «Power conductivity of parts of a system» in order to improve driving skills?

According to the second consequence of this law «It is necessary to provide power conductivity between this part and control units in order to operate the part of the technical system ».

Absence of such communications made driving difficult and unreliable, demanded special and long preparation of drivers. To say it differently, they constrained development of the technical system and the quantity of produced cars. For firms-manufacturers it meant the missed profit...

It is important and useful to know the laws of development of technical systems not only for engineers, but also for researchers of the market. Their lack of knowledge or ignorance can lead to prognosis which may now cause a smile:

“Worldwide demand for cars will never exceed one million – primarily because of a limitation in the number of available chauffeurs”.
Market Research Study, Mercedes Benz, 1901.
Wehnert, Timon
European energy futures 2030 : technology and social visions from the European energy Delphi survey / Timon Wehnert .... - Berlin ; Heidelberg : Springer Berlin, 2007. (page 53).

Happily, managers and designers of the known firm have not listened to this prognosis, and have improved the car, have made it simpler in operation...

Example (The management of the firm)

The operative problem of the fastest car will seem easy in comparison with a management problem of a small firm. The law «Power conductivity» is applicable in this case as well. Known advisers who are concerned with the management of firms (Josef O'Connor, Ian McDermott) give an example of an unsuccessful innovation in a firm in their book. One company has invited the expert (not authors of the book) to improve work of department of the administrative account. Thanks to the received recommendations the department began to work more effectively. However, for this purpose the department required much more information from other departments of the firm, for example, from the marketing department. The additional load concerning the data transfer has been laid down on the marketing department, distracting employees from the basic work. As a result of this innovation, the firm experienced difficulties with the basic production of normal manufacture and with sales of products for a long time...

As a result of the described approach, «power conductivity» of the firm structure has been broken; it became uncontrollable to a certain degree.

As a result of the accepted innovation, the department of the administrative account has affected «power conductivity» of the marketing department. And that means that it has affected «power conductivity» of the whole firm.

2.2.6. Self Assessment - (Questions, tasks)

Summary.

We need a through pass trough all parts of a system (the law of «Energy conductivity») in order the technical system functions to a minimal degree besides the presence of all parts of a technical system (the law of «Completeness of all parts of a system»).
It is necessary to provide energetic connection between this part and a control unit in order to control the part of the technical system.

The basic definitions.

Energetic conductivity; a degree of a control; «harmful machine»; estimated parameters.

Questions:

1. What parts are included in the four element model of a technical system?

2. What conditions of the minimum working capacity does a technical system have (in accordance with the law of Completeness of parts of a system)?

3. What conditions of the minimum working capacity does a technical system have (in accordance with the law of Power conductivity of parts of a system)?

4. Specify names of the parts which are included into the four element model of the technical system: Transmission, Product, Engine, Energy source, Tool, Control Unit.

5. (*) Specify names of elements of the four element models of the technical system:

   Transmission, Energy source, Engine, Product, Tool, Su-Field, Environment,

   Control Unit.....

6. (*) What lacks of the dynamo-car which has a transmission mechanism in a bicycle wheel? From your own point of view? (From the point of view of Laws of Engineering System of Evolution)

The traditional dynamo-car (the electric generator) is installed as a source of the electric power for devices of illumination of a bicycle. Energy of rotation is transferred to a dynamo-car by a wheel. For this purpose a dynamo-car has a ridge castor, which is placed on the shaft of a generator. During the contact with a rim of a wheel, the castor rotates and causes a rotation of a shaft and of a rotor of a generator (A photo made by the author).

Fig. 2.10.

Fig. 2.11.

Fig. 2.12.

The Photo illustrates the traditional dynamo-car (generator), installed on a bicycle.

The Exercises.

1. Compose the four element model of the technical system for road illumination on a bicycle. The technical system consists of a headlight (with a bulb, glass and a reflector), supply lines (wires), a bicycle frame (serves as one of conductors), the switch; the generator of an electric current (dynamo-car); a rotating wheel.
2. (*) What is the basic function of the car, in your opinion? What is «Tool», “Transmission”, “Engine”, “Energy source”, “Control Unit” in a car according to the four element model?
3. The first bicycle. Some models of the first bicycles had no brakes and no handlebars as the devices for operation of a forward wheel and turning movement. Construct the four element model of a bicycle as means of transportation and mark power connectivity in it: a through pass of energy; presence of power connectivity between parts of the technical system and a control unit.

The Tasks.

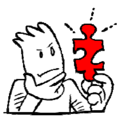

Fig. 2.2 and 2.3 illustrate the sectional view of a magnetic chain of a loudspeaker. For example, the strongest magnets are used in powerful concert loudspeakers. And for the further increase in capacity, it is desirable to lower losses in the magnetic chain, brought at the expense of the case of the coil. Besides, the heavy current proceeds through the coil in powerful loudspeakers, the coil heats up strongly and can fuse. In these conditions it is important to blow the coil by air from different directions in order to cool it. But the case of the coil, made from electrically insulated material, serves as a heat insulator, which prevent the coil from cooling. What do you suggest?

Prompt-1: Examine the technical system from the point of view of the performed law «energetic conductivity», as it was shown in the Example 2.3.
(Prompt-2: let us formulate the contradiction. «The case of the coil should be used in order ***; and the case of the coil should not be used in order ***».

The speed record of the car. The first car with the rocket engine «Blue Flame» became the first car which has overcome speed of 1000 km/hour. This car has reached the speed of 1001,452 km/hour on an equal surface of the extinct (dried up) salt lake of the State of Utah under control of pilot Gari Gabelich in 1970. One of the problems with which designers have faced: how to implement the braking of this car?

2.2.7 References

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See also:
2.5 Law of uneven development of a system's parts

2.3: The law of harmony of the rhythms of parts of the system

I went upstairs using a wide spiral staircase while rising from a hall into office premises in one of the known European banks. This ladder has reminded me spiral staircases, which I saw in many medieval castles and fortresses... What similarity do they have?
The inhabitants of a fortress should protect each brick, each step of the ladder, each turn of a corridor. Those ladders, which should become an obstacle for the enemies rising from the bottom in the upward direction, are twirled in a direction from left to right, if to look at it upwards from the bottom. The matter is that a soldier, who walks upstairs, who battles with a sword in the right hand (and the percentage of such soldiers is 90 %) has to open the left side of a breast – the side, where his heart is located. A soldier, who protects a pass on a ladder and who stands above of the opponent, has a big chance to achieve a victory because the left side of his breast is covered by the right hand at the expense of a turning of a ladder.

2.3.1. Definition

An essential condition for the living viability in principle of a technical system is the harmonization of the rhythms (frequencies of vibration, periodicity) of all parts of the system.
Altshuller, G. S. (1984). *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems* (A. Williams, Trans.): Gordon and Breach Science Publishers.), p. 227.

2.3.2. Theory (Details)

Two conditions of basic viability of the technical system are described in the first and in the second laws:
1. Presence and the minimum working capacity of the basic parts of the technical system, (Engine, Transmission, Tool, Control Unit).
2. A through pass of energy in parts the technical system.

The third law introduces one more condition, one more evaluated parameter of the technical system the harmony of rhythms of parts of the technical system. One typical error during the analysis of a technical system in accordance with the Laws of development of technical systems is that a user begins the analysis without a proper formulation of the function which is required from the analyzed technical system.
Depending on a function, it is required to co-ordinate rhythms of parts of the technical system in one case and in others – disorganize.
The controlled parameters of the technical system can be: frequency, periodicity, a direction, speed, a phase, sequence, integration air space (porosity) and others.
In this example at the beginning of the chapter, the coordination of a direction of movement on a ladder and a direction of movement of hands during a battle is described for the defender of a fortress and a deviation of these parameters for the attacker.

To say it differently, the choice of the mismatch and of the coordination depends on this function, which fulfilment must be provided.
The inconsistency of rhythms of parts of the technical system is one of the reasons of non-

uniformity of development of the technical system (along with the external reasons: occurrence of new requirements of the person to the technical system; interaction with other technical systems, etc.). The detailed description of the Law «Non-uniformity of development of parts of system» is represented in chapter 5.

2.3.3. Model

For the analysis of the technical system concerning the coordination of rhythms of parts of the system, the four element model of the technical system is used. It is necessary to pay attention not only to the presence of the basic parts of the system and power connectivity between them during the analysis of these parameters, but mainly to the parameters of this connectivity – fluctuations, periodicity, etc.

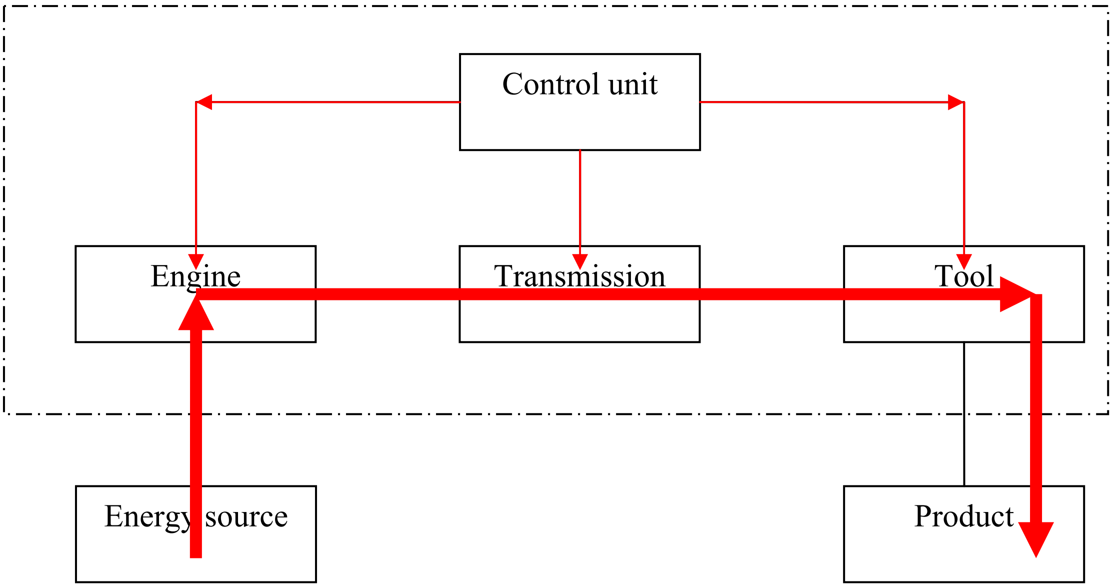

Fig. 3.1.

2.3.4. Instruments - Tools (how to use)

For what purposes to apply? For:

- solution of practical problems: problems of change;
- solution of practical problems: problems of measurement;
- the analysis of the technical system in accordance with the Law - an estimation of


- competitive advantages of the technical system; identification of weak parts of the technical
- system;
- a component for the development of the prognosis of the technical system: what part (parts)
- of the technical system are not co-ordinated with rhythmic?

How to apply?

- the analysis of the technical system on the presence of the basic parts of the technical system using the four element model, the definition- what parts of the system fulfil functions of the Energy source, the Engine, Transmission, the Control Unit.
- to analyse the technical system on presence of contradictions between parameters of various parts of the technical system.

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- to use the model of «the harmful machine» for the analysis. It is necessary to pay attention, mainly, to the parameters of power connectivity.

For what purposes to apply? For:

- solution of practical tasks: a search for reasons of undesirable effects;
- solution of practical tasks: the removal of reasons of undesirable effects
- the analysis of a technical system in accordance with the Law – estimation of competitive advantages of a technical; the identification of weak parts in the technical system;
- development prognosis:one of the approaches is used to forecast the development of the technical system: the presence of the coordination and the mismatch of parts of the technical system

How to apply?

1. To search and to remove reasons of undesirable effects: the presence of the mismatch and the organisation of the coordinated conditions– Examples 3.1, 3.2, 3.3, 3.4, 3.5.
2. To search and to remove reasons of undesirable effects: the presence of the mismatch and the organisation of mismatched conditions – Examples: 2.3, 2.4, 3.3.

2.3.4.1. Example 3.1. Paralympic Games

The following problem appeared on the "Paralympic" Games, which was organized for invalids. There was the race on a long distance for people with the total absence of sight and hearing. Each sportsman of the "Paralympics" Games has an assistant, the sportsman-professional, in order to run in a correct direction. The assistant "leads" the partner – their hands are connected by a thin and easy ribbon. There was no problem concerning the false direction, each assistant "led" reliably the ward. But sportsmen ran uncertainly, without the feeling of the competitive atmosphere. How to transfer the atmosphere of the presence of fans, their emotions and support to sportsmen with absence of sight and hearing?!
The commentator of competitions has solved this problem within some seconds, having seen the uncertain run of sportsmen of the "Paralympics" Games. He has addressed the spectators with the request... (With what request – you will know after small theoretical explanation).

The traditional solutions:

- the sportsman-assistant should pull a string, designating applauds;
- to give the receiver with a vibrated ring to each sportsmen of the "Paralympic" Games, and
- to give the transmitter to the commentator ;
- not to hold such competitions...

Notes:
The "Paralympic" Games- the international sport competitions for invalids. They are held traditionally after the main Olympic Games, and since 1992 — in the same cities; this practice is fixed by the agreement between the International Olympic Committee and International Paralympic Committee in 2001. The summer Paralympic Games are held since 1960, and the winter Paralympic Games — since 1976. The name «Paralympic» is formed from the Greek prefix of « para » — «nearby, like everyone else»; parallelism and equality of Paralympic competitions with Olympic Games is meant.

Let us try to solve this problem. It is necessary to create the channel of « power conductivity» between spectators and sportsmen. We will begin with the definition of the function. **Function.** So, sportsmen should receive support from spectators. Any kind of energy should be used as the carrier of this information. Thus, the technical system is necessary in order to transfer information from spectators to sportsmen with the total absence of sight and hearing.

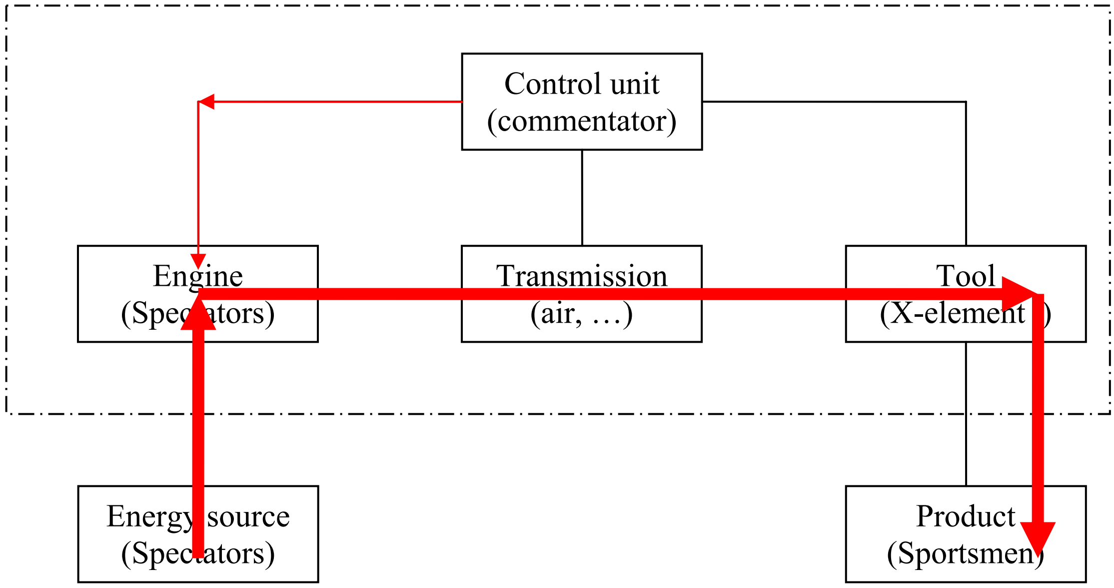


Fig. 3.2.

The Product in our case – the sportsman of Paralympic Games.
The tool – that directly surrounds the sportsman. In accordance with the conditions of competitions the sportsman-assistant should not help the partner, besides, to support him on the right track, on his path. Any technical means are inadmissible (various receivers, sensing devices, etc.). Other resources from an environment: air, a racetrack covering.
Transmission – a chain of objects that surrounds him from his body to spectators.
The engine and the Energy source – spectators.

A mechanical (acoustic) field and electromagnetic field of a visible diapason of waves (light) are accessible to sportsmen with hearing and sight. The tactile perception (a strong mechanical field) is only accessible to sportsmen without any hearing and sight. Exclamations of fans are not audible to sportsmen. It is necessary to strengthen the influence. Whether actions of spectators are co-ordinated? The sport commentator has asked spectators to applaud rhythmically and he himself has set this rhythm. The applauses of the spectators became rhythmical and co-ordinated. And the fluctuations of air strengthened by this resonance have achieved the object – sportsmen have felt a friendly greeting of spectators with their skin. (People without any sight and hearing have raised tactile sensitivity. On the one hand, it is the compensation of the organism mechanism, on the other side, – the ability strengthened by experience).
The note: compare the received solution with the traditional solutions represented above which are offered during the first minute's analysis of a problem.

2.3.5. Example (Problem-Solution)

Example

In order to increase the general power of loudspeakers they are often united in pairs or in groups and are placed in the special general case. In this case, all loudspeakers in the group should be connected in phase. What does it mean? When a signal is supplied on windings of sound coils, diffusers of all loudspeakers should move tactfully in one direction, but not in opposite directions.

Fig. 3.3. Loudspeaker

Example

In drawings, the fragment of history of development of a loudspeaker is presented. Actually, the head of a loudspeaker without registration badly reproduces low frequencies. The reason is acoustic short circuit. Sound pressure before a diffuser is not created, as the loudspeaker pumps over air from a forward wall of the diffuser to the backward wall, which moves already in an opposite direction by the time of the appearance of a wave from a forward wall. Thus, one wave extinguishes another in accordance with the terms of four elements model. (The motion of a diffuser and air which is moved by the diffuser are not coordinated for the fulfilment of the function «to create air vibrations »)

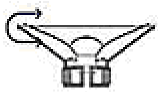
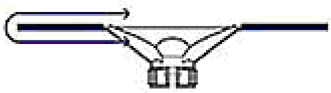


Fig. 3.4.

A loudspeaker is installed in the sound shield in order to avoid the occurrence. It is a board which sizes are calculated in such a way that the shortest distance from a forward wall of a diffuser to the backward wall is equal to the half of the length of a wave in accordance with the calculated frequency. Thus, the coordination of rhythmic, fluctuations of parts of the technical system of «Loudspeaker» is achieved. (In this case, the motion of air masses caused by the direct and the backward motion of a diffuser does not suppress each other, but are folded in order to increase the power of vibrations.)

* It is a question of transmission, its various parts in terms of four elements model.



* consider the interaction of the «harmful» and the useful technical system

Fig. 3.5.

However, in this case, the following problem appears. The sizes of the sound shield do not allow applying this solution in household sound-reproducing equipment. The sizes of the screen should be 3x3 metre, in order not to admit the acoustic short circuit with frequency of 50 Hz. To be more precise, these sizes should correspond to the size of the length of a half- wave at this frequency. The screen should be big in order not to avoid the acoustic short circuit, and the screen should be not big in order the loudspeaker could be installed in household radio equipment. (In this case, the sizes of the acoustic screen do not match with the sizes of the body frame of household radio equipment – radio, tape-recorder, etc.) It is necessary to specify the parameters «the size of the acoustic screen» and «the size of the box» in order to solve the problem. The contradiction was resolved using the tree dimensional frame construction – the acoustic screen in the form of an open box. The equipment dimensions of vacuum lamps allowed using this decision. (Now it is possible to see the radio receivers of the last century in the sizes of 1x0,7x0,5 metre only in museums). However, with the advent of semi-conductor devices – transistors and devices on their basis, the sizes of equipment have decreased in ten or more times.

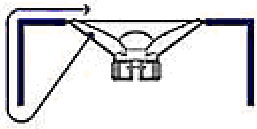


Fig. 3.6.

The box was made closed in order to prevent completely the acoustic short circuit in the small volume. However, there appears another problem. Low frequencies began to be reproduced badly, but it happened as a result of another reasons. If the air volume did not resist to the fluctuations of a diffuser dynamics in an open box, the closed box became similar to a spring. Resonant frequency of a dynamic has increased at the expense of elasticity of air volume in a box. (In this case, the vibrations of the air volume of the box do not match with the vibrations of the diffuser. To be more precise, the inner air volume of the box and of the loudspeaker cone do not match in accordance with the parameter«elasticity».

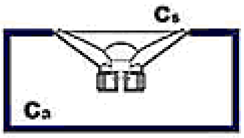


Fig. 3.7.

It was necessary to produce the boxes of the big sizes in order the elasticity of this air spring was much more below the elasticity of its own means of support of the dynamic. This solution allows us to specify the inner air volume of the box and of the diffuser in terms of the parameter «elasticity». Though, this solution leads to the mismatch of sizes of the loudspeaker box with sizes of a building. The direction Hi-Fi (High Fidelity – High fidelity of reproduction) has generated the huge size of loudspeakers – speakers. The most complicated and the biggest stereo speaker in the world (the volume approximately 50000 litres) belongs to the American firm *Wilson Audio* and occupies the volume of a 20-metre room.

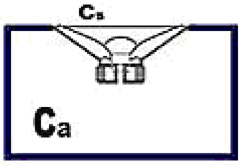


Fig. 3.8.

During the exemplified fragment of history of development of the acoustic design of loudspeakers the approaches to the solution of only one problem is illustrated – qualitative reproduction of low frequencies – basses. The coordination of rhythmic of parts of the technical system is the basic mechanism of the detected decisions.

How to resolve the contradiction « the volume of the loudspeaker should be big in order to decrease the resonant frequency of the dynamic; and the volume of the loudspeaker should be small in order to place it in premises». All this will be explained in the example of chapter 6 «Law of transition to a super-system (higher-level system)».

Example

In the last century, in many countries, telephone calls of emergency services: firemen, police, medical aid – were carried out using different phone numbers. After understanding that such mismatch leads to time losses, it was offered to call emergency services using one telephone number.

The arrival time of emergency services was decreased. Though, in some cases, it is very important that all services arrive together. The work of all services should be coordinated and they should not disturb each other. Firemen who come earlier than medical men and police men are not able to give first aid to injured persons and can liquidate available proofs. Policy or medical men who come at first are not able to stop the spread of fire and reach the injured persons… It is very important to provide the coordination of arrival of all services.

The new solution appeared to this problem in South Korea. They wanted to coordinate emergency calls and arrivals of all three services to an accident. Thus, cars and the personnel of these services are located in one building, whence they can leave all together.

Example

In many northern countries the traditional material for the building of cottages is logs. The lags were used for the building for centuries and this method is still used in Finland, Sweden, Russia and many other countries. Many old secrets of building have remained till now.

Fig. 3.9. The cottage made of logs (source: www.lesoryb.ru)

Fig. 3.10. The end wood blocks of logs (source Kon Corporation, http://www.dom.kon.ru/)

Logs in rotation round a longitudinal axis were put so that the side of a trunk turned during time of growth of a tree to the north, would appear outside of a building in the construction: annual rings of the North side are thinner, wood from this part is denser, possesses smaller structure and is steadier against influence of natural factors: the sun and moisture.

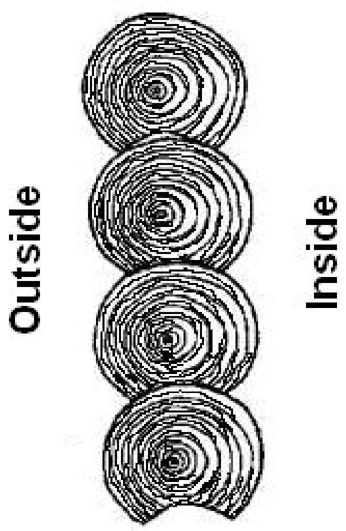


Fig. 3.11. Log's orientation

Fig. 3.12. The ends wood blocks (source: www.lesoryb.ru)

Thus, the log structure in the construction of a house has been made in accordance with natural factors for the purpose of improvement of quality of a structure.

2.3.6 Self Assessment - (Questions, tasks)

Summary.

The coordination of rhythmic of parts of a system is necessary in order the technical system was technically viable, besides the presence of minimum efficient basic parts of the system and the through pass of energy in parts systems.

The basic definitions.

Rhythmic, oscillation frequency, rate, coordination.

Questions:

1. What parts are included in the four element model of a technical system?
2. What are the conditions of the minimum working capacity of a technical system (in accordance with the law of Completeness of parts of a system)?
3. What are the conditions of the minimum working capacity of a technical system (in accordance with the law of Power conductivity of parts of a system)?
4. What are the conditions of the minimum working capacity of a technical system (in accordance with the law of the Coordination of rhythmic of parts of a system)?

Exercises.

Bumpers in cars are intended to damp the force of a blow at collision with an obstacle or with another car. Analyse, whether the parameters of a bumper are co-ordinated with values of the parameters of bumpers of another cars.

Tasks.

1. Protection of medicines from children. It is known that children are very inquisitive and often try to open and to taste things they find. There are things which can not be given to children. For example, medicines must be reliably protected from opening by children, even if they take the medicines. Analyse the technical system of «a jar for medicines with an unscrewing cover» in terms of a through pass of energy. How to break this power link at an attempt to open a jar by children?

2.3.7 References

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2.4 The law of increasing of the degree of Ideality of the system

Public transport has appeared since more than 100 years ago and travel papers such as tickets appeared at the same time. It is possible only to assume how many tons of paper were spent for this short-living technical system...
The announcements, «a mobile phone-ticket, the travel ticket which a person can buy using a mobile phone» have appeared recently in a tram of the city Karlsruhe (Germany, Baden-Wurttemberg). Payment is made by a SMS-message on the phone of the transport company. The SMS-message is the travel ticket. There is any traditional ticket, but the function of the technical system «a travel ticket» is fulfilled. In this case, the function of the ticket is performed by the mobile phone and its facilities.
We have exemplified the extreme case, when the technical system does not only change its parameters to the higher levels, but also disappears, "is dissolved" in another technical system, transfers the function to it. The similar solution in the finance area is already known for a long time. These are "EC-cash". How works the law of increasing of the degree of Ideality of the systems, what are its peculiarities, its tools? We will explain all in this chapter.

2.4.1. Definition

The development of all systems proceeds in the direction of increasing the degree of Ideality.
Altshuller, G. S. (1984). *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems* (A. Williams, Trans.): Gordon and Breach Science Publishers.), p. 227-228.

2.4.2. Theory (Details) to the Law of Increase of Ideality

We use idealised descriptions of real subjects, processes and phenomena – with the help of models in the most different sciences. The minor, insignificant details are dropped in models for the given consideration in order to underline the main features. For example, we do not need the complete set of the constructional documentation of the Eiffel Tower in order to represent one of symbols of Paris. Sometimes, it is enough to draw a silhouette of the tower, made by several lines, or to represent a children's drawing.
The idealised concepts are used not only in models, but in various theories and sciences (physics, mathematics, geometry).
For example: «infinitely remote point», «the ideal thermal machine», «ideal gas», «infinitesimal sizes» and other concepts.
Let's consider a number of the key definitions used in TRIZ and which are connected by the concept of Ideality in detail.

The Basic definitions of Ideality

In our daily practice, we deal with the phenomena and processes for which organisation of work we should spare certain expenses: energy, time, money, etc. We need the reference point, which is unattainable in the reality, but can serve as the standard for the comparison in order to estimate the concrete technical system or the problem solution.
It is possible to explain the concept of Ideality with a fractional example: the maximum effect (E) at the minimum payment (C).

$I = E/C$

The more significant result we receive at the least expenses, the higher Ideality will be achieved. It is the general case. We will consider two special cases: 1. Increase of Ideality at

the fixed expenses by increase in the Effect and 2. Increase of Ideality on the fixed basis of the effect by the reduction of expenses.
When we have the fixed factors of the payment (economic, social, ecological and other aspects), the concept of Ideality reflects the achievement of the maximum possible result. For example, the achievement of the additional effect, which earlier was not expected. The cause of increase of Ideality is often the improvement of parameters in another area. Accordingly, during the solution of the technical problem, the economic, the ecological and the social indicators can be improved as well.
To receive the desirable result using the minimum factors of a payment. The ideal is the zero factors of the payment. (see «Ideal system»).

The Ideal system
The system which performs the function without any expenses, i.e. using the zero factors of the payment (economic, social, ecological and other aspects).

The ideal solution
The Ideal solution is not achievable basically, and is used as a reference point in order to estimate the obtained solutions.
The ideal solution is a solution which does not create any negative effects, no matter how wide we extend the limits of the System Operator (the Multi-screen scheme: the quantity of screens of the Scheme on all axes aspires to infinity).

The use of the Multi-screen scheme.
Usually, during the assessment of the solution, we estimate the potential negative effects of this solution during the analysis of a concrete situation using the multi-screen scheme.
The multi-screen scheme which displays a concrete problematic situation, as a rule, has a limited quantity of screens. First, the quantity of screens is limited by our stereotypes (psychological inertia). Secondly, requirements, inquiries, needs of a concrete situation which contains many subjective factors.
The concept of **the ideal solution**, which was described above, is represented in order to increase the level of objectivity of an estimation of the received solution. Taking into account this definition of the ideal solution, we should avoid at the maximum capacity to use our stereotypes and to estimate the received solution from the different points of view arising at all categories of potentially interested persons in an unlimited historical interval of time.

The most desirable result (MDR) of the solution of a problematic situation
The Most Desirable final Result (MDR) is the maximum explained aim or the system of the aims which we would like to receive as a result of the solution of a problematic situation. (MDR – Most Desirable Result).
According to the axiom of "Impossibility" of General Theory of Powerful Thinking while defining the Most Desirable end result (MDR) we consider that there is nothing impossible which can not be resolved. Though it seems to us that there are limits of possibilities and in this case, we should imagine that we have "a magic wand" which will help us to achieve the impossible results.
The Most Desirable final result (MDR) is an integration of all ideal systems which is necessary in a given problematic situation (see **Ideal system**) and Ideal Final Result (see **IFR**) with the aim of the maximum approach to the ideal solution.
It is necessary to distinguish MDR and the Ideal Solution. MDR is a solution which is represented to us as an ideal one within the limits of stereotypes of a concrete situation in the set interval of time in certain space, with certain resources, i.e. according to an axiom of “the Con-

crete situation» of the classical TRIZ-theory (see the axiom of "the Concrete situation»).
The Most Desirable end result (MDR) is an average concept which is found between Ideal Final Result (IFR) and the Ideal system, on the one side, and the Ideal Solution on the other side. The Ideal Final Result is formulated for one concrete contradiction which is included in the description of this concrete, problematic situation. The ideal system is a description of one of the systems involved in this concrete problematic situation. The Most Desirable end result (MDR) is an integration of our visualisations about the Ideal Final Result (IFR) and Ideal systems in the defined problematic situation. These visualisations are changed and specified in the course of the complex solution of a problematic situation

The note

It is necessary to notice that at early stages of development of TRIZ there was practically no distinction between the Ideal system, the Ideal Final Result (IFR) and the Ideal solution. But in the course of TRIZ evolution, there appeared the necessity to divide these concepts. Therefore, in OTSM-TRIZ, the Ideal Final Result (IFR) and the Ideal system are bricks for the construction of an image of MDR. And the Ideal solution is used to estimate the obtained solutions.
One more function of the Ideal solution is to serve as a tool which is used to overcome psychological inertia. When we have obtained the solution close to or coinciding with MDR, we should try to find parts of the multi-screen scheme where this solution creates or can create a negative effect. We should find these parts of the systematic operator (the Multi-screen scheme) which were not taken into consideration during the construction of an image of MDR. In other words, the model of the Ideal solution helps us to step out the limits designated by an initial problematic situation in the frameworks of which the image of MDR was defined and to look at a situation with eyes of the observers who are located outside of our consideration of the defined problematic situation, and who will react anyhow on our solution.

The Ideal Final Result (IFR)

According to rules of ARIZ-85-C of IFR (the Ideal Final result) which is formulated as the concrete contradiction in which two incompatible requirements, which should be combined as a result of the contradictory solution, are accurately defined. IFR defines the aim and the criteria of an estimation of efficiency of the soluble contradiction. The closer our solution is to IFR, the better it is. Thus, the Ideal Final Result serves as a reference point in the course of work on a problem. That is why in the course of ARIZ- evolution, IFR was developed from one step into the system of steps which G.S.Altshuller named «the Package of IFR»: IFR-1; Strengthened IFR; IFR-2.
In OTSM technologies of « Contradiction » of the Package of IFR has been expanded by additional steps: IFR-2 is divided into the «Partial IFR-2» and the Folded IFR-2.

Each of partial IFR-2 matches the certain Strengthened IFR and also is defined after the corresponding formulations of the physical contradiction (in OTSM – the Contradiction of parameters) at the macro-level and at the micro-level. Thus, each Strengthened IFR matches at least two partial IER-2: on the macro- and on the micro - level.
Each partial IFR-2 is an element of the mosaic, which draws the Folded IFR-2.

2.4.3. Model

The life of the technical system (as well as of other systems, for example, the biological system) can be illustrated with the image of dependency of the main parameters of the system on time. Such model of the technical system in the form of a S-curve (Fig. 5.3.) is widely used in OTSM-TRIZ. The S-curve shows clearly how the main parameters (speed, capacity, productivity, etc.) of the technical system are changed during its life. Each system has its own peculiari-

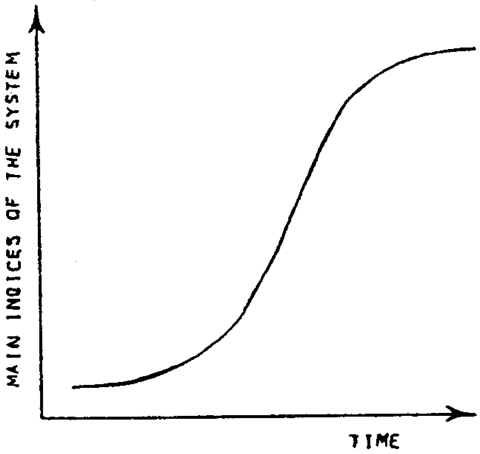


Fig.4.1 S-curve.

ties, its own «portrait» of the S-shaped curve. But there is something common in each «portrait», which is characteristic for all systems. 1 – «Childhood»; 2 – «Maturity»; 3 – «Old age» are such areas.

In the course of development of the technical system its main parameters are increased, the system becomes better, more ideal. It is necessary to construct the scheme of change in time of one of the main indicators of the system, using the patent fund and other sources about the previous development of the analyzed system. Further, using the received S-shaped curve to draw conclusions about that stage of development on which the technical system is found.

There are several stages, steps of increase of Ideality:

- improvement of parameters of a system (1-2 main) at the increase of costs;
- improvement of parameters of a system (1-2 main) at the unchanged costs;
- improvement of parameters of a system (the appearance of new functions) at the increase of costs;
- improvement of parameters of a system (the appearance of new functions) at the unchanged costs;
- improvement of parameters of a system at the decrease of costs;
- improvement of parameters of a system (the appearance of new functions) at the decrease of costs;

The significant decrease of expenses which are used to support the existence of the system and the appearance of new functions, and which extend significantly the application of the system takes place by the complete disappearance (by the rollback) of the technical system, for example, by its connection with another system or its transition to the sub-system with the transfer of its main functions to the new system.

2.4.4. Instruments - Tools (how to use)

The stages of increase of Ideality	The methods of achievement
improvement of parameters of a system at the increase of costs	The intense usage of resourses; engineered methods of the constructional design.
improvement of the main parameters of a system at the unchanged costs	The resourse-saving technologies; optimal solutions; standard resourse-saving solutions.
the appearance of new functions at the increase of costs;	The engineered methods of the constructional design; Value Analysis (at the insignificant increase of expenses)
the appearance of new functions at the unchanged costs;	The engineered methods of the constructional design; Value Analysis
improvement of parameters of a system at the decrease of costs;	Value Analysis, OTSM-TRIZ
the appearance of new functions at the decrease of costs;	Value Analysis, OTSM-TRIZ
The significant decrease of costs which are used to support the existence of the system and the appearance of new functions of the system.	Value Analysis, OTSM-TRIZ;

Tools used to achieve the correct solution: Instrumental laws – the law of the completeness of parts of the system; the law of "energy conductivity"; the law of harmonizing the rhythms of parts of the system.

2.4.5. Examples

Example

Sailors used stars in the sky as the directional orientation for a long time. Any of sailors has reached a star. However, think how many ships have found the harbour, without going astray and how many human lives have been rescued thanks to this directional orientation.

The ideal is not achievable, but only with the orientation towards it; we can move ahead in the right direction.

Example

The raft for transportation of logs is the ideal system. (We will notice that for real systems and solutions we can speak only about Ideality in the comparative degree because the ideal solution is by definition unachievable). Thus, it is possible to assert that a raft made of cargo – transported logs, is the more ideal solution, than the transport vessel transporting the cargo of logs.
But the world is weaved from contradictions. And we can notice that transported logs on a vessel remain dry in comparison with the raft logs. Hence, other parameter – safety of a cargo has the smaller value. There appears a new problem...

Example

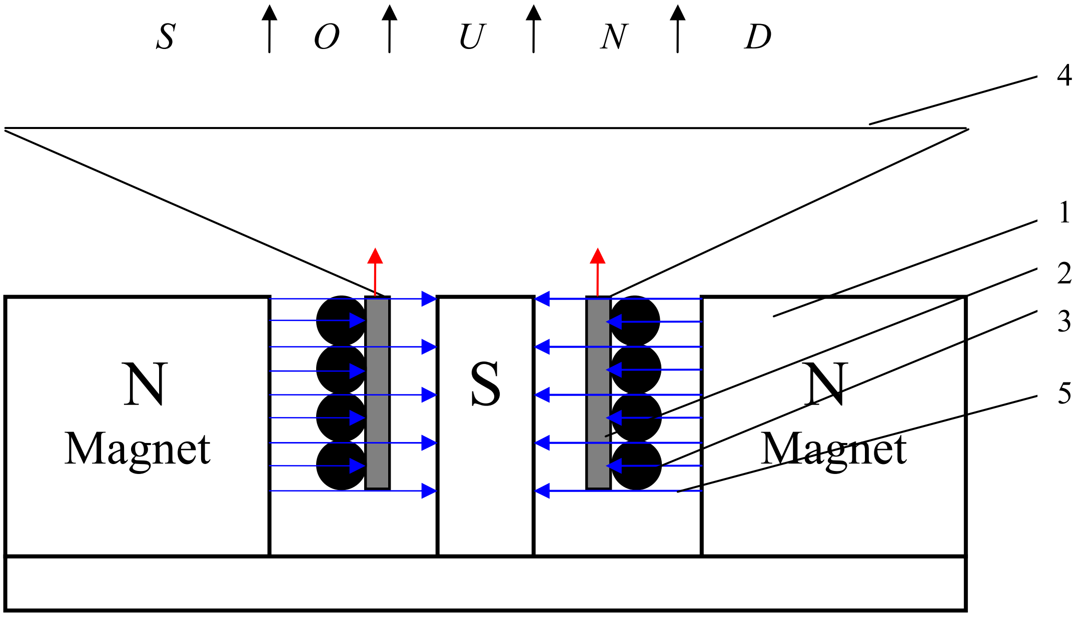
Each kilogramme of the cargo is highly prized in a spaceship put into the Earths orbit. It is not an exaggeration. Really, in order to launch a kilogramme of the cargo into the orbit the Earth, it is necessary to spend means, which are comparable with the cost of one kilogramme of gold.
At the end of the 20^{th} century it was offered to make separate elements of interior decoration of a cabin of a spaceship of the pressed foodstuff. In emergency, when there will be any foodstuff it is possible to use parts of an armchair or an internal wall of the ship as food.

Example

It is necessary to have enough fuel supply at distant space flights. How to provide the ship movement without any fuel? The spaceship trajectory is calculated in such a way that it is possible to use the gravitational pull of various planets. Fuel is not present, but the function «to Move a spaceship from one point of space to another» is performed.

Example

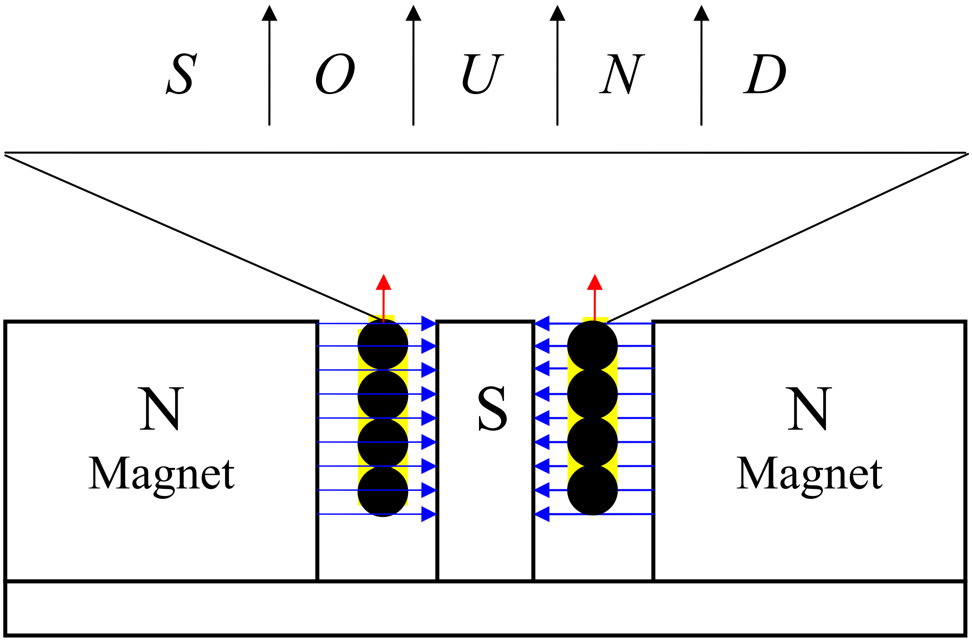
Bellow, the fourth figure illustrates the cut (cross section) of a magnetic chain of a loud-speaker.



The figure includes:
1 – Magnet
2 – Coil assembly
3 – Coil laps
4 – Diffuser
5 – Lines of source of a magnetic field

The coil with a conductor, which is located in a magnetic field, are "Engine", the converter of energy of electric and magnetic fields in mechanical fluctuations of a diffuser and then of air. Earlier (chapter 2, an example 2.2, the task at the end of the paragraph), we already discussed a magnetic chain of a loudspeaker.
Usually the coil of a loudspeaker is reeled up on the special cardboard or plastic case and is installed between magnets. What is the function of the case of the coil? The case of the coil keeps the coils of the conductor in the centre of a magnetic chain of a loudspeaker, between poles of magnets. According to the earlier exemplified rules (see Chapter 1 "The law of the completeness of parts of the system" à "How to determine function of the technical system correctly") we will specify the formulation: «to compensate the action of elastic forces of laps of the coil and forces of gravitation on change of the location of the coil».
However, the case of a coil leads to undesirable effects. First, it brings losses of a magnetic stream. It occupies the small, defined place in an opening between magnets. And the more the distance between magnets is, the weaker a magnetic stream will be, and therefore, the capacity of a loudspeaker will be weaker as well.
Secondly, the most undesirable effect is worse of cooling of a conductor of the coil. In powerful loudspeakers, the big current proceeds through the coil, it is heated up strongly and can be fused. In these conditions it is important to blow a coil with air from different directions in order to cool it. But the case of the coil made from electrically insulating material serves as a heat insulator, which prevents from cooling a conductor of the coil.

What is the ideal case of the coil? This is the case which fulfils the specified function, but does not take a place. The expenses for its manufacturing aspire to zero. To say it differently, the case which is not present, but the function is performed.



The coils without frames were created in which laps are fixed by special glue-compound. It is necessary to notice that in the old system the prototype of the compound existed already – laps of a coil were covered with lacquer in order to achieve the high resistance and the protection of a surface against the mechanical damages. But its resistance was insufficient to fix laps of a coil in the defined condition without the case of a coil. Besides, the problem of the positive and negative effects, which are made by the case of the coil, has not been discussed and described and as a consequence of it, it was solved only some time ago.

Example

The dynamo-machine on a bicycle is usually installed in the form of the separate device. Mechanical energy of rotation of a wheel is transferred to a dynamo-machine by the contact of a castor of a dynamo-machine with a surface of a wheel of a bicycle. For the achievement of higher parameters of a system of illumination of a bicycle (brightness of illumination and thus, the capacity of a bulb, electric capacity) a more powerful dynamo-machine is necessary. The mechanical contact of a surface of a wheel and a castor of the dynamo-machine is based on a friction and it transfers its fource with great effort to a more powerful dynamo-machine. The development of the system of illumination and the bicycle alarm system was constrained by the construction of a dynamo-machine based on the transfer of mechanical energy by means of friction during the direct contact of a dynamo-machine with a surface of a wheel.

In latest models of bicycles there were the dynamo-machines which have been installed in an axis of a back wheel. The axis of a wheel with the magnets which are located on it serves simultaneously as a rotor of a dynamo-machine. Transmission – a castor of a dynamo-machine and a surface of a wheel of a bicycle has disappeared because it was superfluous. The friction losses by the transfer of mechanical energy have disappeared after this. In such cases, we say that the system became more ideal.

2.4.6 Self Assessment - (Questions, tasks)

Summary.

The peculiarities of existence of technical systems at a stage of their development (at the second and the third stage of an S-curve) are described by the following law.

Development of all systems goes in a direction of increase in Ideality. It includes many various mechanisms and consists of several stages. At first, it includes the increase in the key parameters, then, the decrease in a payment for performance of a function and the appearance of new functions. And a final stage – the connection with another system and the transfer of the function to this system or the performance of functions of another system.

The Basic definitions.

Ideality; Ideal system; Ideal solution; MDR – Most Desirable Result; Ideal Final Result (IFR).

Questions:

1. How we define the concept of Ideality?
2. How we define the concept of the Ideal System?
3. What solution is an Ideal one?
4. What is the difference between the Most Desirable Result and the Ideal Final Result solution?

How we define the concept of the Ideal Final Result?

2.4.7 References

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See also:
2.7 The law of the transition from the macro to the micro level

2.5 Law of uneven development of a system's parts

I am writing these lines in a new high-speed train TGV, crossing back and forth Europe at a speed of 350 km/hour. The speed is amazing, but with a high degree of probability it is possible to state that it lies next to the limit of a wheel-rail type of transport.
What was the most difficult problem while constructing such train? More powerful engines, the construction of a new railway track, a more advanced braking system? Yes, partly these challenges too. However, according to developers, the most challenging was …a current collector.
In a TGV train the current collector bears a strong outward resemblance to the construction of current collectors in common trains. In the given paper we do not tell you about technological solutions applied in a TGV train.
We point out the most important issues in this example. During the life of any technical system (TS) its parts undergo an uneven development. Firstly, in every time period TS parts have a different level of development. Secondly, changes in the parts of a system take place not evenly, but in the form of an avalanche. There is always a part that holds back TS from its further advancing and increasing of its main parameters. It is this part («bottle neck») that gives rise to sharp contradictions. Thus, it is of great significance to determine this part.

Fig. 5.1 New high speed train TGV

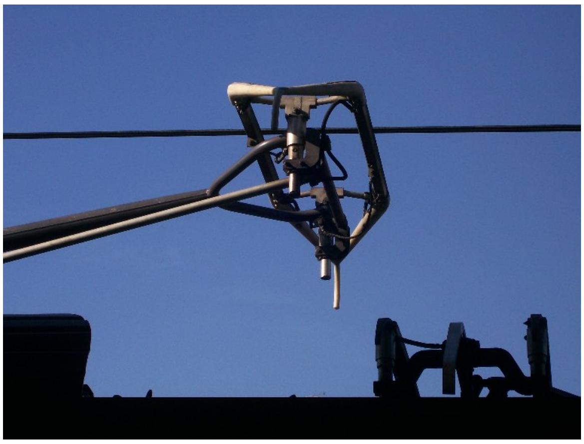


Fig. 5.2. Current collector of a train TGV

In the history of train development there were various factors that acted as restraining force in achieving necessary parameters (speed, length and weight of a train set, braking distance ...). The power of a steam engine gradually grew until it came into conflict with the quality of a rail track. Some years later technological achievements in the field of metallurgy have allowed creating more durable, lengthy and rather inexpensive rails for mass production. As a result, the technology of railing was responsible for a quality of a track and of a multi-branch network. Trains became quicker, transported more cargoes and connected remote towns. But the engine was not able to provide necessary power to reach the speed that a new track could allow.
The last «breakthrough» for a steam engine was the transition to a more power-producing, valuable fuel: petroleum products were used instead of coil. Surely, the engine was changed too – a higher steam pressure was necessary in order to produce more power. For that purpose,

a more durable (and heavier!) engine was required. The further increase of the main train parameters became possible with the transition to a new type of engine, i.e. an electrical engine.

Thus, while solving practical tasks and forecasting technological development it is very important to define correctly «a bottleneck» in parts of a TS. Furthermore, it is necessary to identify existing contradictions and direct efforts towards the continuous improvement of exactly this part.

2.5.1. Definition

The development of a system's parts proceeds unevenly; the more complicated the system, the more uneven the development of its parts is.
Altshuller, G. S. (1984). *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems* (A. Williams, Trans.): Gordon and Breach Science Publishers.), p. 229.

2.5.2. Theory (Details)

The law belongs to the group «Kinematics», i.e. for advanced TSs that are on the second and third stages of developments. (See S-shaped curve).
We know that on the birth stage of a new TS, the technical system must contain minimally working main parts for a minimal working capacity. Besides, there must be power conductivity between TS parts as well as between the control body and TS parts. A rhythmic of TS parts must be coordinated in order to further develop a TS and to improve its parameters. It concerns primarily recreated technical systems which are on the first development stage (see S-shaped curve).
With development, the parts of TS undergo modification according to the changing demands of man and environment. TS includes component parts of a different development level on various stages of its life. These inconsistencies can be described with the help of contradictions. Especially, sharp contradictions arise in the «weakest» part of a system, in a «bottle neck».
One of the reasons for the inequality of system parts development is restricted resources. In the first place it is material resources as well as time for development, implementation and entrance to the market. Besides, substantial restrictions at this stage are usually introduced by available resources of methods of task solutions.

Typical mistake:
Very often the improvement of TS begins with... an easily changing part of a system. Especially, it is typical for complicated tasks on overcoming problems in the weakest part. One of the reasons for this phenomenon is restricted possibilities of traditional methods of problem solution.

The falsity of this approach is very brightly underlined in the following joke.
A walking gentleman is looking for something on the pavement under a street lamp. The following dialogue takes place between a policeman and the gentleman.
- Sir, can I help you?
- Yes, I've lost my keys from my flat.
- Do you remember the place where you have lost them?
- Certainly, over there, near to my car... (shows at the car standing nearby)
- And why are you searching for them here, under a street lamp?
- It is lighter here!

We are laughing at this gentleman, but often act in the same way while improving technical systems...
And only after we completely exhausted all development resources of other parts of a system, we come back to our «bottle neck».

If we continue the illustration of the example with development of a TS «train», we will point out the following. To advance a TS, it is important to correctly formulate a function. That also means to define the variation limits of a TS. In case with a train TGV the limits were established in such a way that changes did not concern with the principle «wheel-rail». But exactly the part «wheel-rail» of the system «train» is a «bottleneck».

Remark:
The next development stage of the train is a train on the electromagnetic plate. In the construction of such train the transition from the pair „wheel-rail" (macro level) to the electromagnetic interaction (micro level) is made. A current collector underwent some changes too – there is no sliding contact „current collector-conductor" any more. The function of energy transmission is performed by means of electromagnetic field.
(More detailed information about the next development stage of the train and the development law of technical systems that forms the basis of that stage can be found in 7 Chapter, Example 7.5).

2.5.3. Model
S-shaped curve
The life of a technical system (like the life of other systems, e.g., biological systems) can be described in the form of dependency of a system's main parameters on time. Such model of TS development in the form of a S-shaped curve (Fig. 5.3.) is widely used in OTSM-TRIZ. The curve demonstrates how TS and its main parameters change during its life (speed, power, efficiency and so on). Every system has its peculiarities, its own «portrait» of a S-shaped curve. But every «portrait» has something common, typical for all systems. Such segments are 1 – «Childhood»; 2 – «Maturity»; 3 – «Old age».
It should be pointed out that the development of the whole TS occurs unevenly due to the unequal development of its parts.
In the «Childhood» (Segment 1) a technical system develops slowly. As a rule, this development stage coincides with the stage of «Maturity» or «Old age» of its system-predecessor (Fig. 5.4.). A new system is weak yet; its main parameters can be worse than the parameters of the old system. There is lack of resources for the development of a young system. But a new operating principle has a significant potential.
The existence of an old system holds back the appearance of young „competitors". And only after an old system is gone, a rapid development of a new system begins (the bending point **a**). The stage «Maturity» comes in (Segment 2).
From some moment (the bending point **b**) the development rates decline and the stage «Old age» begins (Segment 3). A new, young TS is ready to come. After the point **g** a technical system is changed by a new one or maintains the reached indicators for a long time (e.g. a bicycle).

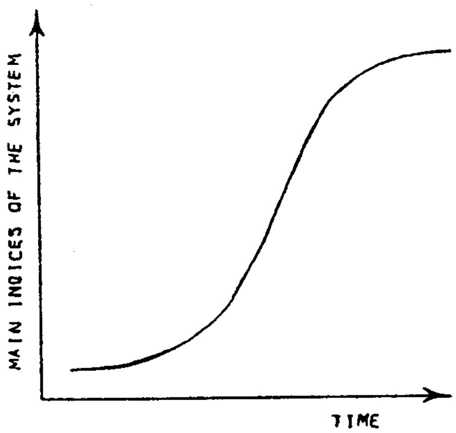
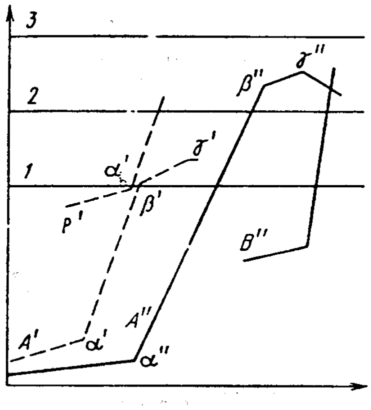


Fig. 5.3. S-curve. (See: Altshuller, G. S. (1984). *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems* (A. Williams, Trans.): Gordon and Breach Science Publishers.) Pages: 205-216)



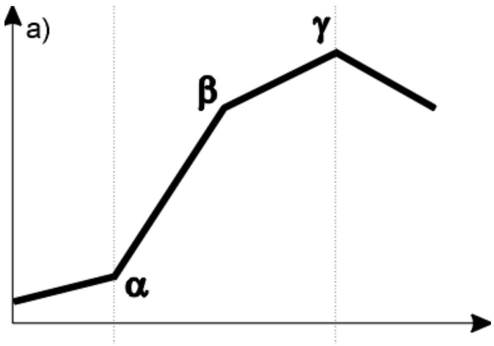


Fig. 5.4. *Fig. 5.5. Performance – Utilization*
(See:Altshuller G.S. (1979). Creativity as an Exact Science. Sovietskoe radio, Moscow. pages: 113-119).

In the course of its development TS is the subject of constant changes. Materials are changed, some parts are replaced by others, more advanced parts. The life line of a specific technical system can be presented in the form of a number of S-shaped curves that constitute TS (Modis, 1994).

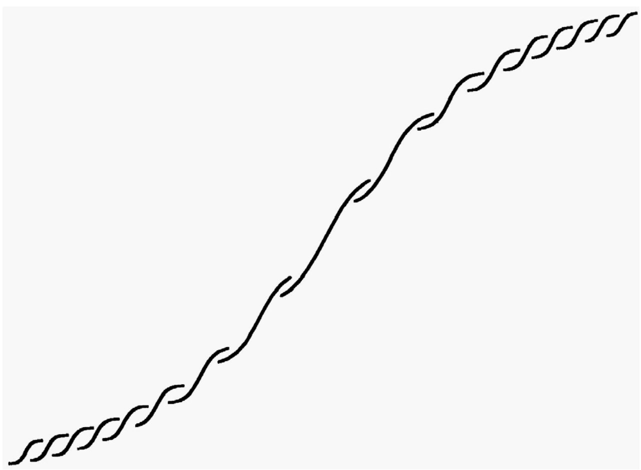


Fig. 5.6. S-curve, consisting of other S-curves representing subsystems.
The horizontal axis represents time.

The development of TS occurs unevenly in many aspects. Several of them are pointed out below:
- TS have different development rates at various stages of its life;
- subsystems that are parts of TS have a different development level in any randomly chosen moment of life time of TS;
- subsystems have different time of life;
- development rates of TS even during one stage of its life are not even;
- a temporal revival of old subsystems is possible, which were excluded before under new conditions;

2.5.4. Instruments - Tools (how to use)

2.5.4.1. Development laws and their tools

It is necessary

to build a model of TS consisting of 4 elements. (see Chapter 1).

to analyze TS for power conducting capacity (see Chapter 2) as well as for matching (or mismatching – in dependence on the function required by us) rhythmic of a system (see Chapter 3).

to compare the whole system and every part of it with the perfect system (see Chapter 4).

During the preliminary analysis contradictions characterizing various parts of TS will be identified. It is necessary to evaluate what contradiction is the most limiting one. For example, in terms of a number of undesirable effects and of contradictions (in the context of the performance of the function chosen by us).

2.5.4.2. S-shaped curve

While solving practical tasks and forecasting the development of technical systems it is crucial to build correctly the «portrait» of the analyzed TS. It is important to know the development reserves of the given TS**.** It is necessary to build a chart of changes in time of one of the main system's indicators using a patent file and other sources about the previous development of a system which is to be analyzed. Furthermore, conclusions about the development stage in which TS is currently situated are to be drawn using the gained S-shaped curve.

2.5.4.3. Building of a network of problems and analysis of its structure

During the description of the current state of things in regard to TS to be analyzed, a network of problems is to be built (see Section ...). The network of problems includes problems and their partial solutions as well as their interconnections. The structure of a network of problems gives information about the uneven development both of the whole system and of the "bottlenecks".

2.5.5. Example

Example

Listening to music was common at all times... In the middle of the last century sound-reproducing equipment saw a further development. Especially, electronic amplifiers were actively developed. In our opinion, the reason for this phenomenon lay in wide possibilities of resources, i.e. electronic base. During several decades of the last century the world witnessed two generations of electronic bases. Electronic lamps were replaced by transistors; transistors were followed by integrated microcircuits. This and other modern technologies allowed improving the sound quality, increasing mass production and making prices more moderate.
Loud-speakers were progressing not so actively. Their main parameters came into contradictions with man's needs to have a more qualitative sound-reproduction, on the one hand and with the possibilities of electronic base, on the other hand. Sound carriers (recording tape, radio

signal, vinyl gramophone records, etc.) as well as electronic amplifiers made it possible to increase the sound quality. Loud-speakers were exactly the «bottleneck» holding back the overall development of the sound-reproducing equipment.
Back to the middle of the last century amplifiers for sound reproduction which had nonlinear distortions of less than 0, 5% at the power of 50 W were produced. It is very good parameter. But a loud-speaker connected to such an amplifier enhanced distortions by 10-20 times! However, amplifiers kept on progressing thanks to the development of electronics. Scientific and engineering journals, exhibition stands and shops received new models of electronic equipment, whose wide possibilities remained practically useless without improving loud-speakers.
«The bottleneck» of a loud-speaker is a flexible suspension responsible for the reproduction of multi-frequency. At that time nearly everything possible was „extracted" from materials.
Besides, a further increase of its flexibility and mildness lead to a contradiction… To solve this contradiction a transition to a new system was necessary.
The problem solution: see Chapter 6: The law of transition to the supersystem. (Example 6.13)

Example
Take a close look at the growth of any plant coming from the ground. As a rule, it has two large leaves. Leaves are not proportionally large compared to the seed itself and a plant's stem. Under the ground the situation with a root system is the same. The reason is that a plant vitally needs solar energy and nutritive substances. In the course of development, other parts of a plant increase their growth rates and sizes compared to the initial ones.

Example
The form of a child can be very well recognised even on a child's drawing: a human's body with an unproportional big head, short arms and legs.
A human body develops unevenly too.
- in the first 10 years of life a human experiences 70% of growth (the height of man);
in the first 3 years of life a human receives 70% of absorbed information.

Example
The development of social systems has an uneven character. Anatole France, the greatest France writer and publisher noticed very subtly and sharp-wittedly: „In a slow and well coordinated progress of a mankind the beginning of a caravan had already entered the shining fields of the science, when the tail was lagging behind among the heavy fog of superstitions, in dark land full of spirits and ghosts. Yes, you are right citizens if you go to the head of a caravan!.."

2.5.6. Self Assessment - (Questions, tasks)

Resume
With the development of TS in time, TS undergoes some changes. Some subsystems are replaced by others, more efficient under certain conditions. External conditions, man demands change too. These changes accumulate, generate new conflicts between the parts of a system, other systems in the course of their practical use and improvement by man and provide new development possibilities.
This development does not occur evenly in time. Some parts of a system have the best parameters, others act as restraining force for the system's general development. Besides, meanings of the main parameters (that provide the performing of the TS functions) are also subject to ***uneven*** change in time.

The Basic definitions.
Technical system (TS); ENV-model; element; name of a parameter; meaning of a parameter.

Questions:

1. How is the development inequality of a system's parts expressed?
2. For what development stage of systems this law is more characteristic?
3. Is it possible to forecast the position of the point **a**) on the curve of the given technical system only on the basis of potential possibilities of TS itself, without taking into account the state of the preceding TS?
4. How does the complexity of a technical system affect the inequality of its development?

   1. With development, the parts of TS undergo modification according to the changing demands of man and environment. TS includes component parts of a different development level on various stages of its life. These inconsistencies can be described with the help of contradictions. Especially, sharp contradictions arise in the «weakest» part of a system, in a «bottle neck». (Theory (Details), page 1)
   2. The law belongs to the group «Kinematics», i.e. for advanced TSs that are on the second and third stages of developments. (See S-shaped curve). (Theory (Details), page 1)
   3. The existence of an old system holds back the appearance of young „competitors". And only after an old system is gone, a rapid development of a new system begins (the bending point **a**). The stage «Maturity» comes in (Segment 2). (S-shape curve)
   4. The development of parts of a system proceeds unevenly; the more complicated the system, the more uneven the development of its parts. (Defenition)

2.5.7 References

Altshuller, G. S. Creativity as an exact science. — M.: Soviet Radio, 1979. (Russian), Page 126.

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See also:
2.5 Law of uneven development of a system's parts

2.6 The law of transition to a super-system

If you ever happened to drink a hot, burning hot tea or coffee with the temperature of 65°C, you will hardly believe in the following fact.
The journal *Science* informed about a heat-resistant grass growing near to hot geothermal sources in Yellow Stone National Park (USA). The grass feels comfortable on the ground with the temperature of 65°C.
The researches conducted by biologists resulted in the discovery of a rare example of triple symbiosis in nature: a plant, a mushroom and a virus unite together in three in order to resist high temperatures.
In nature there are known cases of symbiosis, when plants or organisms group together, accommodate and support each other in order to survive.
The phenomenon of symbiosis, combination of various systems is also known in technology. Certainly, a direct transmission of the given phenomena from biological systems to technical ones would not be correct. However, it is curious to analyze some general regularity.

2.6.1. Definition

Having exhausted all development possibilities, a system is included in a supersystem as one of its parts; in doing so further development takes place at supersystem level.
Altshuller, G. S. (1984). *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems* (A. Williams, Trans.): Gordon and Breach Science Publishers.), p. 229.

2.6.2. Theory (Details)

The law belongs to the group «Kinematics», i.e. the law is applicable for TS that are at the third stage of development (see S-shaped curve).
One of the ways of a system's further development which lies in the point **b** or **g** on a S-shaped curve (see Fig. 6.2.) is unification of systems. Thereby, unification of systems can occur earlier, on the segment 2, before the point **b** is reached. Such unification is possible in cases when there is at least one parameter which does not satisfy a user. Besides, it is necessary to perform a function in order to change this parameter; parts of another system can serve as resources of development.
A typical development chain of the line «mono-bi-poly» is described in the TRIZ literature. The initial system groups together with a system of the same type, of similar type, of different type or with an inverted system (with the opposite meaning of the function). The character of unification depends on the type of the required function. One of the main conditions of unification from the point of view of TRIZ is emergence of a new quality.

2.6.3. Model

S-shaped curve (see Chapter 5).
It is necessary to build a chart representing a time change of one of the system's main indicators. Thereby, we can use patent fond and other sources that reveal the preceding development of a system to be analyzed. Furthermore, with the help of a received S-shaped curve it is possible to draw conclusions about the stage of development on which TS is situated at the given moment.

If results of the analysis show that TS is near to the point **b** or to the point **g** and there is a further necessity to increase the main parameters, it is necessary to define a new technical system that must change an existing one. One of such systems change is transmission of existing TS to the composition of a new, more advanced system.
A combination of systems can take place at any stage of development. It is necessary to define the required function of a system.

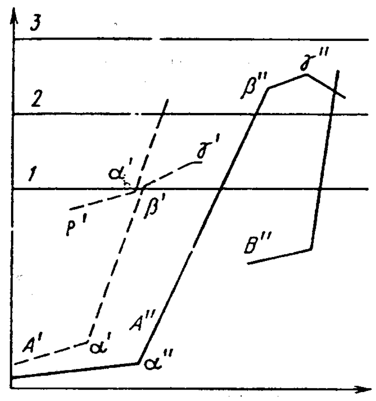

Fig. 6.2

2.6.4. Instruments - Tools (how to use)

Example
So, by combining two knives, mankind invented principally a new cutting tool: scissors.
Instruments of solution: Tools of laws – the law of fullness of system’s parts; the law of power conductivity; the law of rhythmic adjustment.

Example
Just by putting some pencils of the same type on the table, we do not receive a new system or a new quality. However, we can change one of the parameters: time of writing without extra sharpening a pencil, but replacing e.g. a blunt pencil by a new one while writing. Thus, we perform a new function.
Ordinarily, when we put several pencils with the different thickness of a pin on the table in front of us, we can change one of the parameters – a period of writing without any additional sharpening of a pencil (a change from one pencil to another, from a blunt pencil to a sharpened one in the process of writing). And that means that we can provide the fulfilment of a new function: to write letters on a sheet of paper without any pauses used for the sharpening of a pencil.
Instruments of solution: transition monosystem-polysystem with characteristics of the same type.

Example
Another way of combining writing tools was used by Leonardo de Vinci who created the device which made copies. Two writing pins made of lead were bounded on the ends of «flyer» in the form of a letter «Y» with a common pen. While writing a text with such a double pencil, an author received two copies of a document at the same time. (However, a secretary had to write on narrow stripes of paper; the width of which was limited by the space between the branches of a letter «Y»).
Instruments of solution: transition mono-system – bi-system with characteristics of the same type.

Example
As it was already pointed out, systems with slightly differentiating characteristics can be grouped together. In TRIZ they are called „systems with adapted characteristics“. To make notes with pencils of different colours for the purpose of convenience, two pencils - on the one hand, a red pencil and a blue pencil, on the other hand - were combined in one.
Instruments of solution: transition mono-system – bi-system with dislocated characteristics.

Example
Systems with inverse characteristics can be grouped together too. One function «To leave a footprint on the surface» can combine with an inverse function «to remove a footprint on the surface». This can be a combination of a pencil with an eraser or a pen with a correction fluid.
Instruments of solution: transition mono-system – bi-system with inverse characteristics.

Example
Several systems can group together in one system. We know such systems. The example of such a system is a pen with several writing pins of different colours.
Instruments of solution: transition mono-system – bi-system with dislocated characteristics, convolution.

Example
Further development of a system which entered into another system takes place on the level of the whole system. As a system develops, the degree of ideality grows. One of the ways of such process is exclusion of parts duplicating each other from the system. Thus, only one common frame remained while grouping together several coloured pencils into one writing tool since frames of every pencil were left out because of uselessness. In OTSM-TRIZ such operation is called «convolution».
Instruments of solution: Convolution

Example
Further development of a system can take place with the rolling-up of writing tools. So, to draw lines of different thickness it is necessary to have a set of several pins in one frame. We know a carpenters' pencil with a lead of a square section. Such pencil can make either thin lines when using a narrow side of a lead or wide lines when using another side of a lead.
Instruments of solution: Convolution; geometric effect.

Example
A marker with a section of a writing pin in the form of ellipse was suggested. Such marker can be used to draw lines of different thickness – from a small to a large diameter of ellipse. Thereby, thickness of a line can be changed without taking away a marker from the paper. It is sufficient to turn a marker around its axis.
Instruments of solution: Convolution; geometric effect.

2.6.5. Example Loud speakers

Example
Two or three loud-speakers are placed into the frame of a loud-reproducing device or a sound column in order to extend the range of reproducible frequencies. One of the loud-speakers reproduces low frequencies (basses) well, but badly high frequencies. Another loud-speaker, on the contrary, badly transfers low frequencies, but instead reproduces high frequencies well. However, the solution to place several loud-speakers into the frame of a loud-reproducing device has a substantial disadvantage: it requires much additional space and volume. Devices equipped with two and three loud-speakers have a large weight.
The inventor Shifman suggested a loud-speaker that combines two different devices in itself: high-frequency and low-frequency of loud-speakers. It has one magnetic system, one frame, but two coils and two diffusers. Diffusers are located concentrically, i.e. one diffuser inside of another diffuser. In TRIZ such solution is called a bi-system.

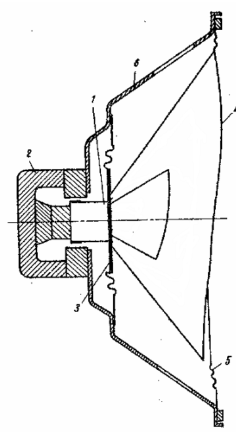

Fig. 6.3

Example

Every loud-speaker that constitutes a bi-system in the previous example has its own range of frequency reproduction. We can go further, following the regularity «mono-bi-poly» and coaxially place not two, but three diffusers into one frame. But in this case the construction of the whole device as well as the manufacturing technique will become substantially complicated. It is a rather difficult technical task to manufacture separately and coaxially set up several different cone-diffusers and several coils located coaxially.

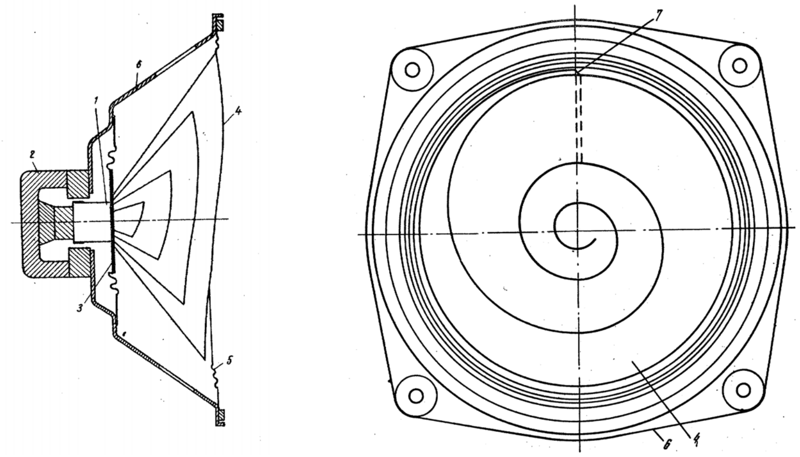

Fig. 6.4.

The inventor G.I. Gelfenstein elaborated a loud-speaker with 3-4 diffusers and one coil. The number of diffusers can be increased. A diffuser is made in the form of an Archimedes spiral with a required amount of whorls and one coil. Every whorl serves as a separate diffuser-transmitter of sound. Every whorl exists on its own and simultaneously constitutes one single system. A whorl-diffuser has its own mass and elasticity and that means it its own certain frequency characteristics.

When an electrical signal of a certain frequency is transmitted to the coil, whorls-diffusers corresponding to this frequency according to their characteristics begin vibrating. In other words, diffusers turn on at the frequency fed to the coil by THEMSELVES. So, when low frequencies (basses) are fed, the whole diffuser consisting of several whorls will begin vibrating as single system. The higher the fed frequency of a signal is, the smaller number of whorls will be brought into vibrations. At high frequencies only the centring part of whorls will send out a sound, the remaining part of a diffuser will not respond to «unfamiliar» frequencies and remains unmoved.

In TRIZ such solution of combining several systems of the same type is called a convoluted poly-system.

Example

Not only one loud-speaker can be grouped together with another one as it was described in previous examples. A loud-speaker can be combined with…emptiness. However, this emptiness is deceiving since the air has a mass.

And that means that it has also its own elasticity.

A loud-speaker is one of the subsystems of many devices for sound reproduction. It is established in radio receivers, tape-recorders, TV-sets... The frame of every of these devices has its own volume.

The first stage of combination with a supersystem, i.e. with the frame of a device (a radio receiver, a TV-set) is a simple mechanical combination. The frame combined and comprised all subsystems: a mechanical part, an electrical device and an acoustic system.

The second stage: air volume «worked» for a loud-speaker but was not adjusted with it.
The third stage: to adjust air volume of an acoustic system with a loud-speaker in order to reach higher values of the main parameters. (for more details see the following example)

Example

To extend the range of reproducible frequencies loud-speakers were placed in closed boxes of a large volume, i.e. column speakers. Such technical solution enables to substantially reduce the low border of a reproducible range and improve reproduction of basses.
However, there arises another contradiction. «The volume of a column speaker must be large enough to reduce the resonating frequency of an acoustic system; and the volume of a column speaker must be small enough to be able to conveniently place it in rooms». This problem lies on the surface. However, as it was already pointed out the main problem is unlinear distortions which the vibrating system of a loud-speaker introduces. We consider the described situation in a quite simplified way. To understand a dramatic nature of the situation in which acousticians found themselves, we have to describe it in the form of a network of problems.
Nevertheless, the inventor Vilchur chose intuitively the main contradiction. The vibrating system of a column speaker, i.e. a centring plate and flute is nothing else like a spring. Any spring at the sufficient amplitude of vibrations is a nonlinear element which is responsible for sound distortions.
Thus, «a spring is necessary to perform vibrations; and no spring is necessary to exclude nonlinear distortions».

Note:
The example is interesting since it shows several laws.

- The Law of transition to a micro-level: replacement of a mechanical spring by an air one;
- The Law of ideality increase: an air spring is more ideal and has a smaller nonlinearity than a mechanical spring;
- The Law of transition to a supersystem: combination of a loud-speaker with an internal air volume of a sound column.
- The Law of rhythmic adjustment: adjustment of the resonating frequency of a loud-speaker and the air volume of a box.

IER (Ideal End Result): There is no spring-vibrating system, but the function to perform vibrations is retained. Vilchur replaced the part of the vibrating system of a loud-speaker, i.e. mechanical suspension by an air spring. An improved loud-speaker had a very soft vibrating system with a maximum possible resonating frequency. However, it did not function properly when it was separated from a sound column. Its suspension (a centring plate and flute) was so soft that required additional support to be able to maintain a normal position. Such support, i.e. the main spring was the internal volume of air inside of a sound column. Being placed in the sound column, such loudspeaker created new TS together with a sound column, i.e. a vibrating system that had desired characteristics: a low resonating frequency and large amplitude of vibrations (and acoustic pressure).

2.6.6 Self Assessment - (Questions, tasks)

Resume.

The law of transition to a supersystem belongs to a TS that has exhausted all possibilities of its development. Under these conditions the next stage of a system's development is its transition to a supersystem as one of its parts. Further existence and development of a system takes place on the supersystem level.

The Basic definitions.

System, super-system, subsystem, symbiosis; rolling-up, mono-system; bi-system; poly-system.

Questions:

How is the law of transition to a super-system expressed?
For what development stage of technical systems this law is more characteristic?
Give some examples which illustrate the law of transition?

2.6.7 References

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2.7 The law of the transition from the macro to the micro level

What are the reasons of the appearance of earthquakes on the Earth?
One theory dominates in the scientific world, which explains the origin of earthquakes as a result of the collision of tectonic plates. According to the theory of tectonic plates the surface of the Earth (the Earth's crust) is divided approximately into 20 separate pieces named plates. Their thickness is approximately 70 kilometres. Under the influence of the processes occurring inside of the Earth, plates move. Movements are insignificant, but cause very big mechanical pressure on the Earth's crust, and as consequence – earthquakes. However, as a result of seismic observations, the incredible facts have been observed.

Fact 1: When some earthquakes took place, tectonic plates did not collide with each other, but dispersed into different directions.

The fact 2: in accordance with the results of the analysis of some seismic waves, the conclusion has been drawn that the tectonic plate moves in opposite directions, whereas it is known from other observations that it represents a unified whole and does not consist of smaller parts.

The fact 3: sources of some earthquakes are not located in the place, where the collision of tectonic plates takes place – not on their borders, but they are found inside of a plate block.
The easiest way of solving this problem is to wave away from the contradictory facts and to realize that there were wrong observations and calculations... Actually, it is a signal that the recognised theory has approached to its limit behind which it does not work any more. It is a signal to create a new theory.

The macro-objects- tectonic plates were considered to be the «Tool» of generated earthquakes in the old theory. A number of researchers had suggested a hypothesis about the possibility of the generation of earthquakes as a result of complex interactions of oscillations in the structure of the Earth – mechanical waves. According to the new theory the micro-objects can serve as the "Tool" which causes earthquakes. These micro objects are oscillations of particles of the Earth's crust which are described by various types of waves.
On the basis of the contradictory facts which were received during the observation and in terms of the suggested hypothesis the new theory is developed- the wave theory which explains the causes of earthquakes.
The special type of the mechanical oscillations has been already determined – stationary waves, which are responsible for earthquakes without the collision of tectonic plates in every spot of the Earth.
The European model of waves which deals with the structure of the Earth is developed and the global model will be developed in the perspective.
We can draw many striking conclusions from this theory. One of them – tools of technical systems are transited from the macro to the micro level in the course of its evolution. It often refers to our visualization about the world – models of different processes and phenomena. A human-being gets closer to the mechanism of Nature in the course of learning.

2.7.1. Definition

The development of working organs ("Tools") proceeds at first at macro and then, at a micro level.
Altshuller, G. S. (1984). *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems* (A. Williams, Trans.): Gordon and Breach Science Publishers.), p. 230

2.7.2. Theory (Details)

In the majority of the modern technical systems the working device (Tool) is «pieces of iron», parts in the form of micro-objects, which reminds often the hands of a human-being.
The Tool is changed at first – as a result of the new necessity to perform the new function.
As a rule, the mechanism of the Law of transition from the macro to the micro level can be used to solve the contradictions of the Tool. So, at transition of the Tool to micro-level the space and the volume occupied by the Tool and the technical system decreases; its efficiency increases; its multifunctionality increases.
This transition is often performed by the new principle of the work, by the new physical, chemical, geometrical effect or by the phenomenon. For this reason the practice of the application of the law is closely connected with other tools and technologies OTSM - TRIZ: ARIZ, Standards, Methods, the Multiscreen scheme and others.

2.7.3. Model

The models which illustrate the law of the transition from the macro level to the micro level include the following elements:

- the multi-screen scheme;
- S-shaped curve;
- the line of development of «the mono-bi-poly chain»**;**
- the list of typical fields which are used in the technical system;
- a split chain of substance;
- and others.

Let us illustrate one of them – a split chain of substance.
There appear the following stages of development in the course of evolution of a part of the technical system:
1. a monolithic system;
2. a system with a joint;
3. a flexible construction;
4. particles; small particles (fine particles); granular materials;
5. molecular aggregates, molecule, atoms, ions;
6. elementary particles,
7. a field.

This model of development has a generalised character. The stages of development are illustrated in the close view. If necessary it is possible to examine "Line" in more details. For example, the stage «System with the joint» can be developed in some sub-stages: «the system with one joint», «system with two joints» etc.
Logic of its application requires not only the obligatory and the unconditional transition of a system to the next stage of development in accordance with the split chain. The main condition of the necessity for the transition is the requirement for the performance of the new function, on the one hand and impossibility of its performance by the given technical system, on the other hand, to be more precise, the presence of a problem, the administrative and the technical contradiction. The means providing the possibility of such a transition are the revealed physical contradiction and the way of its decision which corresponds to one of transitions of «a split chain».
It is very important to know and constantly to remember about the split chain. But on the other hand, it should be applied not mechanically. It is important to analyze a technical system; the evolution of its development; arising problems. It is necessary to define correctly the function which is demanded from the technical system. And only after that to apply «the split chain» and other tools of OTSM-TRIZ.

A lemma. (Lemma) – the assumption applied without the proof owing to its obviousness.
For the technical system (TS) or its parts there will be at least one function which the given TS is not capable to perform. It is necessary to change the given TS or its part in accordance with one of its transitions through «a split chain».

2.7.4. Instruments - Tools (how to use)

At a stage of posing a problem.
During the practical application of the given law it is necessary to define that stage of development where a Tool of a system (a working body) is found. To estimate, whether there is a limit of its development. Whether there are alternative systems which have the micro-level structure.
At a stage of the solution of a problem.
During the search of the solution to a problem, it is necessary to pay attention to physical, chemical, geometrical effects and the phenomena, which give the possibility of the transition to the micro level.
The law of the transition from the macro to the micro level works often together with other laws. For example, the law of "energy conductivity" of parts of the system; the law of harmonizing the rhythms of parts of the system; the law of increases of Su-Field. So, the criteria which are put forward by the laws of "energy conductivity" and the law of harmonizing the rhythms of parts of the system can be reached, when the transition from the macro to the micro level is completed. And the mechanisms of the law of increase of Su-Field can serve as the transitional method from the macro to the micro level.
Illustrations of «a split chain» are shown in the example of a subsystem of "wheel" of means of transport.

1. the monolithic system:
A monolithic wheel made of such materials as stone or tree.

2. a system with the joint:
A joint is used to complete the function of the wheel turn;

3. a flexible construction:
A wheel with the rubber coating (surface);
The change of the part of the solid massive of the wheel into spokes;
A track of the tractor or the tank;
A flexible gear (which adopts to the ground contour);

4. particles; small particles; granular materials:
a wheel with air cell chamber;
a construction of the type - brush;
a water-jet motor;
a reluctance motor;

5. molecular aggregates, molecules, atoms, ions;
Air flow («air cushion»);
The ion engine (this idea is described in the science fiction literature);

6. elementary particles.
The «solar sail» (the idea is described in the science fiction literature);

7. A field
The magnetic cushion (the trains "Transrapid" and "MAGLEV" – Magnetic Levitation);

2.7.5. Examples

Example

Let's consider briefly some examples from the history of the record and the storage of a sound for its subsequent reproduction.

The first technical devices for this purpose were: a striking clock with various melodies; the mechanical piano; a street organ. It should be noticed at once that it is not actually the recording of a sound, but its programming. The carriers of the sound information in such a system are: the succession of teeth, hollows, ledges on a rotating shaft, on a wheel.

Besides, the strings, vibrating plates, etc. are necessary for reproduction of the sounds which are «recorded» in such a way. The size of all these elements for the record and the reproduction of a sound fluctuates from millimetres (in a pocket watch) to several centimetres and to tens centimetres in a tower clock.

The size of an element of the storage of a sound: 0,1 mm – 10 cm.

Example

The sound recording has actually begun with the invention of a phonograph performed by Edison. Mechanical fluctuations of a recorded sound left a trace on the wax rotating platen. This "trace" of a sound was transferred then on the firmer basis – metal, and then, on the plastic basis. An element which preserves a sound recorded was the variable sound track (groove) which is created by a sound itself. The size of this element varies in millimetres. The sizes of an element of the storage of a sound have decreased in comparison with teeth, hollows, and strings.

The size of an element of storage of a sound: 0,01 mm – 0,1 mm

Example

With the transition to a magnetic way of a sound recording there were new technical systems – tape recorders. Originally, the record was performed on a thin, metal wire, then – on a plastic recorder tape with the dust, ferromagnetic powder. In these cases magnetic particles and magnetic domains became the carrier of sound fluctuations which sizes vary in 1-10 micron. The size of the element which stores sound fluctuations has decreased by several times. The size of an element of the storage of a sound: 0,001 mm – 0,01 mm (1-10 micron).

Example

Now optical disks, stores on magnetic disks, solid-state elements (crystals) serve as the data carriers and are used for a sound recording. The apertures in optical, laser disks; magnetic structures – domains in magnetic stores; nanostructures in electronic chips are used as a storage element in such systems. The sizes of elements of the storage have decreased by several times in comparison with the previous example.

The size of an element of the storage of a sound: fractions of a micron.

We intentionally consider the evolution of development of means of the record and the sound storage simply, passing many details and sketching the technology only in general. The aim of this consideration is to show the transition of elements of the storage of the information from the macro-level to the micro-level.

Example

What constrains the further increase in speed of trains? The problems appear, when a train moves at high speed and there is the contact of a wheel with a rail.

The next stage of development of a train – a train on an electromagnetic cushion bolster instead of usual wheels. The transition from the pair "wheel-rail" to the electromagnetic interaction is carried out in the construction of this train. This kind of transition has solved some problems: smoothness of movement, noise decrease, a transmission of energy from the source to the train engine. The current collection (transfer) has also undergone changes –there is no sliding contact "current collection-wire" in it. The function of the transmission of energy is also carried out by means of a field.

Fig. 7.2. "Transrapid" train.

Fig. 7.3. Speed indicator for passengers.

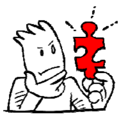
2.7.6. Self Assessment - (Questions, tasks)

Summary.

The «Tool» of many technical systems is the macro object. Its development is performed at first at the macro level. Later on, after the resources of its development are exhausted, the Tool is transferred to the micro level.

The basic definitions.

Micro level; Macro level; multi-screen scheme; S-shaped curve; line of development of «the chain mono-bi-poly»; list of typical fields, which are used in the technical system; the split chain of substance.



Questions:

1. How can we define the transition from the macro to the micro level?
2. What are the main conditions of the change of the Tool and its transition from the macro to the micro level?
3. Give some examples of the transition from the macro to the micro level.

2.7.7. References

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Vedi anche:

2..4 La legge di incremento del grado di idealità del sistema

2.8The law of increasing the S-field involvement

A wonderful photo of a wolf lies in front of me: a careful and cautious look of the clever eyes, fearful fangs in a rapacious grin and muscles are strained before a decisive jump.
But it is rather cleverness and inventiveness that attracts me most of all in these animals. We can draw many analogies and parallels in the evolution of biological and technical systems. There is even a science called bionics that studies possibilities of application of biological solutions in technology.
We are not interested in solutions, but primarily in methods of solutions. Here is a task. Even children know that a wolf eats a raw meat and does not brush his teeth. Those who have ever seen a wolf in a zoo know what unpleasant and strong smell comes from the animal's mouth. However, it is his smell, the smell is natural for him and even serves as its „business card" while meeting and communicating with other wolves.

But this smell can disturb a wolf. Often a wolf attacks its prey from a cover, ambush. He crawls towards the habitat of its prey from the downwind side - so that the wind blows from the side of a prey in direction to a wolf and not the other way round. In this case a wolf smells an animal it haunts for and the smell of a wolf is carried away in the opposite direction.
But what is the way of acting in windless weather or when the distance to a prey is very short? This problem is especially acute in winter. Smells from the heated breath of a wolf in the cold air spread out very well. There are no masking scents of flowering plants and other manifestations of the nature. Everything has died out till the spring comes again...
A wolf stands still in his ambush too. He does not brush his teeth, neither knows he the way to solve the task. He is guided by a powerful, centuries-old instinct, experience and knowledge of his ancestors and his personal experience and mind. Very often the price of ignorance and non-observance of rules is his life, life of his offsprings....
That is why before a decisive jump at a prey, a wolf takes a full mouth of… snow at his winter ambush! Snow reduces the temperature of a wolf's mouth and evaporation of moisture, i.e. his smell for a while. Besides, this natural filter from a variety of small snow crystals has a large surface and keeps down smells. Finally, snow melts in a wolf's mouth and water takes away smells with itself, without giving them a chance to spread out in the air. If the time for a convenient moment to attack a prey lingers, a wolf takes a full mouth of snow again and again…
What has changed in the structure of a system? For the sake of brevity we give only a S-field formula of a conflicting part of the system «wolf-prey» before and after introducing the change «snow in the mouth to eliminate a smell». For a more detailed explanation of the tool see Chapter «Examples».

Problem:

$S1_{(mouth)} \rightarrow F_{(smell)} \rightarrow S2_{(prey)}$

Solution:

$S1_{(mouth)} \rightarrow F_{(smell)}$ $\quad S2_{(prey)}$

$S3_{(snow)}$

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2.8.1. Definition

"The development of technical systems proceeds in the direction of increasing the S-Field involvement".

Altshuller, G. S. (1984). *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems* (A. Williams, Trans.): Gordon and Breach Science Publishers.), P. 231.

2.8.2. Theory (Details)

We know already that parts of a technical system develop unevenly in the course of the evolution of a TS. At certain development moments one of the parts of a technical system becomes complicated. But this complication, this development can be logically explained.

That part of a technical system undergoes development (in a particular case: gets complicated) which comprises a conflict, technical and physical contradictions. Correspondingly, a S-field model reflects exactly this situation. In this case we can speak about the direction of TS development that a S-field model reflects as increasing of S-field involvement.

To describe a simple technical system tool, a S-field consisting of 2-3 elements is sufficient. As a rule all technical systems at the stage of generation are a product that is processed with a tool by using manpower. It is simple instruments of labour like a spear, a knife and so on. Gradually, drawbacks of this technical system come to the fore, new needs and solutions regarding the change of the initial technical system to satisfy these appeared needs.

In the course of changes of the initial technical system, a technical system reveals new subsystems with its drawbacks which require solutions in regard to their improvements.

To analyze and identify problems and ways of their solution, it is necessary to clearly demonstrate the structure of a technical system, a conflicting zone, i.e. a „bottleneck" as well as changes that take place in this structure as the technical system develops. It becomes possible with the use of a S-field model.

2.8.3. Model

A technical system can be described as a S-field. This model consists of the main fields and substances of a technical system and its interconnections. Not all fields and substances which are present in a technical system are included in the model, but only those that directly work to achieve the function of a technical system.

S1 → F → S2

Let us take an electrical kettle for water heating as an example. The function of this technical system is to heat liquid (water) from the initial temperature (a room temperature) up to the boiling temperature». Or: «to change the parameter of the element WATER from the Value «a room temperature» to the Value «boiling temperature». In this case the S-field formula is:

S1 – electrical heater of a kettle;
F – Thermal field;
S2 – water in a kettle.

The formula means: electrical heater of a kettle S1 heats water to the boiling temperature with the help of a thermal field F.

A S-field model of an electrical kettle can be unfolded in a more detailed and wide model depending on objectives of the analysis. For instance, if we want to analyze, identify and describe problems connected with the transformation of electrical energy into thermal one, we have to build a S-field. In this case a S-field formula will be complemented by an element: «field of electrical power».

F(electricity) à S1(spiral) à F(heat) à S2(water)

2.8.4. Instruments - Tools (how to use)

It is possible that the given technical system will not meet a customer's needs. For example, we can be dissatisfied with the operation mode of a kettle. By turning on a kettle into an electrical power network, water in a kettle will be brought to the boil, afterwards water will convert into steam until water steams away and the spiral of a heater burns out. Let us specify a required new function for us. When the boiling temperature of water is reached, a kettle has to be turned off automatically.
A possible partial solution is reflected in a new S-field formula. In a TS a new substance S2 is introduced (for instance, a bimetallic plate that bows when reaching the temperature of 100º C, i.e. a steam point and unlocks contacts of a spiral-electrical heater).

$S2_{(\text{bimetallic plate})}$

$F_{(\text{electricity})} \rightarrow S1_{(\text{spiral})} \rightarrow F_{(\text{heat})} \rightarrow S2_{(\text{water})}$

2.8.5. Example

Example

Let us consider the example with a wolf from the point of view of a S-field analysis in a more detailed way.
The problem is that a prey can perceive the smell of a wolf at a short range:

$S1_{(\text{mouth of a wolf})} \rightarrow F_{(\text{smell})} \rightarrow S2_{(\text{prey})}$

What is the way of keeping back, eliminating the smell that comes from a wolf's mouth? It is necessary to destroy a harmful connection in order to perform a hidden function:

$F_{(\text{smell})} \rightarrow S2_{(\text{prey})}$

It is necessary to build a S-field by introducing a new field or a new substance:

$S1_{(\text{a wolf's mouth})} \rightarrow F_{(\text{smell})} \quad S2_{(\text{prey})}$

$S3_{(\text{snow})}$

The conventional names are given to substances and fields. The purpose of these names is to improve understanding of the situation. In fact, chemical substances in a wolf's mouth serve as a source of the smell. From a physical point of view a smell field is volatile chemical compounds which reach another animal through a wolf's breath. Substance-2 marked as «prey» in a detailed consideration is receptors of sense of smell. However, for analysis it is more important to create a mental image of a S-field. An integral perception of a situation is more important than details and precision of definitions.

Example

How to pull small items (for instance, metal fillings) out of a deep hole? It is difficult to do that with the help of mechanical tongs. In the formula of a S-field it is expressed in a bad interaction of a mechanical field with fillings:

$F1_{(\text{mechanical})} \rightarrow S1_{(\text{fillings})}$

Let us complete building of a S-field by introducing a new substance (magnet) and a new field (a magnet field): $F1_{(\text{mechanical})} \rightarrow S2_{(\text{magnet})} \rightarrow F2_{(\text{magnet field})} \rightarrow S1_{(\text{fillings})}$

How to solve this problem, if fillings are not magnetic? The logic of the solution is the same, but it is necessary to select a field that has a good interaction with fillings. It can be an adhesive substance and power of mechanical adhesion (mechanical field) with fillings, for instance.
$F1_{(mechanical)} \rightarrow S2_{(adhesive\ substance)} \rightarrow F2_{(mechanical)} \rightarrow S1_{(fillings)}$

Example
Figure 8.1 below shows a section of magnetic chain of a loud-speaker.

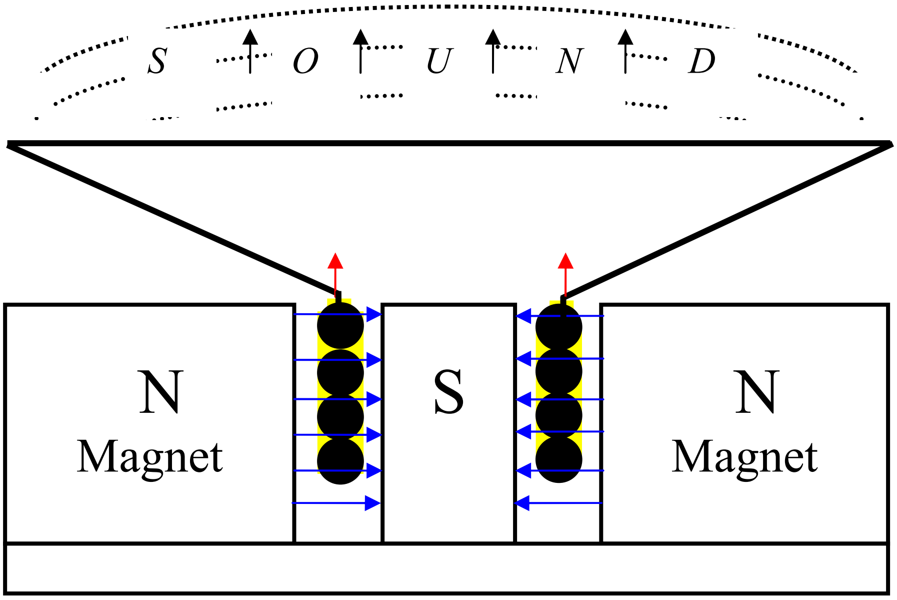

Fig. 8.1. *Section of a magnetic chain of a loudspeaker*

Legend:
1 – magnet
2 – compound that performs the function of a coil frame
3 – a coil
4 – diffuser
5 – lines of a magnetic field

A coil with a conductor which is in a magnetic field is «engine», transformer of electric and magnetic fields into mechanical vibrations of a diffuser and afterwards of the air.
Earlier (Chapter 2, example 2.2, task at the end of section and Chapter 4, example 4.5.) we have already considered a magnetic chain of a loud-speaker.
After replacing a coil frame by a compound which fastens whorls of a coil it became possible to improve the cooling of a coil, and reduce the gap of a magnetic chain. However, to reduce losses in a magnetic chain and increase the efficiency of the whole technical system «Loud-speaker», it is necessary to reduce the distance between magnets. The larger gap, the more losses there is.
Thereby, a new contradiction appears: the gap must be small to reduce losses in a magnetic chain; the gap must be large to improve the cooling of a coil. Ideally, there must be no air gap in a magnetic chain.

We can consider various situations with the help of a S-field analysis:
- model of a technical system while performing the main function;
- model of a technical system while performing the main transformation of energy by

«Engine»;
- conflict-1: energy losses in the gap;
- conflict -2: coil cooling;
- and others.

Let us consider the situation with losses in the air gap of a magnetic chain. We point out a contradiction: there must be an air gap in order to provide a free movement of a coil; there must be no air gap in order to avoid losses in a magnetic chain.
Let us build a S-field formula of this conflict:

$S1_{(magnet)} \rightarrow F_{(magnetic)} \rightarrow S3_{(air\ gap)} \rightarrow S2_{(coil)}$

The given contradiction can be formulated in the following way: a gap between magnets must be continuous to be magnetic; the gap must not be continuous in order to allow moving of a coil.
The given contradiction is solved by a breakdown of a S-field by introducing a new substance in a gap, an air gap of a magnetic chain:

$S1_{(magnete)} \rightarrow F_{(magnetico)} \rightarrow \cancel{S3}_{(traferro)} \rightarrow S2_{(bobina)}$

We get the following S-field by replacing an air gap by a magnetic liquid:

$S1_{(magnete)} \rightarrow F_{(magnetico)} \rightarrow S4_{(liquido\ magnetico)} \rightarrow S2_{(bobina)}$

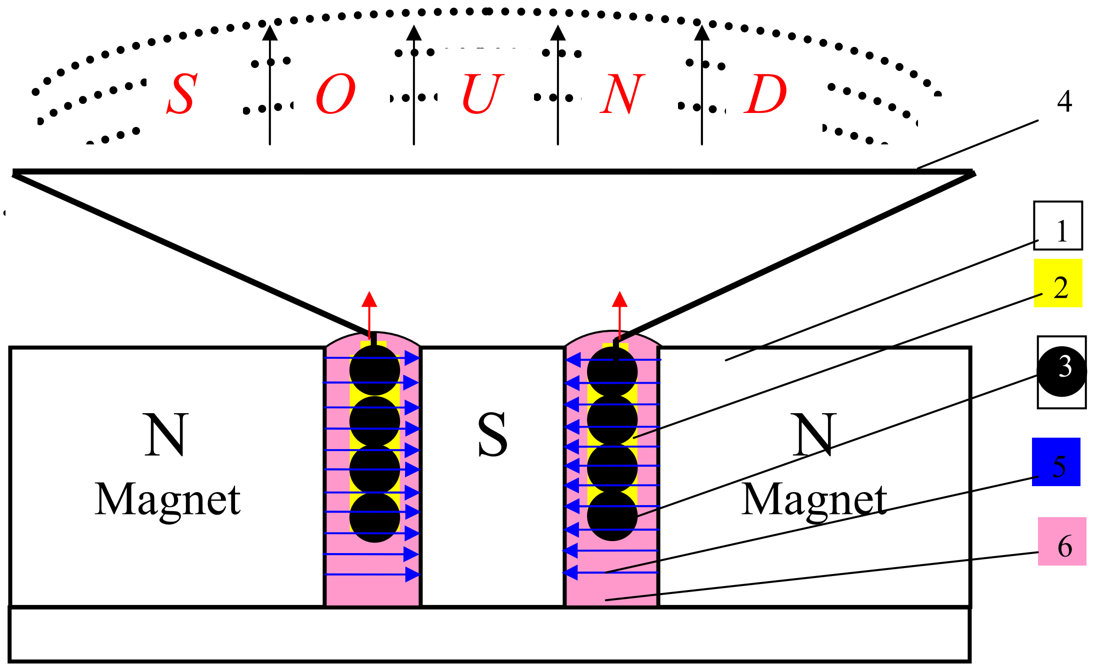

Fig. 8.2. Section of a magnetic chain of a loudspeaker with a gap filled by a magnetic liquid (6)

Legend:
1 – Magnet
2 – Compound that performs the function of a coil frame
3 – A coil
4 – Diffuser
5 – Lines of a magnetic field
6 – Liquid magnetic material

A magnetic liquid is very small particles of a magnetic material which is in a suspension state in liquid. Such mixture has properties of two substances: on the one hand, it is magnetic. On the other hand, it has the property of liquid, i.e. it is fluid. Thus, by filling the gap, a magnetic liquid reduces energy losses, but enables a coil to move freely.

The given solution with the introduction of a magnetic liquid into an air gap allows solving one more important problem: a coil cooling. By reducing the gap in order to decrease magnetic losses, we worsen the removal of heat from a coil. It is known that air has a very low heat capacity and a bad thermal conductivity. That is why by decreasing its volume in the gap, we reduce the amount of removed heat. Its replacement by a magnetic liquid enables to transmit heat from a coil to the environment more efficiently.
moment to attack a prey lingers, a wolf takes a full mouth of snow again and again…

2.8.6. Self Assessment - (Questions, tasks)

Resume.

A technical system and its part can be represented in the form of a S-field model. A S-field model represents substances and fields which are included in the given TS or its part used to perform the described function as well as interconnections and their character between substances and fields of the given TS or its part.
The development of technical systems proceeds in direction which is reflected in change of a S-field model. These changes take place in direction of increasing of S-field involvement. In particular: the increase of a number of elements (substances and fields); the increase of the amount of connections between elements; the increase of sensitivity of connections between elements; introduction of new elements; change of the structure of a TS.

The basic definitions.

S-field, a S-field model, substance, field

Questions:

What is a S-field model?
What is the law of increasing of S-field involvement?
Give examples to manifest the law of increasing of S-field involvement.

2.8.7. References

Altshuller, G. S. Creativity as an exact science. — M.: Soviet Radio, 1979. (Russian), Page 127.

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See also:
4 Su-Field Analysis and Standard Solutions
5.3 Techniques to resolve Physical Contradictio

3 Short Review of Altshuller's Algorithm of Inventive Problem Solving (ARIZ) Illustrated by the Analysis of a Real Problem

This article is aimed at facilitating the understanding of the general principles of ARIZ operation, but not at a detailed assimilation of all the steps of this algorithm. We are only going to discuss the goal of each Step and its role in the entire process of the analysis. We would also like to remind that the ARIZ Author advised to undergo training before applying TRIZ to real problems. There exist numerous nuances important for performing separate steps of ARIZ. It is difficult to illustrate all of them while analyzing one problem only; therefore, it would be better to learn ARIZ under the guidance of an experienced teacher using a large number of training problems as examples.

3.0 ARIZ creation and development

In the course of ARIZ evolution, the analysis and contradiction resolution steps were permanently improved, developed, specified and tested on complicated problems collected by the ARIZ author during 40 years, starting from 1946 till 1986. By the mid-80s, Altshuller had collected over 120 problems where previous ARIZ versions where of little help. Those problems were used to test and polish new ARIZ versions, including their use at workshops and by distant students.

ARIZ development is also connected with the development of the technical system evolution laws and the understanding of how these should be applied to the design of new systems or improvement of existing ones. Thus, in the current version of ARIZ and its OTSM supplements, the evolution laws are mostly present in an unobvious form.

Currently, ARIZ is a highly detailed method and may seem complicated. This material is designed to facilitate the understanding of the general logic of Altshuller's last ARIZ version (ARIZ 85-C). Using a real problem as an example, we will try to illustrate the assistance OTSM can render in resolving some difficulties occurring while using ARIZ-85-C.

It should also be mentioned that thorough execution of the steps according to ARIZ-85-C considerably simplifies the analysis compared to the previous ARIZ versions. Thoroughly performing these steps forms certain thinking skills in students, which can be effective while dealing with a problem.

It is also necessary to mention some peculiarities of bringing ARIZ assimilation to the level of automatism in its application to real problems.

First, additional nuances of performing each step depending on a specific situation are learned by repeatedly practicing ARIZ steps on training and real problems. As a result, the performance of the steps becomes automatic and the steps begin to be performed faster and on a subconscious level.

It often happens that students themselves do not realize their achievements at this step. Not infrequent are cases when some of them think that a problem has been solved without using ARIZ and demonstrate quite an acceptable, practically realizable solution. Discussing the situation with such a student proves that he has formulated a contradiction, analyzed the resources available in the given situation and found the way to use those resources for resolving the contradiction, the result being close to IFR (Ideal Final Result) to the extent permitted by the resources available in this situation. This generally proves that the skills of performing many steps of the first parts of ARIZ have already been formed in the student but the skill of reflection described in its last part has not been developed to a necessary extent. That is, the student has solved a problem but has not analyzed his own thinking process and the way he has traveled to obtain the solution. This usually happens with relatively simple problems and students may get the impression that they have already penetrated into ARIZ. However, they cannot deal effectively with more complicated problems where the reflection skill is particularly important for performing the third part steps. After passing through this ARIZ assimilation stage, students achieve a higher level of command of the tool. They are able not only to suggest a solution to a problem after getting acquainted with the initial description of a situation, but also to show in general how this solution results from the problem description.

And finally, after gaining some experience in the work on real problems, one more skill is formed. The thing is that training problems are usually more or less adapted to specific objectives of the training Steps. Properly speaking, this situation is typical for training in any other subject which forms skills of practical use of obtained knowledge. In reality, an initial description of a non-standard problem is often either rich in unnecessary and unessential particulars, or, on the contrary, lacks some information important for understanding the problem essence. Professional TRIZ experts often suggest some solutions by mentally passing a problem through all ARIZ steps so as to define more exactly the initial description of the problem situation before starting an in-depth analysis. From outside, it may look as an ordinary error-and-trial method, but in reality, it is quite a different technology of dealing with a problem. Mentally analyzing a problem in accordance with ARIZ steps, an expert evaluates the already available information and obtains additional important information about the problem, which is absent in the initial problem description. After the problem situation description has become sufficiently complete, a serious in-depth work using ARIZ or other OTSM-TRIZ tools starts. For example, if a situation includes numerous problems, it would be wise first to formalize its description in the form of the OTSM Network of Problems. While constructing this network, mental analysis of separate sub-problems and their specification are used, as described above.

Thus, ARIZ is not only a tool for solving complex problems, but also, which is most important, a tool for forming a certain thinking style in work with the knowledge about a problem situation. It is just the work with the already available knowledge with the aim of obtaining and creative use of new knowledge that makes ARIZ an important pedagogical tool which can be helpful in the spectrum of educational processes and technologies. For example, it may significantly improve the effectiveness of the so-called problem teaching, where introduction of a new topic is started with offering some typical problem situation to students which they have to deal with to become prepared for assimilating a new material and understanding how the studied material can help them in dealing with similar typical situations. Thinking skills necessary for performing separate steps of ARIZ also prove useful for various pedagogical and educational situations and technologies.

To summarize this part of the introduction to ARIZ, we would like to note that the skills formed while mastering ARIZ help teachers solve their pedagogical problems arising during the educational process (as well as their private problems). As for students, these skills help them assimilate new knowledge in a more effective and systematic manner. These skills may also be formed by means of separate OTSM-TRIZ trainings, such as the training based on the "Yes-No" game. However, in this case, it is also extremely important to integrate all these segmental skills into a system by doing exercises for all ARIZ steps.

3.0.1 Solving a problem: a short review of the main stages of ARIZ-based work

With any scientific approach, first of all it is necessary to select and create a problem-describing model. It means that an initial situation description should be turned into a model of this situation formulated in a certain manner according to distinct rules. This results in the appearance of the model of the initial problem situation described through a contradiction to be solved.

Transition from an initial description of a problem situation to a description of a problem model occurs in the same way as in physics or mathematics: it is necessary to try to reformulate the situation in a canonical form which will be then analyzed while constructing a solution.

It is very important to note that in the process of ARIZ-based work, just as in the entire Classical TRIZ and in OTSM, the idea of a conceptual solution is not searched for randomly, but is constructed, step by step, in the process of analysis of a problem situation and synthesis of an acceptable solution concept (Satisfactory Conceptual Solution). It is one of the main distinctions of Classical TRIZ and OTSM from many other methods of solving complicated, non-typical creative problems.

Transformation of an initial problem into a model can reduce the problem to a typical, standard one (from the TRIZ viewpoint), the solution to which is already known in a general form. Then, after constructing a model of a problem situation at the end of the first part of ARIZ-85, transition to the system of standard inventive solutions is performed. Currently, this system contains 76 standard problem situations. If the known generalized standard solutions do not suit our specific situation for some reasons, the situation continues to be analyzed according to ARIZ. If further analysis results in a satisfactory solution, the latter should be converted into a typical, standard solution which takes into account the peculiarities of similar specific situations. This is roughly how the collection of Standard Inventive Solutions of Classical TRIZ was created.

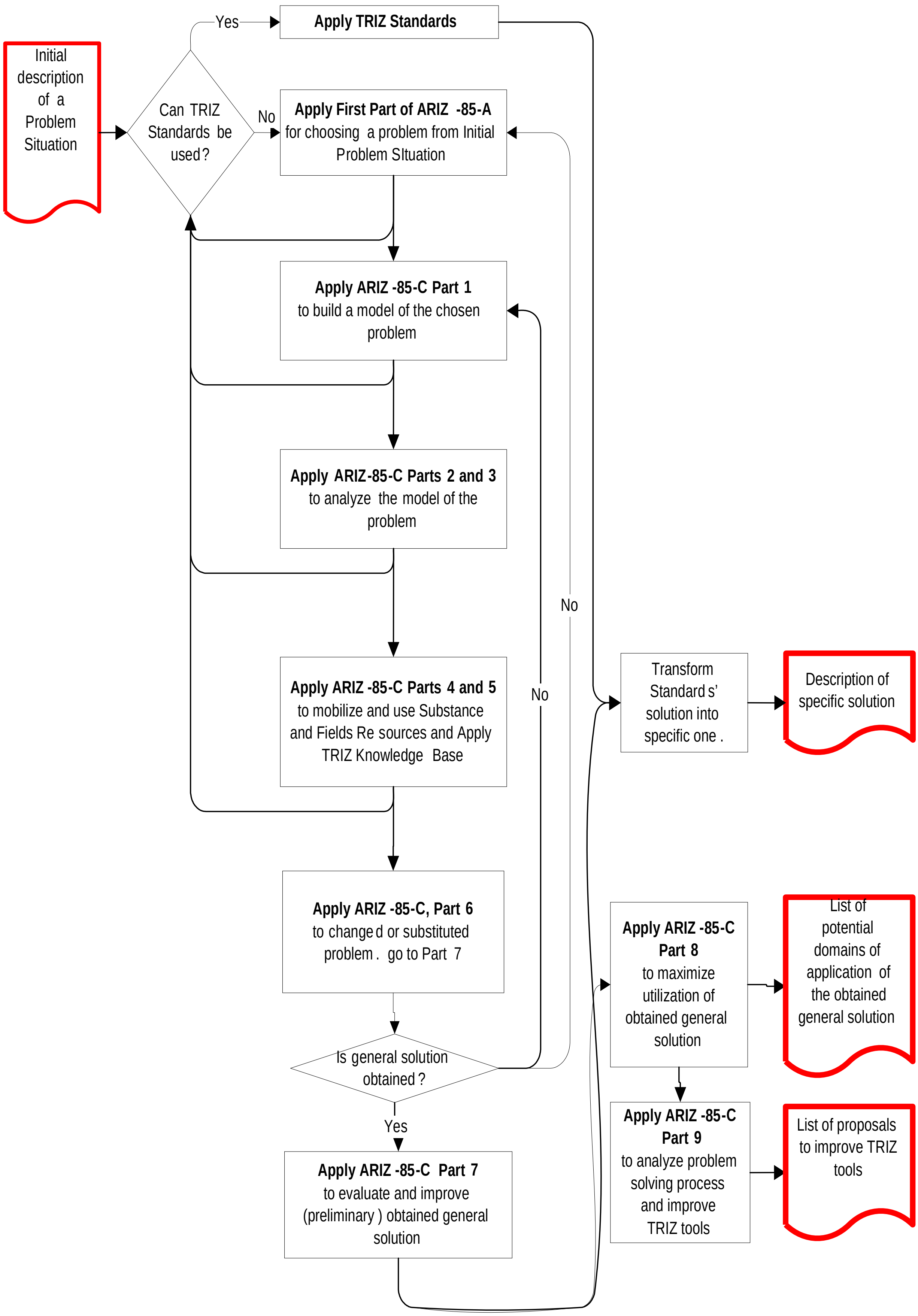

Fig. 1 The scheme of stages of ARIZ-based problem analysis.

3.1 The first stage. Constructing a problem model and using standard inventive solutions

3.1.1 Inventive solutions

Selecting a problem to be solved from a set of problems contained in an initial problem situation is not among the Classical ARIZ tasks. In the ARIZ-based OTSM technology “Contradiction”, the Express Analysis of an initial situation is used for this purpose. It effectively works with comparatively simple problem situations. For more complicated ones, it is expedient to use the tools of the OTSM technology “New Problem”.

The aim of the first part of ARIZ is creating a model of a problem to be solved. At the end of the first part, the problem selected from the initial situation is formulated as a technical contradiction – a contradiction that describes a conflict between two parameters used for evaluating the quality of a given system (evaluation parameters). Accordingly, Technical Contradictions in OTSM are called a contradiction of a specific system, which means that a given system confronted a conflict between two important parameters during its evolution.

Example: There is a system “rubber seal of a hole through which a rotating shaft goes”. The more tightly the seal is retained against the shaft, the better is the sealing property. However, this leads to an abrupt loss of energy caused by friction between the shaft and the seal. Thus, we have a conflict between two parameters which are important for evaluating the quality of the specific system -“Rotating Shaft Seal”.

In OTSM, these contradictions describe conflicts between parameters of non-technical systems (scientific, management, social and business systems, economic systems, etc.).

Example: To effectively solve some problem, a typical solution is attracting a large number of employees possessing knowledge in various fields. These people, however, often do not understand each other’s problems because of the lack of knowledge in other subject areas. Meetings become ineffective, the problem remains unsolved.

Here we have to do with the “Working Team” system where a conflict arises between the parameters “Degree of competence in allied sciences” and “Effectiveness of discussing various aspects of a problem situation”.

If identifying contradictions for the first stage of ARIZ is difficult in a given situation, using the methods of the OTSM Technology “New Problem” is recommended. In comparatively simple cases, you can also resort to the Express Analysis of the initial problem situation, developed within the OTSM Technology “Contradiction”. For more complicated situations, the OTSM “Problem Network” tool may be employed. This tool allows conducting a more detailed analysis of a complicated problem situation and identifying key problems which need to be solved in the first place. It is useful to apply the Express Analysis to such problems to provide a precise formulation of the first step of ARIZ. Applying the OTSM Express Analysis of a problem situation requires additional knowledge about the minimal system notion.

Performing the steps of the first part of ARIZ-85-C on the basis of OTSM comments results in obtaining a problem model which will be further analyzed. But before passing to the second part of the Algorithm, it is necessary to see if the inventive standards of Classical TRIZ may be used.

The thing is that after transforming the description of an initial problem situation into a problem model, only the most important components, responsible for creating the problem situation, remain in the model description. As a result, it becomes easier to give the description of the problem situation a form that allows application of standard inventive solutions accumulated in Classical TRIZ.

3.1.2 The second stage. Analyzing the available resources

The second part of ARIZ is designed for analyzing the obtained problem model and preparing for the identification of in-depth contradictions underlying the problem. To be more exact, this part is designed for analyzing resources that can be potentially used for problem solving, in particular, the resources of place, time, “substances” and “fields”. Partially tested is also the possibility to apply some standard mechanisms of bypassing or fully resolving contradictions. Just like the first part of ARIZ, the second one contains some mechanisms for suppressing psychological inertia.

3.1.3 The third stage. Constructing an idea of a satisfactory solution by analyzing IFRs and Physical Contradictions related to specific resources

ARIZ is designed for revealing the in-depth roots of a problem and removing them by means of resources available in a specific problem situation. In the third part of the Algorithm, the description of a desirable result and contradictions hampering the achievement of this result continues to be specified.

The First Objective of the third part of ARIZ is specifying the problem model obtained in the first part. This objective is achieved by using the additional information obtained through the model analysis conducted in the second part of the Algorithm. This new, specified model is constructed according to different rules and differs fundamentally from the model produced in the first part.

In this part, it is necessary to determine which result can be considered as a solution to the problem and to identify numerous contradictions preventing the use of the available resources for obtaining the desirable result.

The second objective of this part is obtaining partial solutions which will be used for assembling a conceptual solution of the entire problem as a whole. The obtained partial solutions are integrated into a single system of solutions providing the maximum approach to the most desirable result. The principles of removing physical contradictions and the system convolution mechanisms are employed for this purpose.

Generally, starting from the third part, the number of obtained partial solutions begins growing and new final solutions are formulated. In such a situation, there is a temptation to terminate the process of search for solutions. Nevertheless, the Algorithm rules recommend passing through all ARIZ stages because these help obtain additional ideas, strengthen a found solution or detect some other problem-solving ways corresponding to more advanced stages of system evolution.

Executing the third part of the Algorithm results in that our idea of the problem situation essentially changes again and is formed at step 3.5 of the Algorithm. As a result, the last step of this stage refers us once more to the system of inventive standard solutions.

3.1.4 The fourth stage. Mobilizing the resources

The fourth part of ARIZ is designed for understanding how the available resources can be used to solve the problem as the latter is defined in the third part of the algorithm and to increase the effectiveness of the already found solutions.

The fourth part includes a set of operators aimed at obtaining a version that would be more developed from the system evolution theory view point.

If one of the obtained solutions suits us, we can pass to the seventh part of ARIZ for preliminary evaluation of the solutions in accordance with the ARIZ rules.

If, on the contrary, no satisfactory solution has been found, the analysis continues according to the fifth part of the Algorithm.

3.1.5 The Fifth Stage. Using the knowledge collection accumulated in TRIZ

In the Fifth part, a solver is proposed to refer to the collection of various TRIZ tools which describe standard solutions in different forms: the System of Inventive Standards, principles of resolving physical contradictions, effect pointers.
If the use of the data base has not resulted in a satisfactory solution, it is necessary to pass to the **sixth part** of ARIZ.

3.1.6 The sixth stage. Changing and/or correcting the initial problem description

The sixth part of the Algorithm offers recommendations regarding the change or correction of a problem definition or problem model before analyzing it again starting from the first part of ARIZ.

3.1.7 The Seventh Stage. Evaluating the obtained solutions

The seventh part of ARIZ contains rules of evaluating solutions from the TRIZ viewpoint and strengthening the obtained solution.
It is but a preliminary evaluation. In the course of this evaluation, there may appear new ideas specifying or improving the obtained solution.
This is, however, but a preliminary express evaluation of the solution. Sometimes, solving a problem according to ARIZ helps overcome stereotypes of professionals and brings solvers outside their professional competence, so it is necessary to consult respective specialists for evaluating the obtained solutions.
If a solution has been accepted, it makes sense to discuss with patent engineers a possibility of making an application for a patent.

3.1.8 The Eighth Stage. Expanding the application scope and standardizing a creative solution

The eighth part of ARIZ serves to prepare the implementation of a final solution and to check whether this solution can be applied to solving other problems, including those from different subject areas.
This allows giving the solution a more generalized standard form for further practical application. This part is also necessary for providing a better patent protection of your solution (creating a patent umbrella).
In addition, this part helps increase the solution effectiveness and derive an additional profit from its implementation.

3.1.9 The ninth Stage. Reflection about the performed work

The ninth stage of ARIZ helps better understand the core of the performed work. The aim of this stage consists in learning as much as possible in the field of problem solving, thereby increasing the creative potential of an individual or a team.
This stage is designed for developing the skills of reflection about the work being performed. In principle, each ARIZ step should be followed by reflection about how that step was made, what difficulties were faced while performing that step, what difficulties were overcome, how accurately the ARIZ recommendations were performed, whether the performed work differs from what is recommended by ARIZ and why such differences occurred.
The answers to these questions develop the reflection skills and facilitate understanding of the ARIZ-based problem solving process at the stage of assimilating the Algorithm on the examples of training problems. At the stage of professional application of ARIZ to real problems, they facilitate further development of ARIZ itself and improvement of its effectiveness in solv-

ing new, increasingly more complicated problems.
It should be noted in conclusion that the reflection skill is one of the most important thinking skills in general and not only with respect to Classical TRIZ and OTSM tools. The ninth part of ARIZ helps us develop this fundamental thinking skill.

3.2 The list of ARIZ steps

The previous sections shortly describe the designation of each ARIZ part at each stage of work on a problem.
Below is given a list of Algorithm steps. Further, we will show how these steps were executed while solving a problem.

Part 1: Analyzing a problem and creating a model.

Step 1.1. Describing a problem condition.
Step 1.2. Identifying the conflicting elements of a system.
Step 1.3. Creating a graphical scheme of a system of conflicts.
Step 1.4. Selecting a graphical model of a system.
Step 1.5. Aggravating the main conflict.
Step 1.6. Formulating a problem model.
Step 1.7. Searching for a standard solution

Part 2: Analyzing a problem model.

Step 2.1. Analyzing the operational zone.
Step 2.2. Analyzing the operational time.
Step 2.3. Analyzing su-field resources.

Part 3: Defining an ideal final result (IFR) and physical contradictions which prevent the achievement of IFR.

Step 3.1. Formulating an ideal final result (IFR-1).
Step 3.2. Intensifying the IFR-1 definition.
Step 3.3. A physical contradiction (PhC) on a macrolevel.
Step 3.4. A physical contradiction on a microlevel.
Step 3.5. Formulating an ideal final result (IFR-2) for different resources and specifying the initial problem
Step 3.6. Using the system of standards (76 standard solutions to inventive problems, using a su-field model).

Part 4: Mobilizing resources

Step 4.1. Modeling a problem with “little creatures”.
Step 4.2. Using «a step back from IFR” method
Step 4.3. Using a mixture of available resources
Step 4.4. Introducing voids of different types into available resources.
Step 4.5. Using substances derived from available resources
Step 4.6. Checking whether a problem may be solved by replacing some substance with an electric field or interaction between two electric fields.
Step 4.7. Checking whether a problem may be solved by introducing a “field – additive responding to a field” pair.

Part 7: Checking a method of removing a physical contradiction.

Step 7.1. Checking an answer.
Step 7.2. Preliminary evaluation of an obtained solution.
Step 7.3. Checking for the absence of the invention in the patent collection.
Step 7.4. Evaluation of subproblems arising during implementation.

Part 8: Using an obtained solution.

Part 9: Analyzing the solving procedure.

Example of solving a problem by using ARIZ

Above we have described the role of each of the nine ARIZ parts. Now, we are starting to describe the objective of each step constituting these parts of the algorithm. To this end, we are going to use one of real problems solved by using TRIZ.

Initial problem description

To create large-diameter concrete pipes (up to 6 meters in diameter), a concrete mixture is poured into a double steel formwork (see Fig. 1).

To improve the pipe quality, the concrete mixture undergoes vibration treatment by vibrators attached to the formwork. The vibrator's operation principle is very simple: it is an eccentric flywheel slipped over a motor drive shaft. When the motor is running, the eccentric flywheel hits the formwork inducing vibrations which are transmitted from the formwork to the concrete.

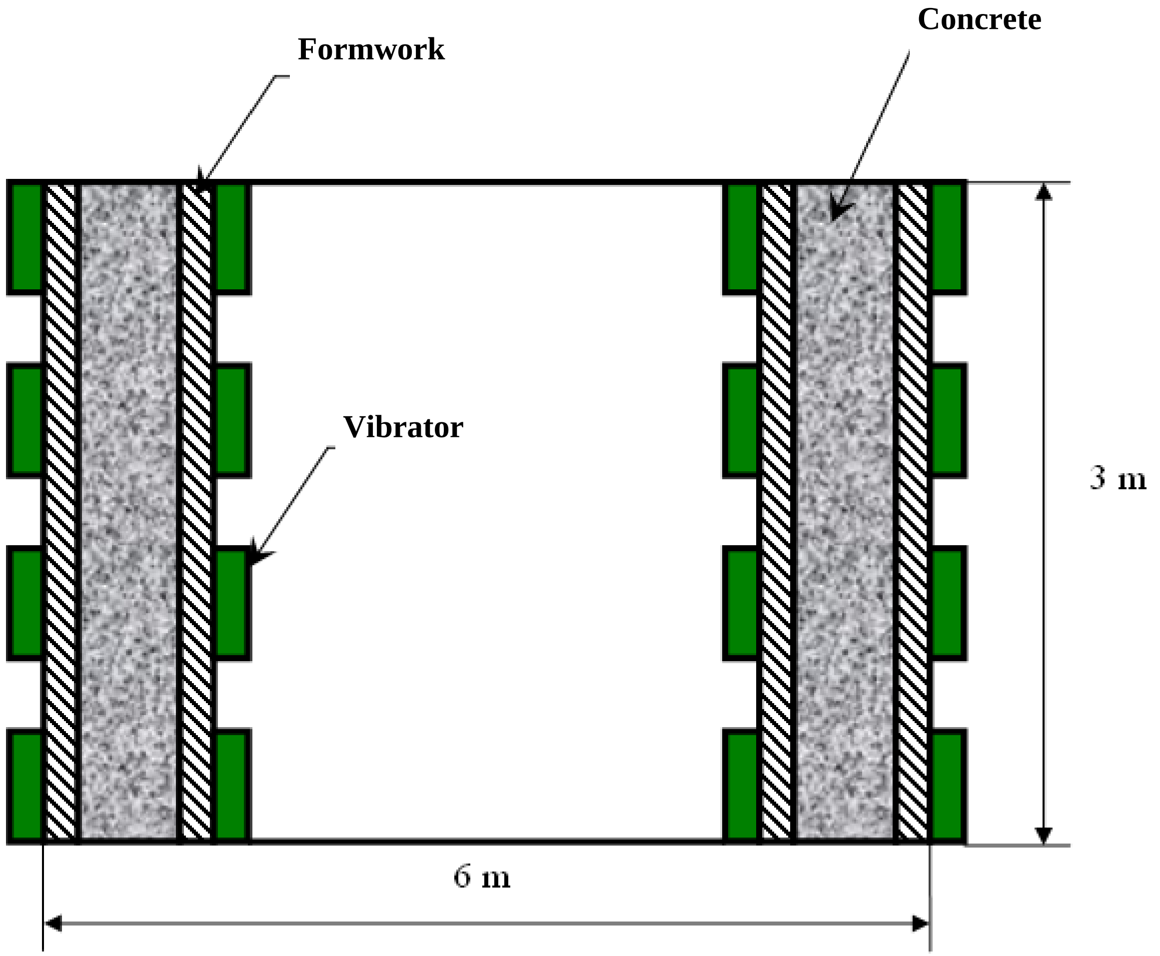

Fig: 2 Section of a formwork for concrete pipe production, provided with a vibrator to make concrete compact.

At the level of a production process, the vibrator performs its function well enough. The only disadvantage of this system is a high-level noise. As the strength of the produced sound is concerned, it can compete with a jet engine. How can this disadvantage be eliminated by introducing minimum changes into the existing system and by using minimum external resources and maximum internal resources available within the system or the surrounding environment?

In terms of Classical TRIZ, such a formulation of a problem is called a mini-problem. A mini-problem is characterized by that it contains maximum restrictions concerning the introduction

of new components. The general rule of defining a mini-problem is “Everything should remain as it is, but the disadvantage should disappear”.
Inversely, a maxi-problem admits any changes up to a radical change of the system itself or its replacement with a different system which is free of the given undesirable effect.
Thus, solutions can be classified according to the limitations within the frames of which they solve a problem, starting with the maximum limitations of a mini-problem and finishing with the minimum limitations of a maxi-problem.
It is evident that the recent advanced technology of self-compacting concrete does not require use of vibrators and is a problem solution differing from that described in this article. However, solving the problem by means of self-compacting concrete is not a mini-problem solution, because it requires more changes and more advanced research than those necessary for the proposed solution.
The idea of such concrete was produced at the very beginning to the problem solving process. At that time, however, creation of such concrete was a serious research problem and required much time. We should also mention that the problem arose at an operating plant and needed to be solved within a short period of time, with available means and at an acceptable price.
And, finally, we would like to remind our readers that this example was written by a TRIZ specialist who is not an expert in civil construction. It is transparent not only to specialists in the given field, but also to the general public.

3.2.1 Part 1: Analyzing a problem and creating a model

Step 1.1. Describing a problem condition

1.1.1. A short description of a technical system, its designation and basic components

The given technical system serves to produce concrete pipes. It is composed of a double steel concentric formwork (into which a concrete mixture is poured) and vibrators (which hit the formwork for increasing the concrete density and removing the air voids formed while poring the concrete into the formwork).

1.1.2. A system of contradictions

From the TRIZ viewpoint, any problem is complicated because it contains a hidden or apparent contradiction. To solve a problem, it is necessary to identify a contradiction and to describe the problem in such a manner as to bypass or eliminate the revealed contradiction.
Thus, to begin with, it is necessary to identify a problem-causing contradiction. In TRIZ, correctly describing a problem means finding this contradiction and defining it as clearly as possible according to certain rules. This may be done by using OTSM Express Analysis of a problem situation. In some relatively simple cases, however, ARIZ may be immediately applied to a problem situation. For this purpose, ARIZ includes a system of technical contradictions called TC-1 and TC-2.
A correct description of the system of contradictions allows understanding which parameters used for evaluating the properties of a given system are connected with a contradiction: two parameters of a technical system under consideration (Evaluation Parameter 1 and Evaluation Parameter 2) are interrelated through a third parameter which can be used to change the values of the Evaluation Parameters. This parameter is called the Control Parameter because changing its values allows the Evaluation Parameters to be controlled (Control Parameter).
While formulating TC-1 and TC-2, it is important to identify the element to which the control parameter, connecting two Evaluation Parameters, belongs, the connection being such that improving Evaluation Parameter 1 worsens Evaluation Parameter 2 and vice versa.
We are not going to describe the initial situation process in detail and will directly give a system of contradiction.

TC-1:
If the vibration force (Control Parameter 3) of the vibrators (element E) is large (value of the Control Parameter 3), the concrete density and homogeneity (Evaluation Parameter 2) are high (value of Evaluation Parameter 2, positive), but the noise level (Evaluation Parameter 1) is very high (value of Evaluation Parameter 1, negative).

TC-2:
If the vibration force (Control Parameter 3) of the vibrators (element E) is not large (value opposite to the value of Control Parameter 3 indicated in TC-1), then the noise level (Evaluation Parameter I) can be reduced (value of Evaluation Parameter I, positive), but the concrete density and homogeneity (Evaluation Parameter 2) are reduced (value of Evaluation Parameter 2, negative).

Parameter 1 - Evaluation	Noise level
Parameter 2 - Evaluation	Density and homogeneity of concrete
Parameter 3 - Control	Vibration force

It should be noted that grouping into control and evaluation parameters is absent in Classical TRIZ. It was introduced within the framework of OTSM for clearly distinguishing the roles of parameters in the course of analysis of complicated problem situations when one and the same parameter plays different roles. In addition, even in the process of ARIZ-based analysis of relatively simple problems, there arises a necessity of introducing new control parameters which can serve as an alternative to the given parameter.

It is important to understand that the Evaluation Parameters selected at step 1.1. remain unchanged during the entire problem analysis. They can only be specified. At the same time, the list of control parameters may be expanded while analyzing the problem in the third part of the Algorithm.

1.1.3 The desired result

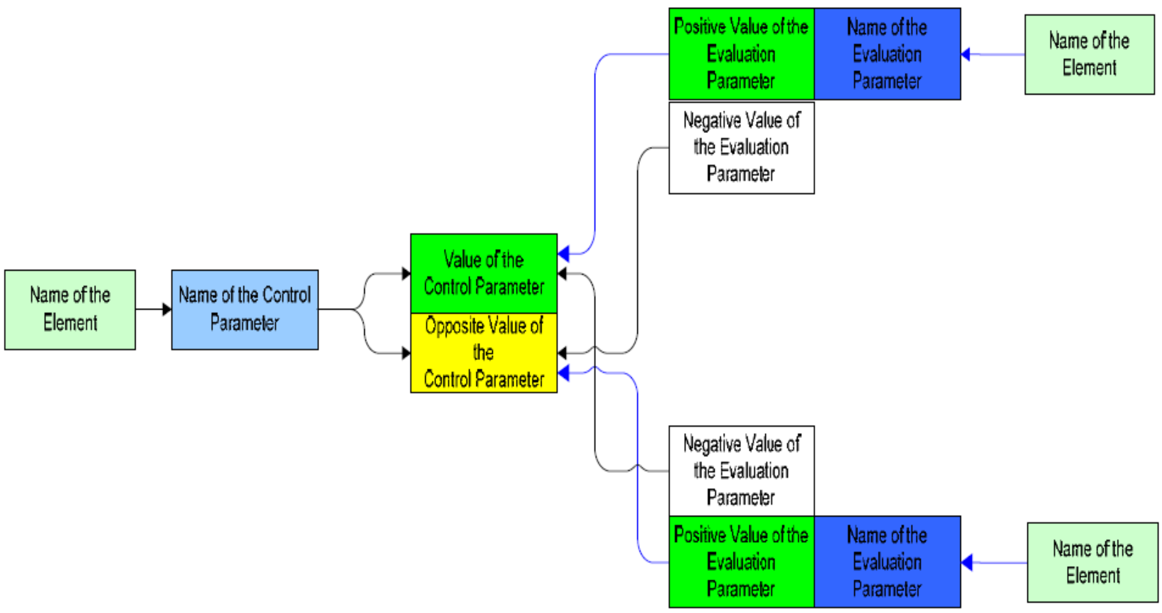

Fig. 2. The OTSM ENV scheme of the system of contradictions.

If the system of contradictions is correctly built and if the model is properly defined, it is enough to assemble the positive values of Evaluation Parameters 1 and 2 of the model of the system of contractions as shown in Figure 2.
The desired result definition
To solve the problem, it is necessary to provide a high density and homogeneity of the concrete (the value of Parameter 2, positive) while preserving the low level of noise (the value of Parameter I, positive).

It is essential to comprehend the laws of the subject area (physical or other) which interconnect the key parameters of the system (the above mentioned evaluation parameters 1 and 2).
In terms of Classical TRIZ and OTSM, the law is a steadily recurring relation between parameters, phenomena or events. If one event occurs, then another one naturally follows. If one of the parameters changes its value, then the values of other parameters, connected with this parameter, also change.

If fulfilling the first step of ARIZ causes difficulties in dealing with some problem, it is recommended to use the OTSM Express Analysis for transforming the initial problem situation into an OTSM ENV scheme of the system of contradictions.

Step 1.2. Identifying the conflicting elements of a system

This step is aimed at identifying the system elements which connect the positive and negative parameters described in step 1.1. through cause-effect relations, laws.
The ARIZ steps are closely interrelated, each following step is always a logical continuation of the previous one. The absence of such interrelation means that some logical mistake has been made and it is necessary to revise the previous steps to find and correct this mistake in the analysis. With a correctly performed analysis, each subsequent step logically results from all previous ones.

If the first step was performed by using the OTSM Express Analysis of the problem situation, then the result f step 1.2 should match with the scheme of the positive system obtained as the result of the express analysis.

The two conflicting elements are the tool and the product.
The product is an element that need to be processed (manufactured, moved, changed, improved, protected from a harmful influence, revealed measured etc.) according to the problem conditions. For problems about detection and measurement some element considered as tool (according its base function), can be considered as product (e.g. a sensor receives a function by the signal source, thus it is a product not a tool).
The tool is an element that directly interacts with the product (e.g., mill rather than a milling machine; fire rather than a burner).In particular, a part of the environment can be considered as a tool. The standard parts from which the product is assembled can be considered as a tool too (e.g., meccano this is tool to create of various "product")
One of the elements in the conflicting pair can be doubled. For instance, two different tools are given, and they have to act on the product simultaneously, where one tool interferes with the other. Or two products are given, and they have to be processed with the same tool, where one product interferes with another.
As to our example, the following participants of the problem situation can be identified as a product and a tool:

Product: concrete mixture
We need to produce a denser concrete mixture. That is, the performance of this function must result in an increased concrete density.

Tool: vibrator and formwork
The formwork directly interacts with the concrete but the formwork itself cannot cause the concrete vibration; therefore, in accordance with the ARIZ rules, we are considering the double tool “formwork+vibrator”.
The tool vibrates and compacts the concrete mixture, which is its main function. However, a harmful (undesirable) product – sound - occurs during this operation. It should be removed without preventing the performance of the tool’s main function. The appearance of a loud sound is a secondary phenomenon. In this situation, it is again considered undesirable. Therefore, to solve the problem, this phenomenon should be removed.
To complete this step, it is necessary to formulate what the system should do, or, in other words, to formulate its function. To describe the function, OTSM-TRIZ recommends using a group of synonyms. It helps to overcome psychological inertia imposed by the professional terminology. By the way, we deal here with one of the general rules of Classical TRIZ which states that all special terms must be replaced with ordinary words used in the everyday life.
This forces a solver to examine a phenomenon of interest at different angles and to better understand what exactly the analyzed system should do.

An even more effective tool for suppressing the psychological inertial imposed by terms and for determining the function even more precisely is the Three-Step Function-Describing Algorithm built on OTSM models which we are not going to describe in this paper.

In mastering ARIZ, it is important that a teacher pay special attention to teaching students to perform self-verification of the performed steps. It is one of the reflection skills which are so important in dealing with complicated problems. Teaching students to carry out self-verification of the step performance quality is closely connected with different OTSM-TRIZ models, postulates and tools. The wider and the deeper the students’ knowledge of the entire complex of OTSM-TRIZ theoretical basics and practical tools, the easier is controlling the quality of the steps they perform and the higher is the quality of the entire problem-solving process.
For example, when controlling the performance quality of step 1.2., it is useful to compare the obtained result with the system description at step 1.1. If a solver is familiar, for example, with the OTSM Three-Step Function-Describing Algorithm, then it would be helpful to use it for determining a product.
But if the OTSM Express Analysis of a problem situation has been carried out, then it would be useful to make a stop at step 1.2. and to check how step 1.2. of ARIZ is coordinated with the models obtained in the course of the Express Analysis.
The process of verifying the performance logic of ARIZ steps is often akin to the process of verifying computation results in mathematics: it is necessary to perform computation by some other method and to compare the results. This is done by means of the next step too.

Step 1.3. Creating a graphical scheme of a system of conflicts
The goal of this stage is analyzing the appropriateness and logical unity of the previously performed steps. To this end, a problem-describing graphical model is created in the course of analysis.
Presenting the text, obtained for describing a conflict at step 1.1., in the form of graphical models (see chapter on Su-Field modeling) is one of the ARIZ inherent mechanisms used to overcome psychological inertia. To perform this operation, other mechanisms of our conscious and unconscious thinking are employed. The thing is that, according to the researchers dealing with the study of the brain activity, different parts of the brain are generally responsible for text and for graphics. Therefore, describing a conflict through graphics and doing that through text are alternative tools which are helpful for self-verification of our work quality.

Generally, after each two or three ARIZ steps, it is necessary to think over and verify the performed work summarizing the performed steps. If the steps logically follow from each other and do not contradict each other, you may pass to the next step.
But if the logic between the previous steps and the one being performed at a given moment is broken, if formal logic is violated, it is a signal denoting that we need to give more thought to the reason of that breakage.
In our example, it is necessary to compare the graphical models of the conflicts obtained at step 1.3. with the text description and ENV scheme (diagram) of the conflicts at step 1.1. In the graphical schemes just as at step 1.1., the evaluation parameters Noise Intensity Quality (density and homogeneity) of Concrete are in conflict with each other. The name of the evaluation parameter "Density and Homogeneity" of Concrete given in the text changed into the "Quality" parameter in the graphical presentation. The thing is that the notion of "quality" depends on many evaluation parameters and acquires different meanings for one and the same product or service depending on a situation; accordingly, this notion is easy to use by substituting it for more specific criteria and specific evaluation parameters. This, however, often reduces the analysis effectiveness. It is generally advisable to avoid wide terms and to indicate specific evaluation parameters which are used to evaluate the performance quality of a function.
Note that conflict schemes should include both the product and the tool identified at step 1.2. Both the concrete and the vibration formwork are present on the graphical schemes.
In conclusion, it should be said that graphical schemes can be executed in an arbitrary form convenient for a solver. The main condition is the logical correspondence to all previously performed steps: correlation with the text description of the conflicts and the presence of the same Product and Tool in the graphical and text descriptions of the conflicts.

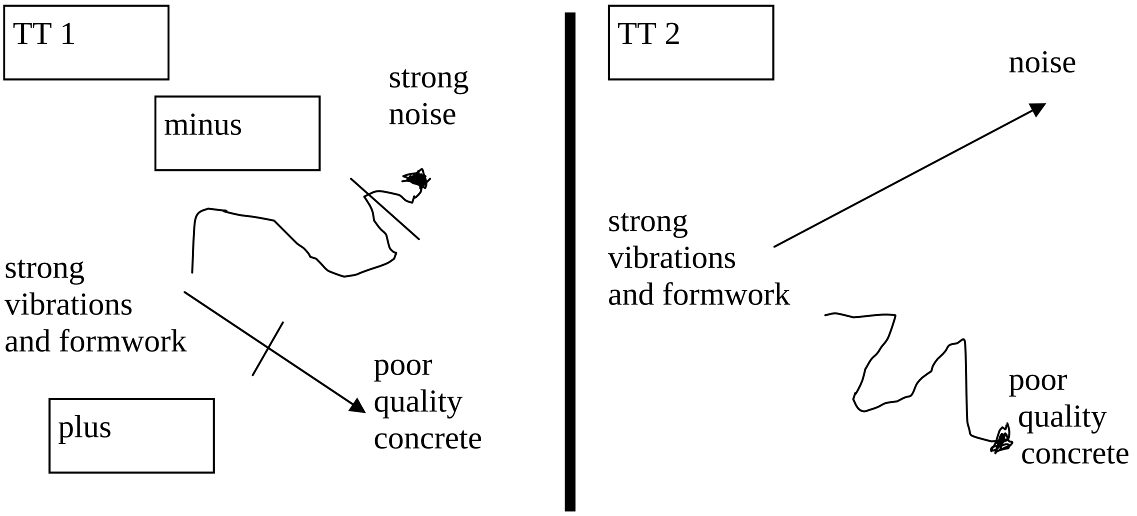

Fig.3: Graphical models of the problem.

Step 1.4. Selecting a graphical model of a system
To build a problem model, we need to select one of the revealed conflicts.
To make a correct choice, OTSM-TRIZ suggests considering the hierarchy of objectives to the system of which the function of the system under consideration belongs.
Such an approach allows a better understanding of what exactly the main production process is in terms of Classical TRIZ. According to the ARIZ rules, it is proposed to select that of two graphical models which potentially improves the realization of the Main Production Process.

TRIZ beginners often confuse the main function of a system with the main production process. To avoid this mistake, it makes sense to start this step with building a hierarchy of objectives. It should be noted that the function and the objective are usually considered as synonyms in terms of OTSM-TRIZ. In other words, the system function is considered as the system existence objective. The main production process is the existence objective (function) of some supersystem to which a system of interest belongs as one of its subsystems.

Example. The Main Function and the Main Production Process.
The function of an electric motor of a lathe tool is converting electric energy into the mechanical energy of rotation. Then the mechanical energy is used to rotate a block of material and move a cutter in different directions. As a result, the block of material is shaped into a necessary part such as a cylinder of an internal combustion engine. Thus, the Main Production Process is the production of internal combustion engines. The Main Function of the "electric motor" system is converting electricity into the mechanical energy of rotation.

To determine the Main Production Process, it is necessary to rise at least 3 or 4 levels above the level of the system under analysis.

1.4.1 The hierarchy of objectives

We need to reduce the noise level. But noise is produced during the performance of the main function by the vibrators.
The vibrators hit the formwork, thereby causing vibrations in the liquid concrete. The vibrations generated are gradually spread in the entire concrete bulk.
As a result, the concrete moves downwards squeezing out the air which got into it during pouring.
As a result, the quality of the concrete pipes produced by this company improves.
High-quality pipes are used for building pipelines of all kinds.

1.4.2. Selecting the graphical model of a problem

According to the analyzed hierarchy of objectives, the building of various transportation systems requires high-quality concrete pipes. Therefore, we are going to use the graphical model which allows producing the best-quality concrete (of high density and homogeneity). In other words, we are going to use the problem model described by contradiction TC-1.

If step 1.1. was performed by using the OTSM Express Analysis of the problem situation, then it would be useful to compare the hierarchy of objectives, obtained at step 1.4., with that obtained through the Express Analysis. If a significant difference is revealed between them, it is necessary to understand its causes and to eliminate them. To this end, we sometimes need to return to the beginning and to check the entire course of the analysis starting with the process of building the hierarchy during the Express Analysis. A solver has to switch attention from problem solving to the reflection about the conducted analysis logic trying to understand where and why the logic was broken causing a significant difference between the hierarchies of objectives and, as a result, a difference in determining the Main Production Process at different analysis stages. In such cases, it often becomes clear that the understanding of the particulars of the problem situation changed in the course of the analysis, but the change remained unnoticed. Hence it is necessary to repeat the entire process of the analysis in accordance with this new understanding of the problem situation.
It should be noted that a problem very often arises through to the absence of a clear understanding of what is happening in a given situation and why some phenomena are considered as

negative. The process of analyzing a problem situation by using the OTSM-TRIZ tool is aimed at better understanding and removing the in-depth causes underlying the occurrence of this problem situation. The problem solving process is organized in such a manner that we can view the identified conflict at different angles just as we do while examining some sculpture.
For better illustration, let us draw an analogy with a video camera. While analyzing a problem, we alternately move away from it to view the situation as a whole and come closer to view some details. Then we move away again and change our position to view the problem at a different angle, verifying the analysis logic and recoding solution ideas arising from subconsciousness. As we do this, our vision and understanding of the problem are being permanently changed and specified.
It is important to mention that in the course of applying the Classical TRIZ and OTSM tools, confirmed was G.S. Altshuller's initial hypothesis that the revealed mechanisms for solving technical problems would also prove useful for solving nontechnical problems. It is only necessary to organize an effective cooperation between TRIZ professionals and experts from narrow subject areas. The OTSM tools moved even farther in this respect. They are practically not connected with any subject area. Whether it be technology or research, business or economics, the OTSM-TRIZ tools allow an effective processing of knowledge in various subject areas. It is knowledge that is needed.
The thing is that analyzing a problem situation in accordance with OTSM-TRIZ often brings narrow specialists to the idea that a problem can be solved by attracting the knowledge from other fields of human activity. Our tools help understanding what kind of knowledge is needed and determining the sphere of activity where this knowledge is used most frequently and effectively. Inviting experts from this area of knowledge may help you find a necessary conceptual solution and bring the general ideas of this solution to a level of detail which enables the implementation of this solution.

Example from my recent practice. One of the students of the innovation design program was developing a project related to the matching of two very small objects for their further assembly. Both he and his colleagues were mechanical engineers. Because most of their knowledge belonged to this area, they were only focusing on finding a mechanical solution to their problem. The problem analysis which they had carried out using OTSM-TRIZ tools brought them to a conclusion that their problem could be solved by supplementing the mechanical part with an optical part. First they were confused because they were not competent enough in the given area of optics. That is why they had never considered and proposed solutions that needed knowledge outside their competence. Nevertheless, ARIZ prompted them to attract specialists from this knowledge area. The company for which the student worked, found respective specialists in optics and, as a result, an application for a patent was filed.

The above example, just as many other examples from our practice, proves that the OTSM-TRIZ tools force a solver to diverge from the beaten track into the area of innovations where very interesting and promising solutions may be found. This peculiar feature of the OTSM-TRIZ tools allows engineers and other users to more effectively create new products and services, to organize business process in organizations in such a manner as to increase the competitiveness of their business under the rapidly changing market of products and services, to make their company capable of steadily producing necessary innovations, doing it effectively and timely. Of course, this requires efforts on the side of the highest level management and respective coordination of efforts between managers and professionals of all levels. But the game is worth the candle. Here is but one example. Samsung Corporation that started introducing TRIZ and the OTSM elements in 1999-2000 came in second in the world with regard to the number of patents registered in the United States, the first place being occupied by IBM. One

of my students employed by IBM told me that such a quick growth of Samsung's innovation potential causes a serious concern at his company…
But let us return to our analysis of the concrete pipes problem.
Having made our choice in favor of the process which ensures a high density and homogeneity of concrete, we thereby also select an undesirable effect which we are going to eliminate using all available resources. The preliminary analysis of the undesirable phenomenon as well as the analysis of the resources potentially available in the initial problem situation will be carried out in the second part of ARIZ. Starting with step 1.4, the negative phenomenon and available resources are always analyzed in parallel and simultaneously. After identifying the details of the undesirable phenomenon, we clarify what resources can be used to eliminate this phenomenon (the second part of ARIZ). Then we see what prevents using the available resources for removing the undesirable phenomenon (the third part of ARIZ). Parts 2 and 3 of ARIZ systematically stimulate the work of subconscious creative mechanisms. The individual nuances of the undesirable phenomenon are being integrated into a more complete and more detailed picture of the occurrence and evolution of the undesirable effect selected at step 1.4. Partial conceptual solutions are arising in parallel. They are tying into a more complete and detailed picture of the future solution to the problem. In this case, to synthesize solutions, solvers may use various tools which are not directly mentioned in the canonical ARIZ text. The ARIZ text is a kind of strategy of using individual tools and theoretical statements of the permanently developing OTSM-TRIZ. Individual ARIZ steps are tactical ploys needed for realizing the strategy. Depending on the development level of the new tools and theoretical basics of OTSM-TRIZ as well as on the awareness of these novelties, the solver performs respective ARIZ steps leading him to a Satisfactory Conceptual Solution.

But before passing to the second part of ARIZ, we have to complete the process of building the problem situation model. Step 1.5. makes OTSM-TRIZ similar to karate. G.S. Altshuller even called Classical TRIZ an intellectual karate. Why? We will answer this question at the next step.

Step 1.5. Intensifying a conflict
Classical TRIZ and OTSM points out, with a high degree of precision, the direction to a solution. However, to move through the labyrinth of the problem, knowing the direction is not enough. It is also necessary to have a "means of transportation" that allows moving in the indicated direction. Such means is often the knowledge in some scientific area. One of the advantages of the Classical TRIZ tools is that they not only point out the direction, but also help to choose a "means of transportation".
In other words, they allow selecting the knowledge which is really indispensable for solving the problem, from a great amount of specialized knowledge. If the necessary knowledge already exists and is available, it brings us closer to the problem solution. If not, the TRIZ tools allow us to clearly understand what knowledge is needed to solve the formulated problem or to find a way to avoid this problem. That is, to change the situation in such a manner as to make problem solving unnecessary.

Example of bypassing a problem.
Many years ago, using a public phone, people had to pay a call by throwing a coin into a narrow slot and there was a special service responsible for regularly collecting these coins. Robbers attracted by this money often broke telephone apparatuses. There occurred a problem of creating an absolutely reliable public telephone sets securely protected against vandalism and robbery.

Many engineers were engaged in the solving of this problem, creating new and new models of

telephone apparatuses. They, however, failed to succeed in this competition with robbers.
What was to be done?
As all of us know today, the problem was solved by entirely changing the approach to paying telephone calls. There was organized a system of selling telephone cards or a direct use of bank cards. Money disappeared from telephone apparatuses and these ceased to attract robbers.

An important step toward solving a problem is step 1.5, intensifying a conflict.
For beginners, it is often difficult to appreciate the creative contribution of this step to problem solving. They unconsciously try to avoid it or perform it formally (just to show that they have performed it). ARIZ is an analysis tool but it cannot replace the analysis itself. Passing formally through all ARIZ stages very often results in a failure to solve a problem. That is why TRIZ-based computer programs do not always lead to a successful solution even if a solver has formally passed through all the stages. These programs help to move in a necessary direction but they are not designed for replacing a thinking person. To understand the recommendations given by ARIZ or TRIZ-based programs, it is necessary to have a good knowledge of TRIZ and to clearly understand how the tools of this theory work.
Let us expand on how step 1.5. works and on the many-sided role is plays, which is actually true with respect to any other step of G.S. Altshuller's Algorithm.
Those familiar with karate or other oriental fighting systems know that the latter includes not only physical motions of a body but also very sophisticated motions of the brain which allow a fighter to perform a necessary motion in the most effective manner.
Once I used one of these thinking mechanisms in wood chopping. But let us start from the beginning.
In karate, there is a general principle of aiming before striking a blow at a respective point of the contestant's body. One needs to mentally focus not on a strike point but on a point that is much farther than the aiming point. In this case, the delivered blow is much stronger, the consumed force being the same.
This principle works very well in wood chopping. You can check it yourself. One should aim not at the top of a log and not even at the surface of the chopping block on which the log stands, but at a much lower point. Then your axe will pass through the log almost without your effort… Why?
One can but admire the fact that the karate inventors found solutions combining psychological, physiological and physical mechanisms.
It turns out that when we are aiming at some point, our subconscious mind gives an order to the physiological mechanisms of our organism, the self-preservation order. As our hand is approaching a blow point, we instinctively, on a subconscious level, begin to slow down its motion for preventing damage of our own body. In this case, first we spend energy on speeding-up and, while approaching the impact point, we spend it on deceleration. As a result, the energy consumption increases and the impact force reduces.
Something like that occurs while working on a problem. A solver is instinctively trying to smooth a conflict underlying the problem and to compromise instead of solving it.
As we know from the theoretical foundations of Classical TRIZ, the tools of this applied theory are aimed at the greatest possible reduction of the number of empty trials and errors under given conditions. Step 1.5 is one of the tools which allow us to reject a great number of compromise, unsatisfactory ideas without generating them. At the start, it looks strange for beginners, but with the assimilation of the entire body of knowledge of OTSM-TRIZ, there comes understanding of how and why it is possible.
The previous steps helped us formalize the problem description and give a more detailed description of the essence of the problem. At step 1.4., we have selected a solving direction, the

point of intellectual blow, on which we are going to focus, not once, our attention at the following steps of the Algorithm.
From the karate terminology, we have selected the aiming point on which we must focus our efforts. Now it only remains to mentally move this aiming point as far away as possible. Then our intellectual efforts will turn out to be more productive in terms of removing the problem and the barriers which hamper its solving.
Let us go back to the pay telephone example. There was a telephone robbery problem. Let us increase the requirements imposed on the solution. When will the robbery of pay telephones become impossible? The answer is quite obvious: when there is no money in them and there is nothing to steal. This general solving direction leads us to an obvious solution: it is necessary to make such a telephone apparatus in which money could never appear. Correspondingly we come to the idea that calls should be paid elsewhere, where money safety is already guaranteed. Thus, instead of the problem of preventing the robbery of public telephones we solve the phone call payment problem.

Let us consider the concrete pipe example. The undesirable effect – strong noise – occurs because it is necessary to compact concrete. There will be no noise if we do not hit the formwork, but then concrete will not be compacted. One of possible formulations of the new problem will sound like follows: there must be no hits on the formwork but concrete must compact itself. This leads to an idea of creating a new kind of concrete. Today, such concrete does exist. However, at the time when this problem was urgent, no such concrete existed. There was also one more important detail. As we have already mentioned, the problem arose at a plant which had no research department capable of creating such concrete. As a result, they had to focus on a mini problem: the concrete pipe production technology must not undergo significant changes but noise must be eliminated or considerably reduced.
The conflict intensification is one of the stages which can be passed purely formally. But his operation will not be able to lead us to a solution until a person who is studying ARIZ has mastered the mechanisms of this stage. The better his knowledge of this ARIZ stage, the higher is his professional level. To properly perform through this step, it is necessary to overcome psychological inertia which prevents finding a solution. Those who are able to do this significantly increase their problem solving abilities. One of the Classical TRIZ tools which can help perform this step in the best possible way is the STC (Size-Time-Cost) operator. We will, however, omit the step performance description and will only give its performance results.

Initial conflict:
The vibrators hit strongly the formwork in order to compact concrete but this causes a strong noise which is considered as a disadvantage under the given conditions.

Because we have selected the mini-problem for solving, we must formulate the intensified conflict as applied exactly to the existing technology:
Intensified conflict:
The vibrators hit the formwork with such a force that the produced noise is insupportable even at a distance of hundreds of kilometers from the pipe production place. This operation induces vibrations which are not dampened (their amplitude is the same in the entire bulk of concrete), thereby proving the best compaction quality.

It should be noted that intensifying a conflict according to the OTSM-TRIZ rules allows passing through stage 1.5. not just formally, but penetrating deep enough into the problem. As we see, to improve the concrete quality we need to provide a necessary vibration amplitude in the entire bulk of concrete. The undesirable effect arouse just because it is necessary to provide a required vibration amplitude of concrete particles in the center of the concrete mass between

two formwork sides. However, due to the concrete properties, vibrations attenuate rapidly while propagating from the wall toward the center of the concrete mass.
One of the rules applied in the above examples points out that the conflict intensification should not be only confined to intensifying the undesirable effect (the strong noise becomes even stronger), but should also forecast the intensification of the positive (desired) effect which we could use (uniform and continuous vibration in the entire concrete mixture).
Step 1.5. proves once again that both the desired and undesirable effects are logically connected with each other. At step 1.5., it sometimes becomes clear that this connection is absent. This means that we have to define the problem in a different manner and it will probably be solved by some typical method.
Thus, step 1.5. also performs the verifying function. It checks whether there exists a cause-effect connection between two evaluation parameters through a control parameter.
After performing the conflict intensification step, an experienced OTSM-TRIZ user already roughly knows where the solution “hides” itself. Nevertheless, even without any special skills in using TRIZ, this stage helps to notice something which slipped attention of specialists who previously worked on this problem, specifically, that to produce a necessary result, it is enough to know how to induce sustained vibrations in the concrete body or how to create vibrations of the concrete itself using resources.

For example, while solving this problem in a classroom, some of the students often come to an idea of producing vibrations by using the reinforcement placed inside the concrete mass.
It is one of the most frequent partial solutions obtained at this step. There are also other solutions, because psychological inertia is beginning to break down and the problem is becoming more and more comprehensible even to specialists who have been dealing with it for a long time.
It is practically impossible to show a beginner all the nuances of work on real problems, only using one problem as an example. The real life will always be much richer than training examples. Therefore, while seriously studying ARIZ, students must solve their own practical problem taken from their professional or private life.
Many ARIZ steps may be used both as self-sufficient, independent tools and in combination with other OTSM-TRIZ tools. However, using them as part of the Algorithm produces better results.

Step 1.6. Formulating a problem model

Step 1.6. summarizes the work done in accordance with the first part of ARIZ. At this step, we play the role of an outside observer and integrate all the results, attained at individual steps, into an organic whole so as to clearly describe the new understanding of the problem situation – the problem model.

1.6.1. Specifying the description of conflicting elements

Now, based on the work dedicated to selecting one of the conflict schemes and on the intensified formulation of the selected conflict, we can again determine the conflicting elements (a tool and a product) and compare them to those identified at step 1.2.:

Tool:
a high-power vibrator which hits very strongly a formwork (vibrator + formwork). It hits the formwork so strongly that sustained vibrations are induced in the entire bulk of concrete.

Product:
a mixture of concrete and air (contained in the concrete)

The product has remained unchanged but the state of the tool has been significantly corrected.

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1.6.2. Formulating the intensified conflict

The high-power vibrator hits the formwork so strongly that the “stirring” (motion, fluctuation, vibration) amplitude of the concrete mixture is virtually not dampened and remains the same in the entire concrete bulk. But the produced noise becomes unbearable.

If step 1.5. has been thoroughly performed, it may seem that its formulation can just be copied. However, it is not worth doing. It would be better to give another thought to how to intensify the conflict still more and to focus on the conclusions that may be derived from the intensified conflict. In the instant case, while intensifying the conflict, we have revealed the best concrete compaction conditions: an equally strong vibration amplitude of the concrete mass over the entire distance between the formwork walls. Now we can correct the desired result description.

1.6.3. Reformulating the desired result

It is necessary to introduce an unknown element or make necessary changes which will be further referred to as an X-element which, on one hand, will provide a necessary force and amplitude of stirring (motion, fluctuation, vibration) in the concrete bulk and, on the other hand, will provide an absolutely noiseless operation of the vibrators.

Note that an X-element is not necessarily a physical object; it may as well be a structural change in the already available elements of an initial system. This is just what we are aiming at: to introduce minimum changes but to eliminate a negative effect preserving and enhancing a positive effect.

Thus, we have analyzed and summarized all the work done in accordance with the first part of ARIZ. In this part, we have obtained a clear formulation of the problem model which we are going to use for analyzing resources available in the system up to the beginning of the third part of the Algorithm. Moreover, as we have already mentioned, due to the conflict intensification, this formulation calls our attention to the recommendation regarding problem solving.

Before finally completing step 1.6, let us use the OTSM rule and separately write out the description of the Positive phenomenon to be preserved and enhanced, giving also a clear description of the negative phenomenon to be eliminated.

The positive effect we want to obtain and preserve by solving the problem:

Obtaining a necessary force and amplitude of “stirring” (motion, fluctuation, vibration) in the concrete bulk.

Undesirable effect to be eliminated:

Noise occurring during concrete compaction. Making possible a noiseless concrete compaction.

As seen, the problem description has been considerably simplified. Now it has fewer details, the essence of the problem being preserved. We do not need to think about different solutions which do not work with this model. Nevertheless, such ideas may occur. They, just like all other ideas, should be recorded separately from the text of the Algorithm steps being performed so as to increase the effectiveness of OTSM-TRIZ-based work on these ideas in due time and not to search for them in the entire text of the ARIZ-based problem analysis.

Step 1.7. Searching for a standard solution

Looking more attentively at the problem model description, one can notice that although the system element “vibrators” is preserved in the problem model description but it paled into insignificance only leaving the function he had to perform: to induce sufficiently strong vibrations of a specific amplitude in the concrete bulk.

Therefore, within the Su-Field problem model, it is worth starting with a su-field model, where we only have one substance and to select a corresponding standard solution or a group of such solutions.

Here is one of the standard solutions recommended by the system of standards for a case that is analogous to ours: only one substance, adding one more substance or field to a system, organizing the interaction of both substances and the field in such a manner that the undesirable effect disappears while the positive effect remains or even improves.

At the given analysis stage, this recommendation seems very vague. However, the subsequent course of analysis will allow us to better understand what substance and field should be introduced into the system so that it can be solved.

The existing version of the System of Inventive Standards proposed by G.S. Altshuller allows the problem to be solved already at this step. But the goal of this material is not demonstrating how the System of Inventive Standards works but describing the work of ARIZ steps if standard inventive solutions do not bring us to a satisfactory solution. Therefore, we omit the detailed description of this step and transition to Altshuller's System of Inventive Standards.

3.2.2 Part 2: Analyzing a problem model

The second part of the Algorithm is designed for revealing and carrying out a preliminary analysis of available resources for resolving the conflict described in the problem model. In this part, we analyze space and time, substance and field resources available in the initial problem situation.

If the problem under consideration is not of a technical character, it will be necessary to analyze other kinds of resources specific for systems which need improvement or which need to be created within the framework of problem solving.

All this is the preparation for the solving process culmination which occurs in the third and fourth parts of the Algorithm.

In the second part of ARIZ, the number of arising ideas usually begins to grow. These ideas often seem ridiculous, unrealistic or just having serious disadvantages. The solvers' typical error is rejecting these ideas without having sufficiently analyzed them, while the reason of rejecting and underestimating them lies in psychological inertia.

All, even the most unrealistic and ridiculous ideas should be registered in a separate protocol, a bank of ideas. This is the general rule of OTSM-TRIZ analysis of problem situations irrespective of whether a Classical TRIZ or OTSM tool is used in the work on a problem.

Step 2.1. Analyzing the operational zone

The goal of this step is focusing, according to certain rules, our brainwork only on the analysis of space where a contradiction arises and checking a possibility of resolving the contradiction in space.

An operational zone is the part of space where a problem arises. It can be identified as the region where the Tool and the Product, identified at step 1.2, have an undesired or unsatisfactory interaction.

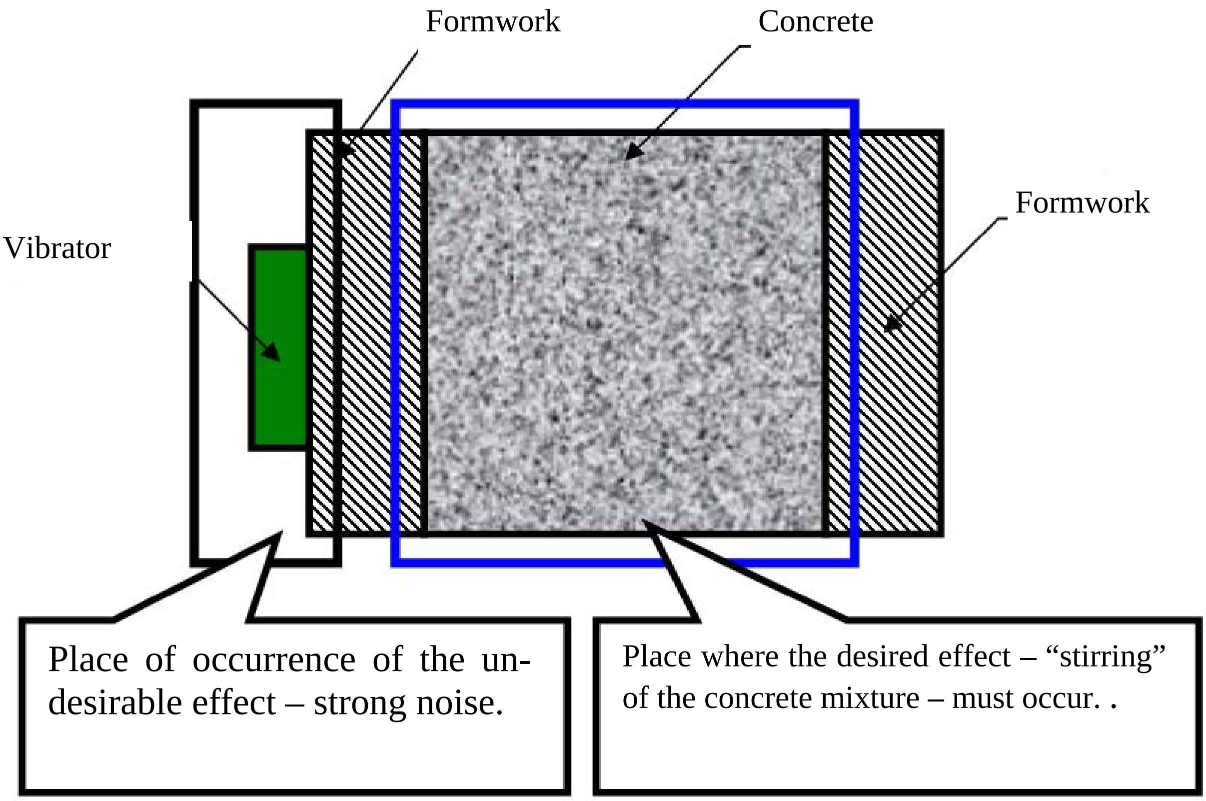

Fig 5: Space zones where desired and undesirable effects arise.

This figure shows that concrete stirring and noise generation occur in different regions of the space.

Analyzing the operational zone figure shows that the zone where the desired effect (stirring of concrete) must arise and the zone where the undesirable effect (air vibration) arises do not overlap in space. This proves the idea that the problem may be solved by separation in space. It is one of the most generalized conflict solutions used within Classical TRIZ. Thus, it is necessary to reflect upon what can be done to induce vibrations in the inner part of the formwork only or even in the concrete only so that there are no vibrations at all in the external part of the formwork or in the entire formwork as a whole. This solution is usually rejected and forgotten by TRIZ beginners, which, however, is a great error. This idea, along with other arising ideas, should be put into the bank of ideas to be used to gradually build the features of the future solution.

This is a kind of prompt to be taken into account and analyzed together with other solution ideas and available resources.

Also note that while describing the desired and undesirable effects, we used a term and gave a short explanation to it. The thing is that according to Classical TRIZ, all professional terminology used in the solving process should be replaced with simple, sometimes even strongly simplified terms which only stress that functionality which is important in a given case. That is why we replaced the term “vibration” with the term “stirring” with regard to the desired effect. For the same reason, the term “noise” is replaced with the term “air vibrations”.

A joint analysis of the term replacement and the operative zone allows us to give some preliminary description of the solution, which will be subsequently specified and supplemented with details. We will describe this prototype of the solution here and now. But we would like to re-

mind our readers that all ideas and combinations of ideas obtained in the process of work on the problem should be registered for their subsequent analysis using OTSM-TRIZ rules and tools.
Thus, let us carry out reflection (summarizing) on the step 2.1. performance analysis.
The problem can be solved by providing concrete stirring only within the formwork, so that the outer part of the formwork does not vibrate and does not induce air vibrations. Then absolutely no noise will occur during the concrete stirring and compaction.
This generalized description may seem too fuzzy, lacking concreteness and unrealistic. Nevertheless, let us register it and continue our analysis. Those more experienced in TRIZ may notice in this description the indication of at least two directions of search for interesting solutions. If psychological inertia still paralyzes the reader's mind, let us go on. If you have arrived at some more or less realizable ideas, you should still continue the ARIZ-based analysis until you reach the fourth part. This will help you to "polish" the obtained ideas and to significantly improve them. In some cases, we can even arrive at absolutely different ideas which will grow out of the above described generalized, fuzzy conceptual solution or out of other ideas obtained in the course of further analysis.
The truth is that summarizing (reflection) should be carried out after each step and the ideas that arise during reflection should be registered in the bank of ideas for further analysis. We, however, do not do this here not to overload the text with superfluous comments and explanations. We are trying to show in a general form the process of analyzing a problem situation and synthesizing a solution.

Step 2.2. Analyzing the operational time

The purpose of this step is focusing, using certain rules, our brainwork only on the analysis of the time intervals during which a contradiction occurs and checking whether the contradiction can be resolved in time.
To this end, we must, just as in case of space analysis, separately analyze the time intervals during which desirable and undesirable phenomena start and finish to occur. Indeed, the operational time is identified as the interval within the Tool and the Product, identified at step 1.2, have an undesired or unsatisfactory interaction.

In our specific case, both the undesirable and desired effects occur at the moment of starting the vibrator and continue till the moment of its de-energizing.
Thus, the time intervals during which the desired effect (stirring of the concrete mixture) and undesirable effect (strong air vibrations) occur are identical.
It is unlikely that we will manage to resolve the contradiction using the time resource, though in some cases it will be possible to change the speed of the concrete stirring process, thereby eliminating the occurrence of sound. For example, if the speed of occurrence of the formwork pressure on the concrete and the speed of eliminating this pressure are low enough, then the formwork vibrations will not generate such a strong noise.
Changing the speeds of the processes is also one of the methods for solving this problem in time.

In order to properly understand the separation in time opportunities it is suggested to become familiar with the System Operator

Comments on the System Operator, ARIZ and TRIZ teaching purpose
Those of the readers who are familiar with the System Operator of Classical TRIZ can notice that, while performing steps 2.1 and 2.2., we analyze a situation along two of the three axes of the System Operator: the time axis and the hierarchy axis.
The TRIZ author, G.S. Altshuller, considered ARIZ as a detailed analysis of a problem situa-

tion according to the System Operator presented in the form of a linear process. By its nature, the System Operator describes nonlinear thinking. As we have already mentioned, the main function of ARIZ is solving a specific nonstandard problem. But the Main Production Process in which ARIZ participates is developing in a solver of the skills of creative thinking built on the System Operator.
The term “System Operator” arose in the environment of TRIZ specialists as a synonym of the fuller name proposed by G.S. Altshuller – “Multi-Screen Diagram of Powerful Thinking. G.S. Altshuller considered the TRIZ training process as a process of development of powerful thinking skills realized in accordance with this multi-screen diagram. ARIZ is one of the most important tools of Classical TRIZ used for forming such skills. A student acquires a complex of these skills with the accumulation of experience in applying ARIZ to various training and real-life problems.
Let us look back and evaluate the performed work from the System Operator application viewpoint.
During our work according to the first part, we initially observed the general picture of the problem situation at the first step. It was a general survey of some fragment of the problem situation according to the System Operator. We considered the system designation (inducing vibrations in concrete for removing air cavities and increasing the concrete density) and its components (subsystems). We also identified the supersystem and the main production process (pipe production) presented in the initial description of the problem.
We also briefly considered the problem situation along the time axis (first concrete is poured into an empty formwork; then vibrators are started and concrete is compacted).
The axis of antisystems was presented in more detail in the form of two problem-solving versions, neither of which is satisfactory (TC-1 and TC-2). The system of contradictions shows us the relations between the System and Antisystem.
We also decided what the supersystem should look like in the future from our point of view (the final part of step 1.1.).
Then we zoomed in on only two system components: the product and the tool. At step 1.3 we again turned attention to the interrelation between the system and antisystems. But this time we presented the conflicts in a graphical form.
At step 1.4., we zoomed out, thereby widening the System Operator zone, and selected the conflict that occurs at the level of the selected system and provides a potentially best performance quality of a sufficiently higher function (Main Production Process). At step 1.5., we focused again on the selected conflict and intensified it mentally.

This fourth axis – the axis of mental transformations – is absent in the classical System Operator. G.S. Altshuller wanted to introduce this axis into the System Operator as early as the 70s, before the publication of the book “Creativity as an Exact Science”. He said that he had rejected the axis of mental changes because he had not managed to find a simple and comprehensible picture for a 4D system operator. It should be noted that the graphical scheme of the operator was 3D in the manuscript of this book but it was replaced with a 2D scheme by mistake during publication. The 2D scheme only has 9 screens whereas the original G.S. Altshuller’s drawing in the manuscript included 18 screens. The axis of antisystems is mentioned in the text of the book but absent in the drawing. During the OTSM development, there appeared an advanced System Operator containing this axis – the axis of mental experiments – as well as some other axes, which were considered equally important by G.S. Altshuller.

At step 1.6., we zoomed out, thereby widening the field of our mental consideration of the situation and described the problem situation model.
In the second part, we are focusing on various resources available in the system, its subsystems and supersystem (Zoom Out). It is just what we are going to do while performing step 2.3.

Step 2.3. Analyzing su-field resources

The goal of this step is focusing our brainwork only on the analysis of substances and fields (material objects) which are available both within the frame of the problem model and within the frame of the entire problem situation. If a problem is related to non-technical systems, subject to analysis are resources on which the given type of system is built: financial resources for business systems; psychology for an individual, social psychology for management and educational systems, etc.
We would like to remind you that step 2.3. only deals with a preliminary analysis of the material substances of the initial situation. Their more detailed, complex analysis will be carried out within the limits of the operational zone within the operational time intervals in the third part of the Algorithm.

2.3.1 Intrasystem resources

The su-field resources of the tool: metal box of the vibrator, electric motor, electric energy, eccentric flywheel, acoustic waves generated by the vibrator and formwork, cables.
The su-field resources of the product: cement, water, gravel, mechanical waves occurring in the concrete bulk.

Intrasystem resources are resources located in the Operational Zone, specified at step 2.1., within the Operational Time, specified at step 2.2.

2.3.2. Outside the system.

The su-field resources of the environment which are characteristic of this problem:
The peculiarity of this process versus the general process which employs this concrete-mixing principle consists in that the formwork is located in a cylindrical recess made in the ground. But locating a sound-insulating cover plate over this recess is undesirable.
The su-field resources of the environment which are common for all problems: gravitation which permits concrete compaction by means of vibration.

2.3.3. In the supersystem

The waste (inexpensive resources) of an external system (if such a system is accessible within the frame of a problem). Really, different plants of a region produce different kinds of waste. In our specific case, we do not know as yet what characteristics the waste we need should possess. It will be possible to obtain answers to these questions while summarizing the results of the 3^{rd} and 4^{th} parts of ARIZ (reflection). The thing is that at the end of the 3^{rd} part and, the more so, after the 4^{th} part, the image of a future solution generally becomes clearer and we can again consider a possibility of using this type of resources.

"Cheap" resources are: external elements the price of which may be almost neglected, such as water and air.

Summarizing the second part:
The analysis of the su-field resources of the system (tool-product) makes one think about the method of generating mechanical waves in the entire concrete bulk without generating acoustic waves in the environment. Such space separation would for certain be helpful in solving the problem.
The analysis of the internal and external resources of the system did not give any clear answer. It, however, pointed out the resources which may be used for solving the problem after we have clearly defined characteristics necessary for performing the useful function. With the accumulation of experience in ARIZ application and liberation of thought, various ideas of using

different kinds of resources are beginning to arise. As mentioned, these ideas sometimes look ridiculous and unrealistic. Nevertheless, they should be preserved in the bank of ideas for subsequent analysis in accordance with OTSM-TRIZ in order to synthesize them into a single operable system of ideas.

At step 1.7., we obtained a prompt from the System of Inventive Standards that in addition to the concrete mixture, there should appear some second substance and field in the operational zone. We have a very dim idea of them as yet. It is only clear that they must ensure concrete stirring within the formwork in the entire bulk, with a necessary sustained amplitude, without generating strong air vibrations beyond the formwork.

Readers who are more experienced in TRIZ and ARIZ could probably add that all this must cause minimum changes in the system, that is, must use the initial system resources available at the plant – vibrators.

When we develop a new system and our system only exists in our mind at first, we have much more possibilities to select resources than when we deal with an already existing system. The second case is generally typical for production companies where some equipment has already been used but this equipment does not satisfies all the requirements made of the technological process. TRIZ beginners often face difficulties while analyzing already existing systems and their components. These difficulties are due to psychological inertia inherent in anyone. We wish to find a ready solution to a nonstandard problem, just as is the case with standard problems. If there is some standard problem corresponding to some typical problem description, then, to solve this problem, we need to use a corresponding standard solution.

When, on the contrary, we are dealing with non-standard problems, this approach is impossible and much effort is required to cope with our own psychological inertia in order to destroy thinking stereotypes affecting our thinking process and search for creative solutions. We should be ready to decompose the existing systems into independent components, consider these components as absolutely independent resources and try to understand how one or another component can help us solve our problem…

It is necessary to mention one very important moment for problem solvers, especially for managers.

The thing is that using OTSM-TRIZ tools in our work, we overcome, step by step, our psychological inertia. As a result, an obtained creative solution is so different from known standard solutions that it is usually immediately rejected by the people who have not participated in the solving process and, therefore, are unable to immediately accept the obtained solution; they are often not even ready to discuss such an extraordinary solution. This situation usually occurs when obtained ideas are too prematurely presented to managers. Being unprepared by the solvers, managers generally reject unusual ideas, because they are still influenced by psychological inertia unlike the solvers who have managed to overcome it in the course of work on the problem.

In 2000, we worked for one of the well-know European companies trying, together with the specialists of that company, to solve some problems. The obtained solution was unusual: the problem could be solved by replacing a monolithic piece of metal with a metal brush. It was something unprecedented in this industry. When that solution was submitted for approval to the manager, the latter just threw the sheets of paper where the ideas were described into a waste-basket without giving the specialists two or three days more for modeling the ideas on a computer.

The company invited OTSM-TRIZ specialists because the problem was complicated. We worked on it all together using OTSM-TRIZ tools. Step by step, we were producing new ideas, overcoming psychological inertial and generating new, creative ideas, trying to integrate them into a system of solutions and to build a solution which would be acceptable to the company. Much money and the specialists’ working time had been spent. It seemed that allocating other

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two or three working days of one specialist for simulating and testing the solution were not a problem and were worth the candle. The developers went to the manager for solving a seemingly simple question of allocating the time of one person for performing computer modeling of the obtained solution but ran against a volitional, ill-founded emotional decision to fully stop the work…

All of us were very disappointed.

It is not an extraordinary example. There were also situations in our practice when solutions rejected by managers were found and introduced by competitors after a time.

This is the price paid for the premature presentation to managers of obtained nonstandard, creative solutions to persistent world-level problems.

Managers are usually very busy and overloaded. Permanent work under stress, lack of time and the necessity to coordinate complicated processes sometimes prevent them from making well-founded decisions. Before submitting new, nonstandard ideas for their consideration, it necessary to think twice how to help them overcome psychological inertia within several minutes (specialists themselves usually spend several weeks or months doing this).

Unfortunately, managers themselves are generally unaware of ineffectiveness and irrationality of some of their decisions. In this connection, it would be interesting to remind about the research results given in the IBM's report dedicated to innovations in the companies worldwide. The report states that 85% of managers think they are able to make right decisions. At the same time, the results of another research prove that 65% of decisions made by managers are cancelled or undergo significant correction because of their inefficiency…

Altshuller's study of numerous situations related to the introduction of new ideas demonstrated that the higher the idea's novelty level, the stronger is the resistance this idea encounters on its way to implementation…

The paragraph, describing the relationship between managers and problem solvers, seems to be in no way related to the problem under consideration and TRIZ. But the thing is that the tools created within the framework of Classical TRIZ and OTSM development often allow finding nonstandard technical solutions containing a high innovation potential. Companies often reject such solutions on that ground that nobody does in this way and, thereby, lose patent priority, which, in its turn, leads to lost profit. Later, they bethink, come to TRIZ experts, express regret and ask for help in circumventing the competitor's patent…

Unfortunately, such situations are not infrequent in our practice. Ideas are often rejected not only by managers but even by the working group members. The combination of psychological inertia, when people do not want to accept partial solutions because those seem empty and unnecessary, with certain personality features of a specific man sometimes stops any work that does not lead to known standard solutions. Complicated nonstandard problems cannot be solved by applying standard solutions known to professionals. That is why they are difficult to solve. Solving such problems requires stepping over the bounds of traditional thinking. Violating the canons seems inadmissible to such people and they do their best to block the work of the working group which uses OTSM-TRIZ for solving the problem, and try to bring the work back to familiar solutions which do not work in a given case. This causes a considerable damage to the company's interests.

Looking ahead, we must say that the solution to the described problem also met with a strong resistance at first. Yet the solver was given a chance to prove the realizability of the obtained ideas.

The reverse is also possible. An obtained solution is so simple and easy to implement that managers think that it was quite obvious and there was no need to invite TRIZ experts. At the same time they often forget that the company's best intellects have grappled with the problem for months and years without finding a satisfactory solution version. Nevertheless, the OTSM-TRIZ tools helped the specialists to overcome thinking inertia and to choose quite an unex-

pected solving direction where a simple and seemingly simple solution was found. All the above proves that the Classical TRIZ and OTSM tools are helpful in effectively overcoming psychological thinking inertia. Thus, one should understand that the first attempts to present an obtained solution will run against psychological inertia and cause incredulity of colleagues or rejection.
The psychological inertia of both specialists and managers often cause a huge damage to their own interests as well as to the interests of their companies.
We have touched upon a very serious problem related to innovation projects. It turns out that having effective tools for producing innovations is not enough to succeed in applying innovations. Serious changes in the corporate culture and structure of a company are also required…
In this area, innovation ideas of overcoming management's psychological inertia are needed.

3.2.3 Part 3: Determining the ideal final result (IFR) and physical contradictions which prevent obtaining IFR.

The third part of ARIZ differs markedly from the previous ones in structure and performance of the algorithm steps.
In this part, actions leading to a problem solution change their direction. In the previous parts, we primarily dealt with analysis (parts 1 and 2) while in the third part of ARIZ we pass to the activity which is first aimed at synthesizing Partial Solutions and then at synthesizing Satisfactory Conceptual Solutions (parts 3, 4 and 5). The third part is a kind of problem analysis culmination and transition to the synthesis of a Satisfactory Conceptual Solution.
We would like to remind that TRIZ tools are designed not for search for a solution, but for a planned, stage-by-stage creation of a solution image that would be sufficiently detailed to ensure transfer to the development of a prototype or a computer model for testing the obtained conceptual solution.
The image of a future solution is built step by step and is becoming increasingly clear. The image is created through the accumulation of conceptual solutions which partially correspond to technical requirements. We call these solutions "partial" because they only solve a problem partially. Partial solutions serve as a raw material for creating a Satisfactory Conceptual Solution. A satisfactory solution is obtained on the basis of partial solutions by using various Classical TRIZ and OTSM tools.
Those elements of partial solutions which prevent them from being full solutions can be presented in the form of requirements that should be met by any satisfactory solution. It is a kind of additional technical specification. Applying OTSM-TRIZ tools to this technical specification, we build additional partial solutions which are then integrated into a single system of solutions – Satisfactory Conceptual Solution.
This is the advantage of using the "partial solution" notion: revealing the reasons for which a partial solution cannot be considered as a satisfactory solution allows us to specify technical requirements and to better identify the restrictions to be observed while creating a Satisfactory Conceptual Solution. The Satisfactory Conceptual Solution makes it possible to create a technical solution: drawings, computations, etc. The technical solution will allow us to create a prototype which, when tested, will lead us to an improved solution version.
Thus, proceeding to the third part of ARIZ, we should aim at the solution synthesis but, at the same time, perform a needed analysis. In this situation, ARIZ can be compared with the blood-vascular system of a human body. The first and second parts of ARIZ correspond to arteries carrying information about a problem. The third part of the algorithm is similar to a capillary network where the collected information is changed and gradually turned into a solution. Partial solutions together with critical comments form brooks of ideas feeding an emerging image of a satisfactory solution. This part also threads all subsequent parts of ARIZ just like the blood

flowing in veins. Now let us look at how the problem analysis gradually changes into the solution synthesis in the course of ARIZ implementation. This transition occurs simultaneously in several parallel branches merging at the end of the third part of ARIZ.

Step 3.1. Formulating the ideal final result (IFR)

The goal of step 3.1. is reformulating a problem once again so as to start gradually synthesizing a solution. This stage is dedicated to determining the problem description for further use and requirements to be satisfied while solving the problem. Subsequently, we will use the problem description obtained at step 3.1. instead of the problem model produced at step 1.6., because in the second part of ARIZ we specified the details of the place and time of the problem occurrence. In addition, we made a preliminary list of resources that can be used for solving the problem. All this will lead to a transformation of the problem model at 3.1.

It is often said that a well defined problem is at least half of a solution. That’s why the idea of specifying a problem and requirements imposed on a solution runs through the entire ARIZ.

IFR-1:

X-element, without complicating the system and without causing any harmful phenomena, eliminates the undesirable effect – “strong noise” during the <Operational Time> inside the <Operational Zone>.

In other words, the undesirable effect must not occur in the environment surrounding the vibrators (outside the formwork) when the vibrators work and hit strongly the formwork for compacting the concrete mixture.

At the same time, the vibrators must preserve their force and amplitude required for compacting the concrete mixture throughout the entire formwork volume.

Already at this problem specification stage, some new ideas may come into readers’ heads or some old, long-forgotten ones may come back. Because of psychological inertia, those known solutions were not previously connected with the given problem in our consciousness.

As seen, performing the ARIZ steps results in planned specification of the problem causes and the requirements imposed on a future solution. At the same time, some new solving ideas are beginning to appear. Even if these ideas seem quite realizable and ready for implementation, it is worth proceeding with the problem analysis until the forth part is reached. This is an obligatory ARIZ rule. The thing is that all ARIZ steps are lined up in accordance with the system evolution laws. Performing these steps, we essentially follow the system evolution laws. And an obtained solution may be developed and improved by performing subsequent steps of the algorithm.

We can write down in the **bank of ideas** (a special notepad where we collect partial solutions) that one of possible conceptual solutions consists in placing vibrators within the concrete mixture. Then the noise level will be considerably reduced. However, formwork users are against this solution.

As we have already explained, to help in creating a problem solution description, objections to proposed solutions and critical comments should be turned into requirements.

In our case, the idea of placing the vibrators within the concrete mixture looks very attractive because concrete itself can play the sound insulating role and reduce the noise level around the installation. However, the external requirements imposed on the production process do not allow placing the vibrators within the concrete mixture. Thus, we can formulate a new requirement for the solution: it is necessary to provide vibration inside the concrete mass without introducing any mechanisms which would be impossible to remove after concrete hardening… How can this be achieved? It is not easy to say but this idea should also be recorded in the **bank of ideas**, no matter how ridiculous it looks.

Step 3.1. is preparation for executing step 3.2. All other ARIZ steps work in exactly the same manner – executing one step prepares our thought for performing operations of next steps.

Step 3.2. Intensifying the IFR-1 formulation

At step 3.2., the analysis is beginning to turn into the first steps of solution synthesis. The thing is that IFR formulated at step 3.1. should be replaced with one of the resources described at step 2.3. Now one of the mechanisms for overcoming psychological inertia comes into play. To master this mechanism, one should have some experience and be familiar with other TRIZ tools. The key idea of the third part is studying the causes which prevent obtaining solutions, satisfying the requirements described at 3.1., by using one of the available resources. The analysis mechanism proposed by Altshuller stimulates subconscious creative processes which sometimes result in jokey and sometime in very serious partial and even satisfactory solutions. The appearance of jokey solutions is a good mark. It shows that we are gradually destroying psychological inertia and are beginning to think more openly, as they say in the United States, “to think out of the box” which hinders imagination and thinking and wherein we were held by our professional education which developed in us professional thinking inertia within the limits of standard solutions to standard problems.

Standard solutions constitute professional wealth and skills in any line of profession. They help professionals solve problems quickly and effectively, until they face a non-standard problem that cannot be solved by means of professional standard solutions. In many cases, systemic use of OTSM-TRIZ tools results in that an initial problem which originally looked non-standard acquires the form of a standard problem, not only from the OTSM-TRIZ viewpoint, but also from the viewpoint of narrow specialists. This often happens at the end of the first part of ARIZ. But even in such cases, it is useful to proceed to the end of the fourth step of ARIZ. The experience of TRIZ specialists proves that solutions obtained in the first part may be considerably improved and an entire range of satisfactory solutions may be obtained and used for creating a range of products.

The ideas collected in the bank of ideas during the performance of the ARIZ steps or application of any other OTSM-TRIZ tools can be divided into three groups. The first group includes ideas that can be implemented quickly enough. The second group consists of ideas which require some time for additional research and development, purchase of equipment, etc. The third group is composed of ideas which are left for the future, the ideas about the system development direction and about new products, services and technologies which can be created with the time.

Unfortunately, OTSM-TRIZ is often considered as a tool for removing emergency situations, when a solution needs to be obtained and implemented now and here. This is generally the competence of lower management at the point where an emergency situation arises. They have to eliminate the problem at any cost. Banks of ideas are not their competence. It is the competence of higher level managers, sometimes even of the highest level such as heads of organizations or companies. Managers of this level are generally unaware of the OTSM-TRIZ existence and the opportunities it offers to upper management. The second and third groups of solutions are but a relish of what could be used by upper management in their difficult work. OTSM-TRIZ can also offer assistance to heads of subdivisions engaged in the development of the strategy and evolution of a company and business. In this case, however, ARIZ is included as an element of more complicated OTSM tools.

For brevity sake, we are only dealing here with three parallel ways of using three resources: the vibrator, formwork, and concrete mixture.

TRIZ beginners are usually bewildered by phrases built according to TRIZ rules. Indeed, from the linguists’ point of view, these phrases are not quite correct. The advantage of these phrases consists in that OTSM-TRIZ can play the role of interdisciplinary language in work on compli-

cated and/or interdisciplinary problems. This language is designed for work on problems which usually become more complicated due to the use of the ordinary language because the latter causes psychological inertia. In addition, the ordinary language is well-adapted for use as the means of communication but does not always allow us to effectively solve problems. Sometimes, a good literary language even hampers problem solving. At the same time, a good figurative language is often a helping hand to OTSM-TRIZ in dealing with a problem. OTSM-TRIZ tools create image features – partial solutions.
The figurative language allows these separate features to be synthesized into a single image. That is why Tatyana Sidorchuk has developed a special pedagogical technology for teaching children to find metaphors and compose metaphorical figurative statements. This method is currently used by adults in advertising for creating figurative texts and video clips. The standard language, everyday phrases and expressions are often carriers of psychological inertial. This inertia can become an insurmountable obstacle to finding a problem solution. It means that one should boldly build phrases according to the OTSM-TRIZ rules even if these are not always beautiful and often do not originally have any literary value …

Intensified IFR-1, using the "Vibrator" resource.

The vibrator itself, without complicating the system and without creating undesirable phenomena, eliminates the undesirable effect: "strong noise" in the space surrounding the system of vibrators (i.e. outside the formwork) when the vibrators work and hit the formwork very strongly for compacting the concrete.
At the same time, the vibrators provide the vibration force and amplitude required for compacting the concrete mixture in the entire volume confined by the formwork.
After writing down the formulation of step 3.2 for the "Vibrator" resource, it is necessary to identify those Control Parameters of this resource which determine the "Noise Level" and "Concrete Density" Evaluation Parameters.
In our case, both the parameters depend on the Control Parameters:

- Vibrator hit force
- Formwork vibration amplitude created by the Vibrator.

Can you say which other parameters influence both the Evaluation Parameters simultaneously?
Dear Reader, try to perform the subsequent steps of ARIZ with the parameters you yourself proposed.

Intensified IFR-1, using the "Concrete Mixture" resource.

The Concrete Mixture itself, without complicating the system and without creating harmful effects, eliminates the undesirable effect: "strong noise" in the space surrounding the system of vibrators (i.e. outside the formwork) when the vibrators work and hit the formwork very strongly for compacting the concrete.
At the same time, the Concrete Mixture does not prevent the vibrators from providing the vibration force and amplitude required for compacting the concrete mixture in the entire volume confined by the formwork.
After writing down the formulation of step 3.2. for the "Concrete Mixture" resource, it is necessary to identify those Control Parameters of this resource which determine the "Noise Level" and "Concrete Density" Evaluation Parameters.
Dear Reader, try to find those parameters of the "Concrete Mixture" Resource which affect the Concrete Density. Make a list of those parameters.
The next step is writing a list of the "Concrete Mixture" Resource parameters which influence the "Noise Level" Evaluation Parameter of our system".
Compare the two lists and make a separate list of parameters which influence both the Evaluation Parameters simultaneously.

The following algorithm may be helpful while performing step 3.2.

- Replace “X-Element” with “[Resource] ITSELF”. The word [Resource] should be replaced with the name of a corresponding resource.
- Identify in the Intensified IFR Formulation the names of two Evaluation Parameters the values of which should be provided at a necessary level.
- Using your knowledge and/or the knowledge of experts, identify a list of Control Parameters for the first Evaluation Parameter. Changing the values of Control Parameters can change the values of Evaluation Parameters.
- In the same way, create a list of Control Parameters which will allow you to change the values of the second Evaluation Parameter.
- Compare the two lists of Control Parameters and identify those of them which allow changing both the Evaluation Parameters. They will be later used for performing steps 3.3. and 3.4. of ARIZ
- The absence of common members in the lists of parameters is one of the signs that the problem can be solved by changing corresponding parameters of that Evaluation Parameter which needs to be improved for providing the best possible performance of the Main Production Process (the Main Objective for which the given problem is being solved).

It should be stressed that the Main Production Process (the Ultimate Goal of solving the given problem) is the function of one of the super-systems located in the System Operator 3-4 levels above the system level where the given problem is being solved.
While describing an initial problem situation and selecting a Product and a Tool at step 1.2., one should not confuse the Main Production Process (MPP) and the Main Function of a system indicated at step 1.1.

Similarly to other additional recommendations regarding the performance of ARIZ steps, this algorithm was proposed in the course of research into the transformation of Classical TRIZ and its tools into OTMS and its tools.
OTSM has developed similar detailed procedures for each ARIZ step. Their detailed description is beyond the scope of this paper. Mastering these procedures constitutes the main production process of ARIZ assimilation. This review is part of the system of in-depth training in professional ARIZ secrets, just like concrete vibration is part of production of large-diameter concrete pipes which are then used to build pipelines. Laying a pipeline is the Main Production Process (MPP) for the sake of which vibrators compact concrete.
Making, together with specialists, a list of parameters which may be used for changing concrete density, we can find such of them which can increase concrete density without producing noise. This leads us to the idea of creating the currently well-known self-compacting concrete. But the problem arose many years ago when this type of concrete did not exist. Creating such concrete required research-and-development activities. The problem was that the production plant where this problem occurred did not have any R&D departments. In addition, the situation was urgent and a solution which would entail minimum changes of the production process had to be found as soon as possible.
As is seen, ARIZ brings us to interesting ideas. Sometimes, some of these ideas seem unrealizable under conditions existing at the moment of their occurrence. TRIZ and OTSM history knows many examples when ideas of this type were rejected at the moment of occurrence but were later implemented.

It should be noted that ARIZ application often results in a number of ideas that can be and must be classified into three groups.
The first group includes ideas which are immediately accepted for implementation.
The second group consists of ideas which require some minor research or acquisitions. Or it is just necessary to wait for some propitious moment in the company's life, for example, change of production equipment or manufacture of new moulds for the production of plastic articles.
The third group is formed by ideas which require considerable time and investments. Some of these ideas may look fantastic or even unrealistic. Nevertheless, even such ideas should be put into a special bank of ideas. After a time, these ideas will be analyzed using Classical TRIZ and OTSM methods designed for transforming the unreal into what can be implemented under certain conditions.
Fantastic and unrealistic ideas should be accumulated and discussed, if only because they shatter and defeat psychological inertia and help to create an image of the Most Desirable Result (MDR) we are trying to approach. How this occurs, what tools are used is beyond the scope of this review and is the subject of more intensive courses in Classical TRIZ and OTMS.

Intensified IFR-1, using the "Formwork" resource

The Formwork itself, without complicating the system and without creating any harmful effects, eliminates the undesirable effect: "strong noise in the space surrounding the system of vibrators (i.e. outside the formwork), when the vibrators work and hit the formwork very strongly for compacting the concrete.
At the same time, the Formwork does not prevent the vibrators from providing the vibration force and amplitude required for compacting the concrete mixture in the entire volume confined by the formwork.

At the first glance, such a formulation seems to offer nothing beyond what we already know. This, however, is a superficial glance, because ARIZ is a tool for thinking but not instead of thinking…
Let us give this formulation, produced in a formal manner, a step-by-step consideration. One of ARIZ remarkable features is that one can formally perform all its steps without actually making a single step toward a solution. Thus, after performing each step, it is necessary to look at it as if from the outside and to think what new strokes may be added to the solution image, what new understanding of the situation can be derived from the diagram or formulation obtained by performing the given step.
Let us do this work together:
The question the Solver asks to himself or to experts:
When won't the formwork produce noise?
The Solver's answer to himself (based on his own knowledge or the knowledge he acquires from experts who are able to answer this question:
The formwork will not produce noise if it is not subjected to deformation and does not work as a membrane producing air vibrations in the formwork-surrounding space.
The question the Solver asks to himself or to experts:
When won't the formwork prevent the "vibrators" from transmitting energy, required for producing concrete vibration of a necessary amplitude and force, to the concrete?
The answer:
The Formwork will not prevent energy transmission from the vibrators to the concrete if it is absent in the energy flow way.

Considering the answers to the questions:
In the initial system, the formwork performs the role of transmission by transmitting energy from the vibrators to the concrete. That is why it moves forward and backward due to the action of the vibrator's impacts and elastic stresses produced by these impacts. These movements (vibration) of the formwork cause vibration of both the concrete in the formwork and the air around the formwork.
We do not need air vibration around the formwork but we need concrete vibration within the formwork.
The formwork will not vibrate if the vibrators do not hit it. But the vibrators must hit it to impart energy to the concrete.

Conclusion:
If the formwork is not subjected to vibrator hits, there will be no noise, but it will be necessary to provide energy transmission through the formwork - from the vibrators to the concrete.
In other words, energy should be transmitted through the formwork without producing vibration in it.
It is very important to note that reformulating a thought several times using different words is one of the mechanisms for reconsidering already available ideas (models) regarding an initial situation. It is also a mechanism for stimulating subconscious creative processes by means of the solver's own conscious. In addition, rewording (different verbalization) and use of imagination or drawings (visualization) for presenting an initial problem situation and a situation to be formed by solving a problem are mechanisms for overcoming psychological inertia and breaking thinking stereotypes which are an obstacle to problem solving.
To fight against psychological inertia, it is necessary to replace professional terms with simple, functional terms. This should be done starting with the first ARIZ steps during the entire analysis. Our stereotypes insist on using professional terms. But professional terminology is a good tool for work with standard professional problems. In work with non-standard problems, however, this terminology turns into one of the strongest obstacles to finding a solution. Professional terms produce musty images whereas solving a problem requires use of flexible, dynamic, functionality-reflecting images.
In our case, it is useful to replace the term "vibrator" with the term "vibration energy generator". The term "formwork" can be replaced, for example, with the term "concrete molder".

Continuation of the Conclusion (Partial Solution):
Thus, the vibrators and formwork must change in such a manner as to be able on the one hand to perform all their functions and on the other hand to remove negative phenomena without causing new undesirable effects. Both the formwork and the vibrators must change without changing, i.e. they must change not to produce harmful phenomena and must not change to be able to perform their functions.
The "formwork" Parameters (Characteristics, Properties) which affect both the noise around the formwork and the concrete quality:

- Formwork flexibility
- Susceptibility to mechanical energy
- Stiffness, hardness, the ability to serve as a damper.

ARIZ steps and rules effectively direct our thinking; therefore, teaching TRIZ is reduced to teaching students to understand (to feel, according to some professionals) how, where and when ARIZ directs our subconscious creative thinking. As a result, regular use of ARIZ causes development of parallel thinking along the axes (subspaces of parameters) of the System Operator: Hierarchy of system levels (Subspaces of the system level parameters); time-dependent Characteristics of different-level systems – the Time axis (Subspace of parameters); the Anti-

System axis (Subspace of systems which challenge our system, hamper its operation and stimulate its development).

It should be noted that the System Operator is a much deeper content of the model which, with a sketchy knowledge, is a ”Nine-Screen Scheme”. According to G.S. Altushuller’s concept, ARIZ is not so much a problem-solving tool as a tool for developing System Thinking based on the Classical TRIZ System Operator. Developing in ourselves the ability to use these thinking tools we also develop in ourselves complex problem solving skills. It is very important for mastering ARIZ. One can remember all ARIZ rules, comments as well as all classical examples of ARIZ application by heart, but be unable to use ARIZ in practice.

ARIZ-based thinking or thinking based on the Classical TRIZ System Operator can only be developed through practically solving training and real-life problems. Merely understanding the ARIZ operation logic is not enough. ARIZ is a tool which helps a solver activate, feed and direct his own subconscious creative processes. ARIZ also offers rules for work with knowledge from various areas and for integrating this knowledge with the method. This allows a specific problem to be solved in a specific context but on the basis of a common universal procedure.

Adults only achieve in-depth understanding and assimilation of ARIZ through practically dealing with problems, the teacher’s role being very much like that of a pilot’s instructor. First a future pilot studies separate aircraft fly rules on training simulators. Then he gets on a plane and puts his hand on a control lever. He does not fly the plane but feels all the instructor’s actions through the control lever. Then the instructor allows the beginner to fly the plane but is ready to control the plane by himself if necessary. As the plane control skills are formed in the beginner pilot, the instructor interference in the flight control process becomes increasingly rare. Finally, the beginner pilot is allowed to fly a plane all by himself without the instructor’s supervision. Further development of skills occurs independently through permanently practicing in the air and on the ground. The same occurs while teaching ARIZ.

A professional TRIZ specialist conducts a beginner through ARIZ step by step. As good ARIZ application skills starts forming in the beginner, the latter performs more and more ARIZ steps by himself. The ARIZ mastering process has several stages: acquaintance with ARIZ rules and steps; ARIZ application to training problems and gradual formation of skills of performing separate steps up to the level of full assimilation of ARIZ. The second stage has two substages: first, the student starts using ARIZ rules and steps at a subconscious level without being aware of it. The second substage is transition to consciously performing ARIZ steps at a subconscious level. As a result, the student learns to deliberately use the ARIZ thinking style in his everyday professional and private life. It happens in much the same manner as with a foreign language as a second spoken language when we use it outside our native country.

We have shown how an initial problem is being broken into subproblems at step 2.3, each subproblem illustrating a possibility of solving the initial problem by using one or another resource.

It can be said that training in ARIZ is reduced to the development of the ability to see, understand and accept gradual modifications of a problem situation as well as seemingly unrealistic problem formulations and partial solutions. Sometimes, these formulations seem stupid, unfeasible, inaccessible and impossible to beginners. Accumulating the ARIZ and TRIZ application experience as a hole, they start understanding that solving a non-standard problem requires that we outstep the boundaries of the notions of what is possible and what is impossible.

These new problems and partial solutions should be thoroughly considered for overcoming psychological inertia.

To deal with these new, seemingly unsolvable problems and with seemingly unrealistic or inapplicable solutions, it would be useful to use the OTSM Axiom of the Impossible and corresponding tools for practical application of this theoretical Axiom.

These tools help overcome our prejudices concerning the possible and the impossible in real life. These tools allow us to turn the “impossible” into the “possible”. More detailed description of these tools is beyond the scope of our short introduction to ARIZ.

Special stress should be laid on the fact that a non-standard problem appears just because standard, real, tried solutions do not suit us in the context of a specific situation. To find a solution, we need to outstep the boundaries of stereotypes of the possible and the impossible. For this reason we should not reject unusual ideas just because they initially seem impossible. During the execution of one of the projects, each meeting of the company’s specialists with TRIZ specialists started and finished in the same manner. First, the TRIZ specialists presented to the audience the outcome of the problem situation analysis and some ideas obtained as the result of that analysis. And each time the first words of the company’s specialists were that the ideas were of no worth, unrealizable and that nobody ever did like that.

Each time, after a half-hour analysis of the reasons for which a partial solution could not be implemented, it became clear that something could be done in that direction and the solution could be somehow put into practice. The project was not unique from this point of view. This situation is not infrequent. Really unique was that the company’s specialists answered all questions practically immediately, carried out necessary mental experiments and were eager to discuss seemingly very strange solutions. The thing was that they had worked on the problem for over six years and had carried out many experiments, gained rich experience regarding the problem essence and components. Unfortunately, this situation is not common.

The second reason why the project can be considered unique is that a new unexpected solution was obtained and accepted by the specialists. Much more time was spent to convince the company’s managers. As a result, the managers came to a conclusion that the solution was very interesting and useful and had to be patented. While patenting, it became clear that on those very days when the question of accepting the solution was being discussed, an application for a similar patent was filed by one of the competing companies. An important conclusion is that a successful innovation work of a company requires a corporate innovation culture. Having effective problem-solving methods is not enough. Effective use of produced innovative ideas in companies requires creation of a special system of work with innovations. Innovation activity differs strongly from the company’s everyday activity. The experience of my colleagues – TRIZ specialists – proves that companies are not ready today for work under the market-dictated conditions of permanent innovations.

Transition from dealing with separate innovation problems to systematic control of flows of such problems may prove to be a significant competitive advantage of a company. Such work requires a corporate innovation culture which, in turn, differs strongly from the principles underlying currently existing corporate cultures. Companies which will be first to resolve the problem between the existing culture and a corporate innovation culture will gain significant advantages over their competitors.

The third peculiarity of that project was that the discussion about these accidental coincidences with my old colleagues, TRIZ professionals, revealed a tendency for more frequent occurrence of such coincidences. What could not be noticed by one TRIZ specialist became evident to a group of professionals each of whom had over 25 years of TRIZ work experience… The impression is that companies are starting to use TRIZ elements in their work more and more often, which allows them to find effective solutions to problems. Solutions patented by these companies are increasingly difficult to circumvent even using TRIZ tools. This results in one more competitive advantage. Among other things, systematic use of TRIZ elements along with a corporate innovation culture will allow such companies to organize a permanent flow of innovations of products and services as well as of the company itself and the company’s business. Under the modern conditions of keen competition all over the world and a rapidly changing market, business cannot be random. Random trials and errors are costly for companies and investors. The problem of the quickness and successfulness of innovations is becoming urgent. This seems not to be related to the topic of the material – short introduction to ARIZ. However, as we have already mentioned above, working according to ARIZ rules brings us to a number of strong, effective and advanced solutions. These solutions can be split into three groups: solutions to be implemented "today", "tomorrow" and "in the foreseeable future". This a kind of company's product evolution forecast. This, however, occurs today at the level of subdivisions and managers who, due to their position, are only interested in implementing obtained solutions "right now", without thinking about the future of the company and its business. Results which are important for strategic planning are just thrown away. It is collecting, organizing and analyzing this kind of information that require a new corporate culture that would encompass all company's levels. Future leaders of successful innovation companies are starting their work today. They are rethinking the existing corporate culture and scheduling its gradual but effective transformation into a corporate innovation culture. ARIZ, Classical TRIZ and OTSM can make a significant contribution to solving this difficult management problem. Creating highly effective innovation companies equipped with a corresponding corporate culture is a serious challenge to the management of the beginning of the 21st century.

It is a very interesting topic where ARIZ-type thinking can offer new ideas and trends. So let us go back to ARIZ

See also:
4.1.2 – Model of a Minimal Technical System
4.2.2 – Classification of standard solutions

4 SU-FIELD ANALYSIS AND STANDARD SOLUTIONS

4.1 – SU-FIELD ANALYSIS AND STANDARD SOLUTIONS: BASIC NOTIONS AND RULES

Definition

Su-Field analysis is a TRIZ modeling technique aimed at representing the behavior of a Technical System in terms of elements and interactions

The Standard Solutions are a system of prescriptions for the synthesis and the transformation of a Su-Field model, aimed at the solution of a technical problem.

Theory

The Function of a Technical System (TS) is the motivation for its existence; at the Structure level, a TS is constituted by elements, attributes of these elements and relations among them (see also the ENV model).

Su-Field modeling is a technique to represent elements and interactions characterizing the behavior of a technical system. Thus, a Su-Field model is a means to analyze a technical system and to represent problems in terms of missing, insufficient or undesired interactions, inefficiencies etc.

A problem represented by means of a Su-Field model can be approached by the system of Standard Solutions which suggest transformations of the Su-Field model capable to improve the performance of the technical system and/or to eliminate its undesired effects.

Model

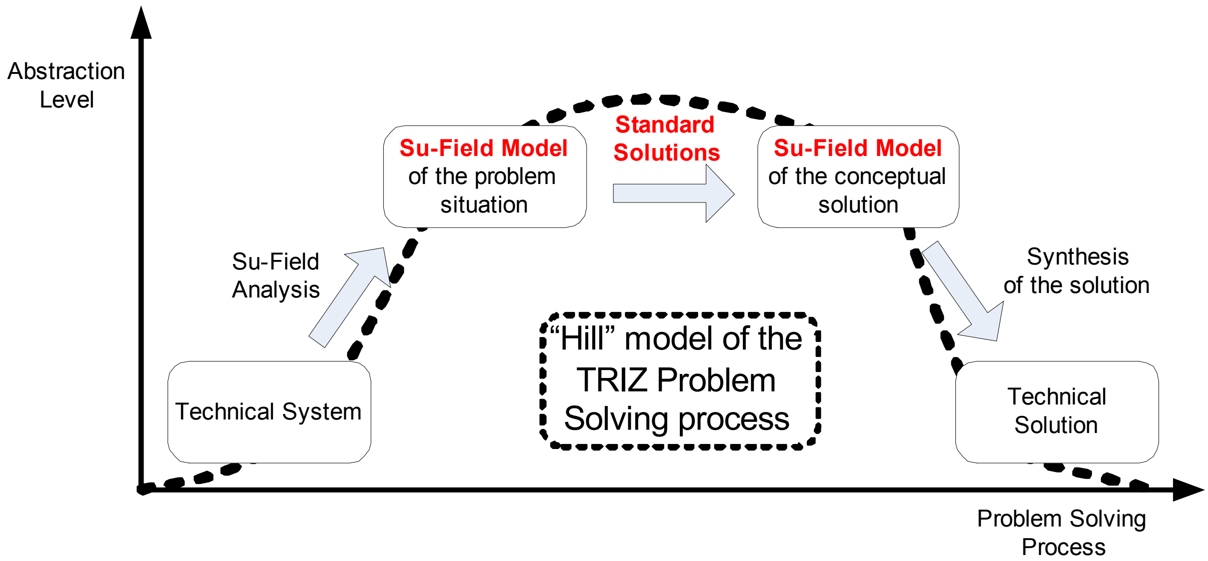

Fig. 1.a – "Hill" model of the TRIZ Problem Solving process and role of Su-Field modelling and the Standard Solutions

Instruments

The problem solving process based on the Adoption of the Standard Solution consists in the following steps (fig. 1.a):

- Describe the problem to be solved by using general terms (technical terms are strong psychological inertia vectors) – Identify evaluation/selection criteria to be applied to generated ideas
- Build a Su-Field model of the problem situation (abstraction process)
- Select the most appropriate Standard Solutions to approach the problem situation according to the characteristics of the Su-Field model (2.2 - Classification of Standard Solutions). Identify the Su-Field model of the conceptual solution
- Generate a practical solution to the problem stated at step 1, by implementing the conceptual solution of step 3 according to the Substance-Field resources available in the specific situation.

Example

<u>Problem situation:</u>

It is requested to improve agriculture opportunities in a sandy region. By means of a piping system, current water has been widely distributed into the fields, but still the growth of plants is too slow.
What should be done?

<u>Step 1:</u>

We want to increase the growth speed of some plants in a sandy area. The plants are properly watered, but their nutritional needs are not properly covered.

<u>Step 2:</u>

A Su-Field model of the problem situation is built according to the directions of section 1.2 – Model of a Minimal Technical System (Figure 1.b): there is an insufficient useful interactions between the earth and the plant by means of a chemical field.

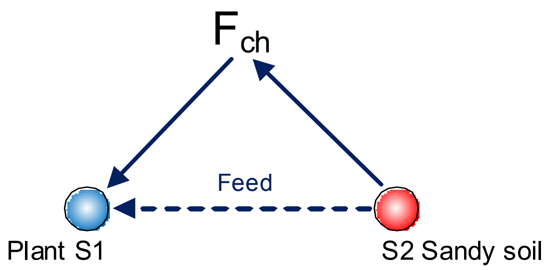

Fig. 1.b – Su-Field model of the problem situation

<u>Step 3:</u>

In order to improve the positive effect of a Su-Field interaction it is suggested to take into account Standard Solutions belonging to Class 1.1 (2.2 - Classification of Standard Solutions).
The first relevant Standard is the number 1.1.2: improving interactions by introducing additives into the objects (Fig. 1.c).

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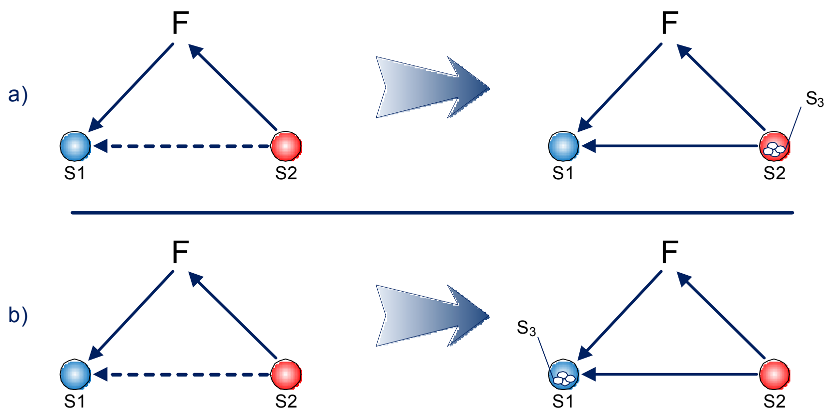


Fig. 1.c – STANDARD 1-1-2: Improving interactions by introducing additives into the objects

The Su-Field models on right side of fig. 1.c represent conceptual solutions to the problem described at step 1 and formalized at step 2.
With a similar approach further conceptual solutions could be identified by applying other Standards.

<u>Step 4:</u>
In order to synthesize a practical solution from the model of conceptual solution it is necessary to take into account the specific situation (Fig. 1.d). It is worth to notice that an alternative interpretation of the same standard solution would point to the introduction of additives into the plant (figure 1.c, below).
What kind of Substance S_3 could be added to the sandy soil in order to improve its chemical interaction with the plant?
A fertilizer could provide the expected improvement.

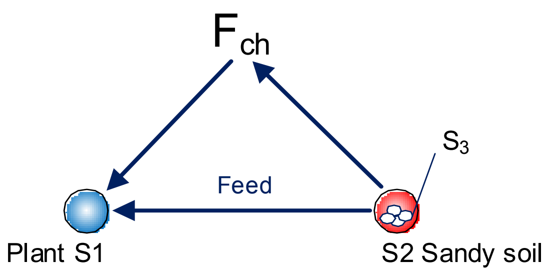


Fig. 1.d – Exemplary application of the Standard 1-1-2 to the Su-Field model of Fig. 1.b: the interaction can be improved by introducing additives into the earth (fig. 1.c, above).

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

See also::
4.1.1.1– Types of fields and related symbols
4.1.1.2 – Types of interactions and related symbols

4.1.1 – ELEMENTS OF A MINIMAL TECHNICAL SYSTEM

Definition

The minimal technical system capable to perform a certain function must be constituted by three elements: two substances and a field.
A Substance is an element of a system (a basic part or a complex subsystem) which can be involved in a functional interaction with other substances both as a function carrier and as the object of the function itself.
A Field is an interaction characterized by a flow of energy (of any type), or information, or mechanical force etc. generated by a substance, potentially impacting other substances.

Theory

The essential elements of a functional interaction are a function carrier (working tool), an object of the function and a field. Both the function carrier and the object are called Substances.
In TRIZ terms, a Substance can be a system of any level of complexity, from a single elementary item (e.g. a pin, a ball, a dust particle) to a complex assembly (e.g. an airplane, a laptop, a satellite).
Whatever is the complexity of the system, its interaction with other substances necessarily requires the presence of at least a Field, i.e. a flow of any kind of energy, a flow of information, a force etc.
There are several types of Fields (1.1.1- Types of interactions and related symbols) as well as there exist several kinds of interactions between two substances (1.1.2 – Types of Fields and related symbols)

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

4.1.1.1 – TYPES OF FIELDS AND RELATED SYMBOLS

Definition

Gravitational Field: the natural force of attraction between any two massive bodies, which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them

Mechanical Field: interaction relating to, or governed by mechanics, i.e. forces on matter or material systems (friction, inertia, elasticity, lifting, buoyancy, pressure of fluids)

Acoustic Field: interaction arising from, actuated by, containing, producing, or related to sound waves, even outside the audible frequency range.

Thermal Field: interaction related to heat transfer of any type (conduction, convection, radiation).

Chemical Field: interaction related to the composition, structure, properties and reactions of a substance

Electrical Field: physical phenomena arising from the behavior of electrons and protons that is caused by the attraction of particles with opposite charges and the repulsion of particles with the same charge.

Magnetic Field: force exerted between magnetic poles, producing magnetization

Electro-Magnetic Field: interactions related to the generation, propagation, and detection of electromagnetic radiation having wavelengths greater than x-rays, e.g. light and vision

Biological Field: interactions relating to, caused by, or affecting life or living organisms, e.g. fermentation, decay.

Nuclear Field: interactions related to forces, reactions, and internal structures of atomic nuclei, e.g. Fusion, Fission, Rays

Theory

A Field is an interaction characterized by a flow of energy (of any type), information, mechanical force etc. generated by a substance, potentially impacting other substances.
The type of field is defined by the nature of the interaction between two substances. It is worth to notice that the definitions of the field types are sometime overlapping: a biological field can be considered also chemical at a deeper detail level; heat transferred by radiation can be considered as a thermal and as an electro-magnetic field. Nevertheless, such ambiguity does not impact the usability and the effectiveness of the modeling technique as far as a coherent definition is followed within the entire analysis of a certain technical system.

Model

Field type	**Symbol**
Gravitational	F_{Gr}
Mechanical	F_{Mec}
Acoustic	F_{Ac}
Thermal	F_{Th}
Chemical	F_{Ch}
Electrical	F_{El}
Magnetic	F_{M}
Electro-Magnetic	F_{EM}
Biological	F_{B}
Nuclear	F_{N}

Fig. 1.1.1.a – Field types and related symbols

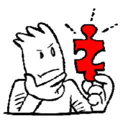
Example

Field type	**Examples**
Gravitational	Gravity, attraction between planets
Mechanical	Friction, pressure, inertia
Acoustic	Sound waves, ultra-sounds
Thermal	Heat exchange by conduction, convection, radiation
Chemical	Oxidation, solution, combustion, reduction, bonding
Electrical	Electrostatics, electric induction
Magnetic	Magnetostatics, magnetic induction
Electro-Magnetic	Light, laser, microwaves, X-rays, gamma-rays
Biological	Fermentation, decay
Nuclear	Nuclear fusion, nuclear fission

Fig. 1.1.1.b – Exemplary fields

Self Assessment

<u>Exercise 1:</u>



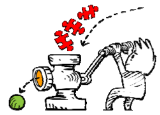
Analyze the following interactions between substances, identify the type of fields and assign the appropriate symbol:

1. a broom sweeping the floor;
2. a fridge cooling a bottle of water;
3. a radio playing music;
4. an oven roasting a chicken;
5. a paint coloring a wall;
6. a torch lighting a cave;
7. the flame of a match lighting a cigarette;
8. the orientation rotating the needle of a compass;

9. a hammer hitting a nail;
10. a vegetable going mouldy;
11. some sugar dissolved into a cup of coffee;
12. a neutron added to a nucleus of hydrogen.

Answer 1:

Interaction	**Type of field**	**Symbol**
a broom sweeping the floor	Mechanical (pushing force)	F_{Mec}
a fridge cooling a bottle of water	Thermal (convection)	F_{Th}
a radio playing music	Acoustical (sound waves)	F_{Ac}
an oven roasting a chicken	Thermal (radiation) or Electro-magnetic (infrared)	F_{Th} - F_{EM}
a paint coloring a wall	Chemical (adhesion)	F_{Ch}
a torch lighting a cave	Electro-magnetic (light)	F_{EM}
the flame of a match lighting a ciga-rette	Chemical (combustion)	F_{Ch}
the orientation rotating the needle of a compass	Magnetic (Earth's magnetic field)	F_M
a hammer hitting a nail	Mechanical (impact force)	F_{Mec}
a vegetable going mouldy	Biological (decay)	F_B
some sugar dissolved into a cup of coffee	Chemical (solution)	F_{Ch}
a positron added to a nucleus of hy-drogen	Nuclear (fusion)	F_N



References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

See also:
4.1.1.1– Types of fields and related symbols

4.1.1.2 – TYPES OF INTERACTIONS AND RELATED SYMBOLS

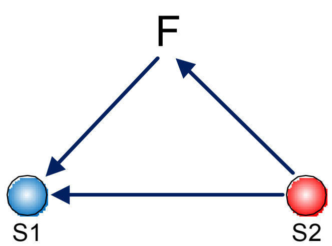
Definition

Let's consider two interacting Substances, S1 and S2, such that S2 exerts a certain impact on a property EP (Evaluation Parameter) of S1.
Useful action: An action is considered useful when the impact on EP is desired
Harmful action: An action is considered harmful when the impact on EP is undesired or goes in the wrong direction
Insufficient, incomplete action: A useful action is considered insufficient or incomplete when the impact on EP is less than the desired value
Missing action: A useful action is considered missing when the expected impact on EP is potentially available, but not implemented in the system
Uncontrolled action: An useful action is considered uncontrolled when the range of values assumed by EP is too large
Excessive action: A useful action is considered excessive when the impact on EP exceeds the desired value
Superfluous action: An useful action is considered superfluous when the impact on EP is not necessary to the functioning of the system, but doesn't provide any harm

Theory

A function is characterized by a function carrier (in TRIZ terms a "tool"), an action and an object receiving the function. The action is properly defined if it can be expressed as a combination of one among four verbs (increase, decrease, change, stabilize) and the name of a property of the object (ENV model). The property of the object, e.g. a size, the colour, the electrical conductivity, the shape, is thus set to a certain value e.g. one meter, red, five siemens per metre, spherical, due to the impact of the function. If the modification of the object property is desired, the function is considered useful, while if the modification of the object property is undesired, the function is considered harmful. Among the useful functions, if the property of the object assumes precisely the expected value, we have a sufficient useful function; besides, if the value of the property is inadequate the function is considered useful but insufficient.

Model

Type of interaction	Symbol
Useful	

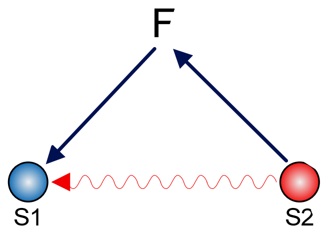
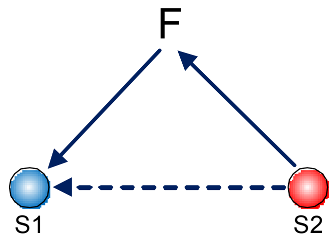
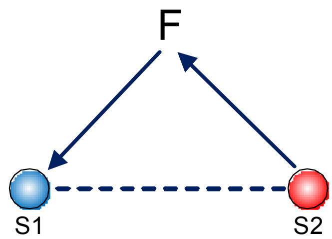
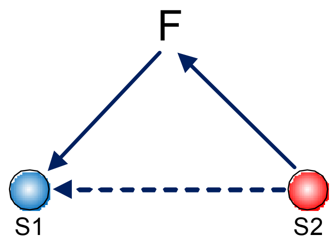
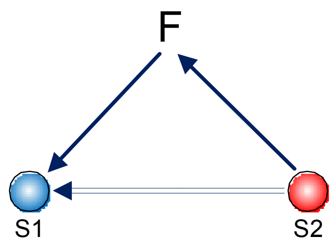
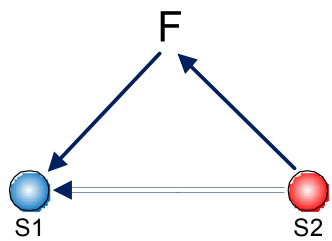
Harmful	
Useful Insufficient	
Missing	
Uncontrolled	
Excessive	
Superfluous	

Fig. 1.1.2.a – Interaction types and related symbols

Instruments

Steps to classify an interaction between two substances:

1. identify the interacting substances distinguishing between the tool and the object
2. identify the type of field (1.1.1 – Types of fields and related symbols)
3. identify the evaluation parameter of the object impacted by the tool through the field
4. analyze the influence of the field on the evaluation parameter (EP):
   - a if the impact on EP is desired, the field determines a useful interaction;
     1. if the impact on EP is desired, but less than expected, the field determines an insufficient useful interaction;
     2. if the impact on EP is desired, but its range of variations is too large, the field determines an uncontrolled useful interaction;
     3. if the impact on EP is desired, but is absent, the field determines a missing useful interaction;
     4. if the impact on EP is desired, but more than expected, the field determines an excessive useful interaction.
   - b. if the impact on EP is undesired, the field determines a harmful interaction;
   - C if the impact on EP is not desired, but doesn't produce any harm, the field determines a superfluous interaction.

Example

Example 1:

Summertime: Nina would like to offer some chilly fruit juices to her friends because they are thirsty and it's very hot. Unfortunately, the fridge is empty and all the juices are quite warm. She puts the juices in the fridge, but it cools them quite slowly, after 15 minutes they are still warm.

Let's classify the interaction of the last sentence.

- the interacting substances are the fridge and the juices, tool and products respectively;
- fridge and juices interact through a thermal field (heat convection in the fridge interior);
- the parameter of the juice (product) impacted by the fridge (tool) through the thermal field is the temperature (EP): the fridge "decreases" the temperature of the juices;
- the impact of the fridge on EP is desired (it is desired that the fridge decreases juices temperature), but less than expected (the temperature is still too high after 15 minutes), thus the field determines an insufficient useful interaction (fig. 1.1.2.b).

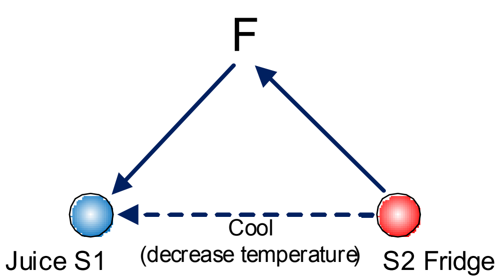


Fig. 1.1.2.b – The interaction between the fridge and the fruit juices is useful, but insufficient since it takes too much time to cool them down.

Example 2:

Wintertime: at Nina's town the temperature in January goes often below 0°C, thus the water in the pipes sometimes freezes. Since ice has a larger volume than liquid water, it exerts a high pressure on the internal pipe surface such that it happens that a pipe breaks.

Let's analyze the interaction of the last sentence.

1. the interacting substances are the ice and the pipe, tool and products respectively (it is worth to notice that the pipe is here considered a product since it is impacted by the action of the ice);
2. ice and pipe interact through a mechanical field (pressure due to the volume increase of the water from liquid to solid);
3. the parameter of the pipe (product) impacted by the ice (tool) through the mechanical field is the material stress (EP): the ice “increases” the material stress of the pipe;
4. the impact of the ice on EP is undesired (it is undesired that the ice increases the material stress of the pipe), thus the field determines a harmful interaction (fig. 1.1.2.c).

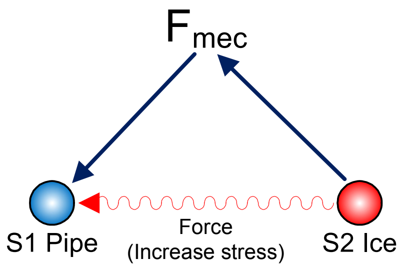
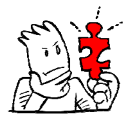


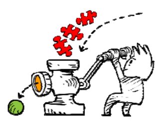
Fig. 1.1.2.c – The interaction between the ice and the pipe is harmful since it is not desired to increase the material stress in the pipe.

Self Assessment

<u>Exercise 1</u>:
Nina is in the kitchen. She notes that the pan is on the gas cooker, and while the fire heats the bottom of the pan heats also the pan haft. Try to model the two situations.



<u>Answer 1</u>:
We have two models to build: the first one is relative to the function of the fire toward the bottom of the pan. There are two substances, the pan bottom (S_1) and the fire (S_2), and a field, a thermal one. The action developed is useful and sufficient, fig. 1.1.2.d.



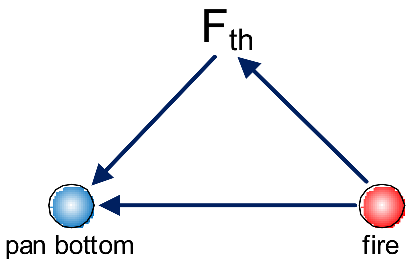


Fig. 1.1.2.d – Su-field model of a pan on the fire

The second model to build is the part of the situation represents the heating of the haft. In this case the two substances are the haft itself (S_1) and the fire (S_2). The field is always thermal, but this time the action developed by the fire toward the haft is harmful, because a hot haft may burn Nina's hand (fig. 1.1.2.e).

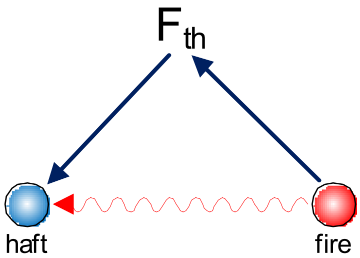
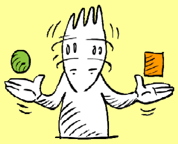


Fig. 1.1.2.e – Su-field model of the harmful action developed by the fire on the haft of the pan

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

4.1.2 – Model of a Minimal Technical System



See also:
4.1.1.1– Types of fields and related symbols
4.1.1.2 – Types of interactions and related symbols

Theory

The minimal technical system capable to perform a certain function must be constituted by three elements: two substances and a field.
Thus the simplest model of a working system is a triad S1, S2, F such that the substance S2 accomplishes an action on the Substance S2 through the Field F (Fig. 1.2.a).
The Field is classified according to the criteria defined in 1.1.1 Types of fields and related symbols.
The action exerted by S2 on S1 can be classified according to the criteria defined in 1.1.2 Types of interactions and related symbols
A Su-Field model is graphically represented by means of specific symbols and rules (1.2.1 Graphical representation of a Su-Field Model)

Model

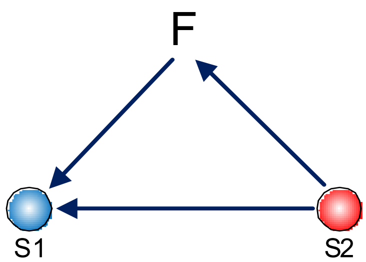
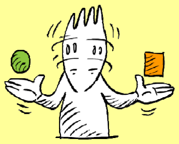


Fig. 1.2.a – Model of a Minimal Technical System

4.1.2.1 – GRAPHICAL REPRESENTATION OF A SU-FIELD MODEL



See also:
4.1.1.1– Types of fields and related symbols
4.1.1.2 – Types of interactions and related symbols

Model

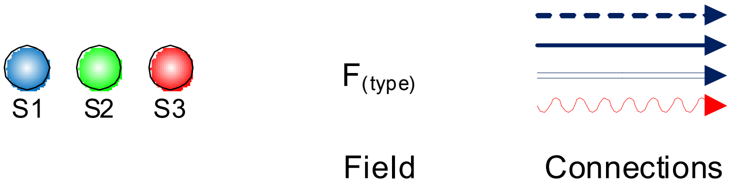


Fig. 1.2.1.a – Elements of a Su-Field model: Substances, Fields, Connections

Instruments

Steps to build a Su-Field model of a functional interaction:
1. identify the substances involved in the functional interaction;
2. check the presence of one or more fields between each pair of substances;
3. classify the field (1.1.1) and the interaction (1.1.2)

assign a suitable symbol to each element (Fig. 1.2.1.a)

Example

<u>Example 1: Nina prepares sandwiches</u>
While cutting the bread to prepare some sandwiches for a picnic, Nina slightly injured her finger with the knife.
Let's build a Su-Field model of the situation.

1. Here we have three main substances: S1, bread (object of the action to cut); S2 Nina's finger (object of the action injure); S3 knife (subject of the actions cut bread and injure Nina's finger) – fig. 1.2.1.b.

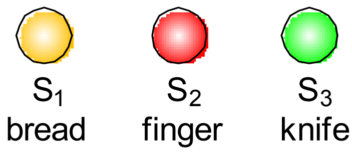


Fig. 1.2.1.b –Substances interacting while Nina is preparing the sandwiches

2. There are no fields between the bread and the finger (according to the description above, it is not relevant to represent that Nina holds the bread by the fingers); there is a field (an interaction) between the bread and the knife as well as between the finger and the knife – fig. 1.2.1.c

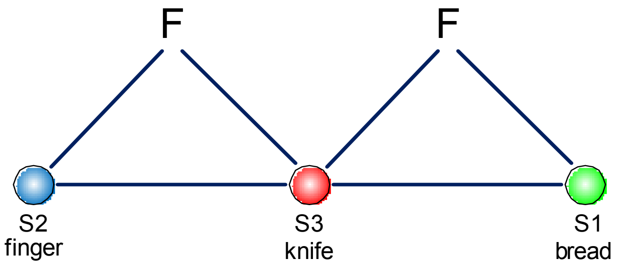


Fig. 1.2.1.c – Fields acting between the identified substances

3. The field F_1 between the knife and Nina's finger is clearly mechanical: the knife causes a wound into the finger by a high local pressure, or with a formal expression "increases the number of wounds of the fingers" (from zero to one) or "decreases the health of the finger". Since the impact of the knife (tool) on the evaluation parameter of the product (number of wounds of the fingers, or health of the finger) is undesired, the interaction between S_3 and S_2 is harmful.
4. The field F_2 between the knife and the bread is also mechanical: the knife cuts the bread, or with a formal expression "increases the number of slices of the bread". Since the impact of the knife (tool) on the evaluation parameter of the product (number of slices) is desired and we don't have any information about an improper amount of slices, the interaction between S_3 and S_1 is useful.

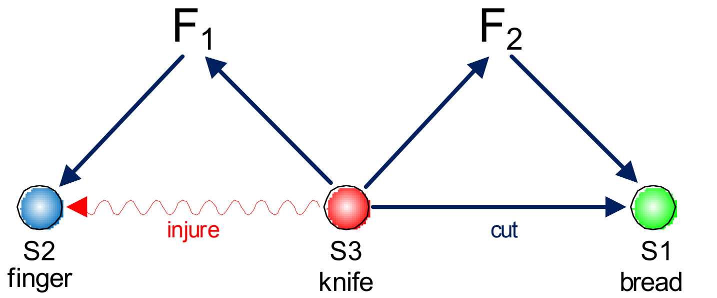
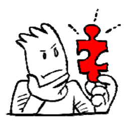


Fig. 1.2.1.d – Su-Field model of Nina preparing the sandwiches

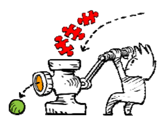
Self Assessment

<u>Exercise 1</u>:



Nina has to give a MP3 famous song of 4.6 Mbyte, that she has in the PC, to her friend Mat. Yet he doesn't have an internet connection, so Nina has to write the file on a support. Her USB pen drive is broken, so she think to use a CD. When she open the drawer she realizes that her CD are finished, and she has only a DVD. Try to build a Su-Filed model of the file transfer.

<u>Answer 1</u>:



The first step is to identify all the substances present in the scene: in this case we have the PC (S_1), the DVD support (S_2) and the MP3 song (S_3), fig. 1.2.1.e.

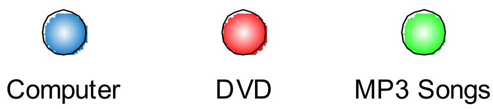


Fig. 1.2.1.e – the three substances presents in the scene

To complete the model also the fields among substances are requested, fig. 1.2.1.f. The first part of the model represents the act of transfer the file from the PC to the DVD, so the act of “writing”, while the second one depict that the file is now contained within the DVD

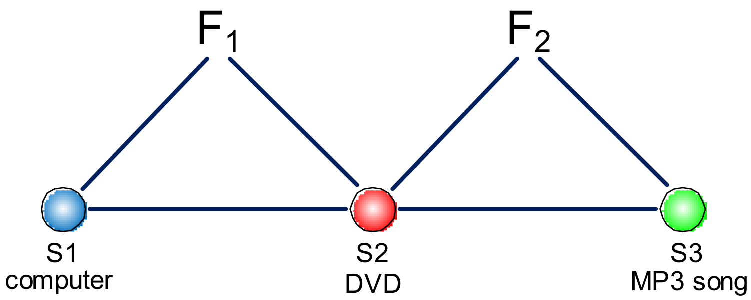


Fig. 1.2.1.f – the first step toward the constitution of a Su-Field model

Now we have to find what kind of fields are F1 and F2. Computer writes file on the DVD by a laser, so F1 could be considered as an electromagnetic field; the DVD contains a magnetic track which represent the file, so F2 could be a magnetic field. The act write, developed by PC toward the DVD is an useful action and it is sufficient; also the DVD develops an useful action, “contains file”, but this time it could be considered excessive: Nina has used a 4.7 GByte of capacity oaf a DVD to transfer a file of only 4.6 Mbyte, fig. 1.2.1.g.

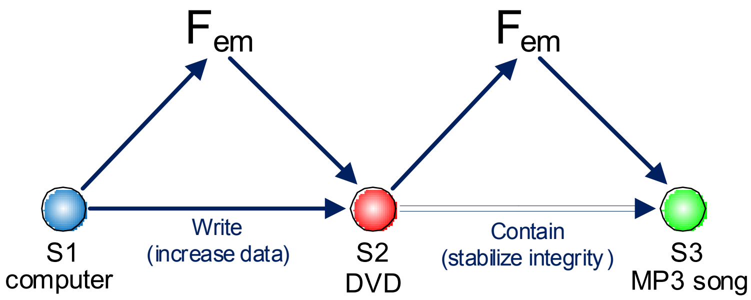


Fig. 1.2.1.g– the final Su-Field model

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

4.2 - STANDARD SOLUTIONS

Definition

A *standard solution* is a model of solution of a typical problem modeled by means of *Su-Field* interactions

Theory

The *Standard Solutions* (sometimes briefly named Standards) are a system of 76 models of synthesis and transformations of technical systems in agreement with the *Laws of Evolution* of Engineering Systems.
Together with *ARIZ*, the database of *Effects* and the *Laws of Engineering Systems Evolution* the Standard Solutions constitute the most advanced and effective set of instruments of Classical TRIZ, thus substituting Altshuller's *matrix of technical contradictions* and the *Inventive Principles*.
The Standards have been developed between 1975 and 1985 with the aim of providing a structured approach to the solution of a technical problem, browsing individual's knowledge, as well as databases of *physical chemical geometrical effects*, systematically.
Originally the standards were listed as separate solution models, numbered according to the order of formalization.
In 1979 a system of 28 integrated Standards classified in three main subsets was presented and published by Altshuller in [1]. In the following years further standards were added and the final structure of 5 classes was released (figure 2) [2].

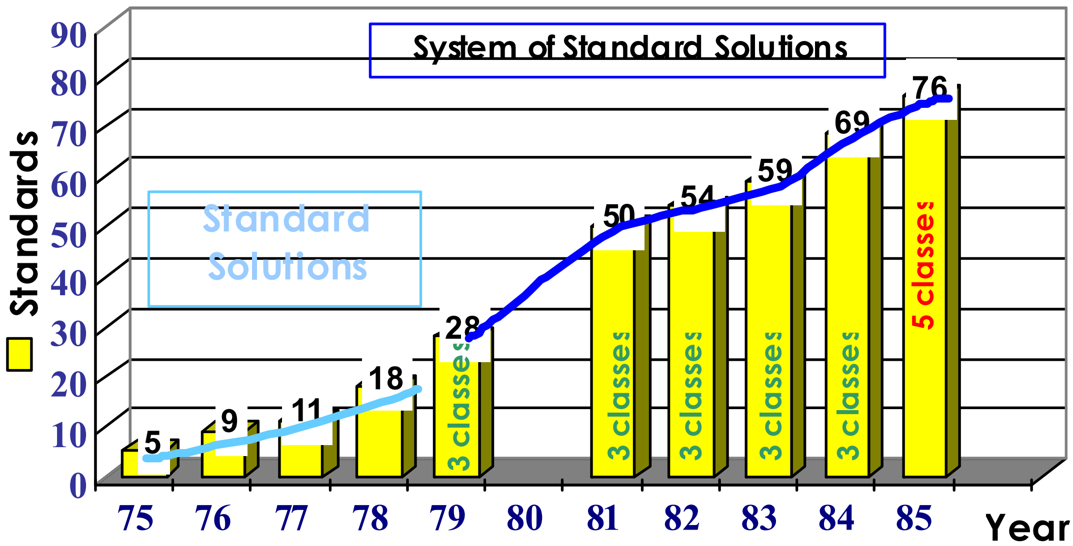


Figure 2 - History of development of Standard Solutions

Instruments

Standards Solutions should be used to solve the biggest majority of "typical" problems to be represented by means of *Su-Field models*, i.e. when an insufficient or undesired interaction exists between two or more *subsystems*.

They allow to overcome or circumvent *contradictions* without the need to identify and formulate the contradiction itself.
Standards are also useful to browse individual's knowledge following a systematic process.

In order to apply a Standard Solution it is requested to:

1. build a Su-Field model of the problem
2. chose the most appropriate Standards
3. follow the guidelines of the selected Standards

References

[1] Altshuller G.S., Selutskii A.B.: Wings for Icarus (in Russian). Petrozavodsk: Karelia, 1980.

[2] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

4.2.1 - STRUCTURE OF A STANDARD SOLUTION

Theory
Each standard solution is structured as a transformation of an initial “problematic” *Su-Field model* into a modified *Su-Field model*, where the undesired characteristics of the interactions between the *subsystems* disappear (Figure. 2.1.a).

Model

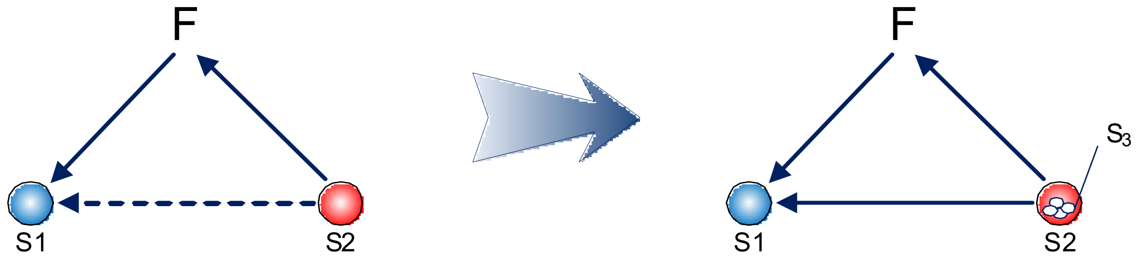


Figure 2.1.a - Exemplary model of a standard solution: an undesired Su-Field interaction (in this case an insufficient interaction) disappear by means of a transformation of the Su-Field model

Instruments
A standard solution is constituted by three main elements:

D: (Description) the description of the typical problematic situation when it is appropriate to apply that standard;

G: (Guidelines) the guidelines to introduce modifications in the system to solve the typical problem;

M: (Model, when available) a visual representation of the transformation by means of Su-Field models (Figure 2).
The visual model of the transformations is not always available; more specifically, it is omitted when the transformation of the Su-Field model deals with a qualitative modification of a substance or a field, instead of the introduction of new/modified elements in the system.

N: (Notes) Sometimes a note is added to the guidelines to provide further explanations about their implementation.

Example
The three elements of the Standard 1.1.2 are the followings:

D: the description of the typical problematic situation when it is appropriate to apply that standard:
“If there is a need in a Substance-Field System to improve the positive effect of an interaction and the conditions do not contain any limitations on the introduction of additives to at least one of the given substances”;

G: the guidelines to introduce modifications in the system to solve the typical problem: ”the problem is to be solved by a transition (permanent or temporary) to an internal complex Substance-Field System, by introducing additives in the present substances. These additives enhance controllability or impart the required properties to the Substance-Field System”;

M: see figure 2.1.b

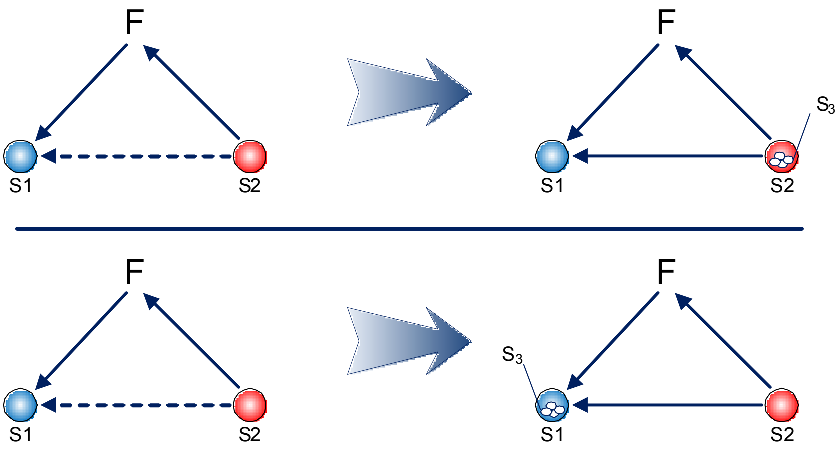
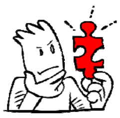


Fig. 2.1.b – Model of Standard 1.1.2

Self Assessment



Exercise 1:
Look at the following Standard Solution and identify their constitutive elements.

STANDARD 1-1-4
If there is a need in a Substance-Field System to improve the positive effect of an interaction, and the conditions contain limitations on the introduction or attachment of substances, the problem can be solved by using the existing environment as the substance to increase the efficiency of the existing interaction.

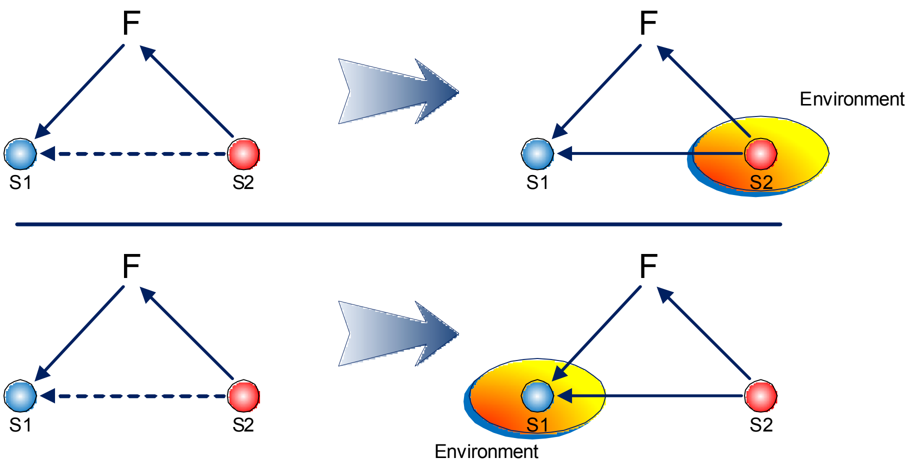
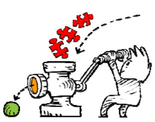


Fig. 2.1.c – Model of Standard 1.1.4



Answer 1:
D: If there is a need in a Substance-Field System to improve the positive effect of an interaction, and the conditions contain limitations on the introduction or attachment of substances,
G: the problem can be solved by using the existing environment as the substance to increase the efficiency of the existing interaction.
M: (figure 1.1.4)

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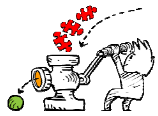
Exercise 2:
Look at the following Standard Solution and identify their constitutive elements.

STANDARD 2-2-2
The efficiency of a Substance-Field System can be improved by increasing the degree of fragmentation of the element which acts as a tool in the interaction.
The standard displays one of the major trends of the technology evolution, i.e. fragmentation of the element or its part interacting with the product ("tool"). The process is ended when the tool is replaced by a new field capable to deliver its function.
Thus, the evolution of the tool passes through the following phases: Non-fragmented object; Fragmented object; Powder; Liquid; Gas; New field.

Answer 2:



D: The efficiency of a Substance-Field System can be improved
G: by increasing the degree of fragmentation of the element which acts as a tool in the interaction
N: The standard displays one of the major trends of the technology evolution, i.e. fragmentation of the element or its part interacting with the product ("tool"). The process is ended when the tool is replaced by a new field capable to deliver its function. Thus, the evolution of the tool passes through the following phases: Non-fragmented object; Fragmented object; Powder; Liquid; Gas; New field.

References

VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

4.2.1.1 - TRANSFORMATION OF A SU-FIELD SYSTEM

Theory
According to the system of standard solutions, the following transformation may be applied to a Su-Field System:

- Introduction of a New *Substance*
  - a new element (figures 2.1.1.a-b)
  - an internal additive
  - an external additive
  - a resource already available in the environment
- Introduction of a New *Field* (figures 2.1.1.c-d)
- Modification of a Substance
  - modification of the *Tool* (figure 2.1.1.e)
  - modification of the *Object*
  - modification of the environment surrounding the substances of the Su-Field System
- Modification of a *Field* (figure 2.1.1.f)
- Use of Physical, Chemical, Geometrical *Effects*;
- A combination of any of the previous transformations.
- The above modifications can be applied to a whole element or to a portion in terms of changes/variations of any *resource*, like:
- Space: number of dimensions, topology, shape, size;
- Time: timing of action, duration of action, frequency of action;
- Properties: chemical properties, physical (electrical, magnetic, optical…) properties
- Energy: amount of energy, type of energy (kinetic, thermal, electrical…)

Model
Exemplary models of transformations of a Su-Field System:

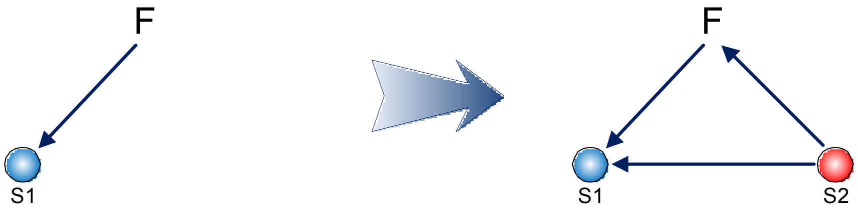


Fig. 2.1.1.a – Introduction of a New Substance

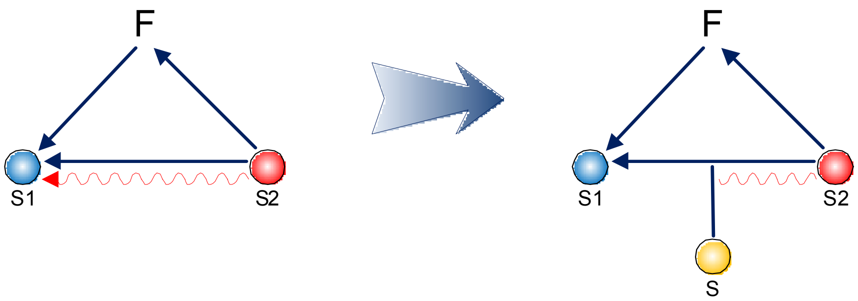


Fig. 2.1.1.b – Introduction of a New Substance

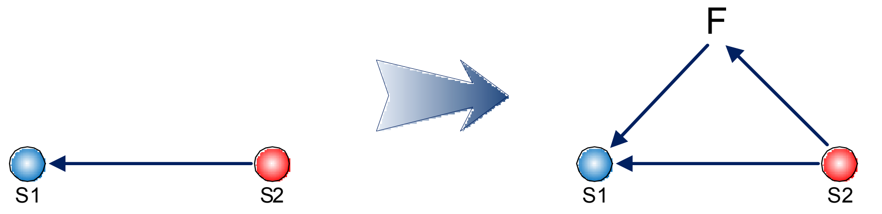


Fig. 2.1.1.c – Introduction of a New Field

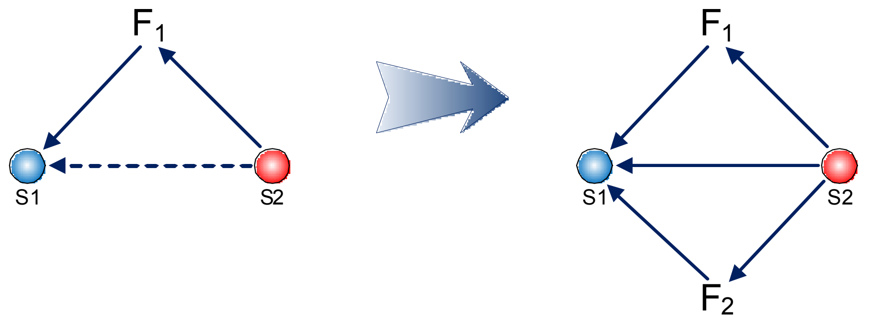


Fig. 2.1.1.d – Introduction of a New Field

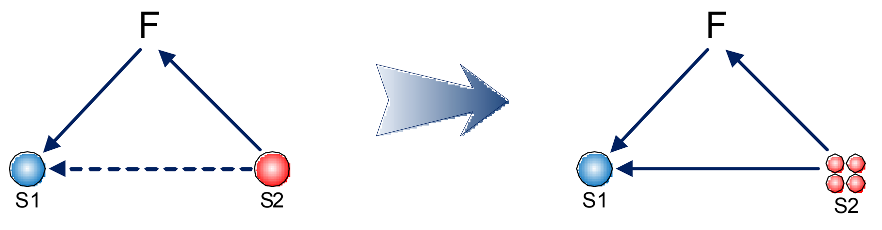


Fig. 2.1.1.e –Modification of the Tool

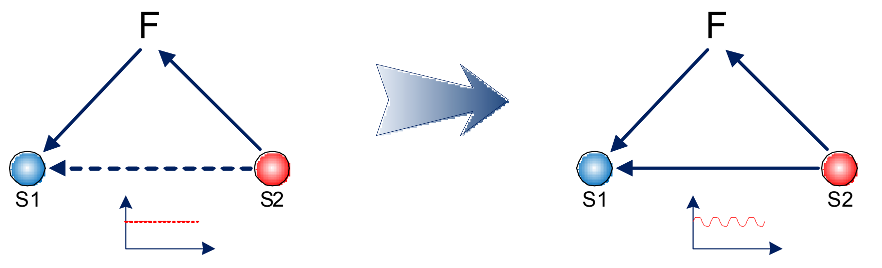


Fig. 2.1.1.f –Modification of the Field

Instruments

The application of a Standard Solution means following the directions of the selected standard in order to transform the original Su-Field System characterized by poor efficiency and/or undesired effects into another Su-Field system where the problem disappears.
The transformation suggested by the selected Standard must be applied taking into account the *Substance-Field Resources* already available in the system and secondarily new/modified resources to be integrated in the system itself.
Such a task can be supported by the navigation of a *database of effects*, in order to complement individual and team knowledge.

Example

It is necessary to speed up the sterilization of a food container by means of chemical reagents. After *building a Su-Field model* of the actual situation, one of the relevant Standards to approach this problem suggests the following transformation (figure 2.2.2.g).

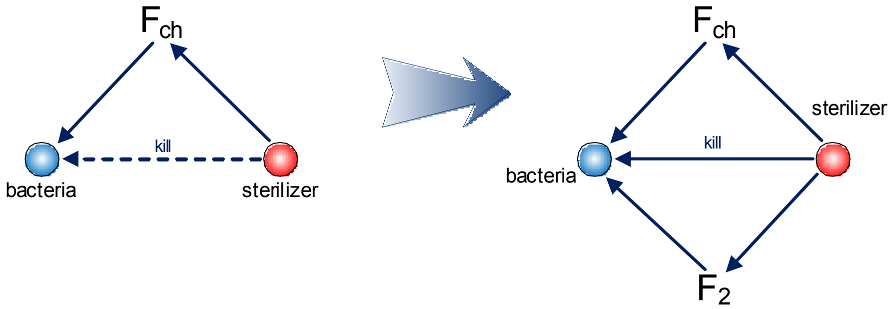


Fig. 2.1.1.g – Suggested transformation to improve the efficiency of a sterilization process

The analysis of the available resources, also supported by a search in the database of effects, suggests hyperthermia as a possible solution to improve the efficiency of the process (figure 2.1.1.h).

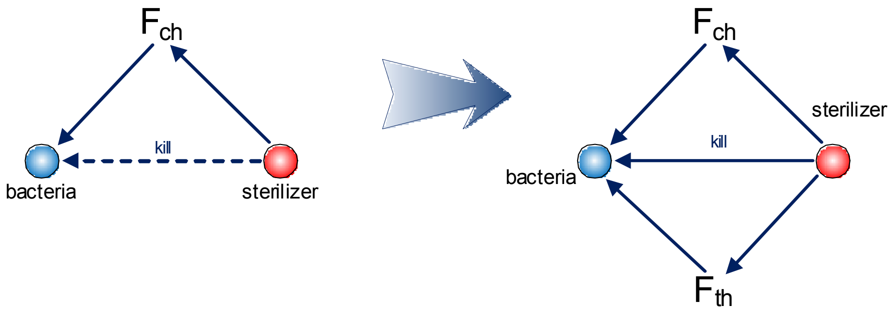
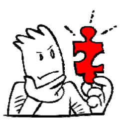


Fig. 2.1.1.h – Adoption of hyperthermia as a complementary action to kill bacteria

Self Assessment



<u>Exercise 1:</u>

When the sound is shut off (e.g. during a meeting), a mobile phone advises when a call is arriving by vibrations, but if the cell phone lays on a soft surface (e.g. leather folder, newspaper etc) the vibration doesn't produce any sound and the user might not perceive it. After building a Su-Field model of the actual situation, one of the relevant Standards to approach this problem suggests the following transformation (figure 2.2.2.i).

Develop a solution according to the suggested direction.

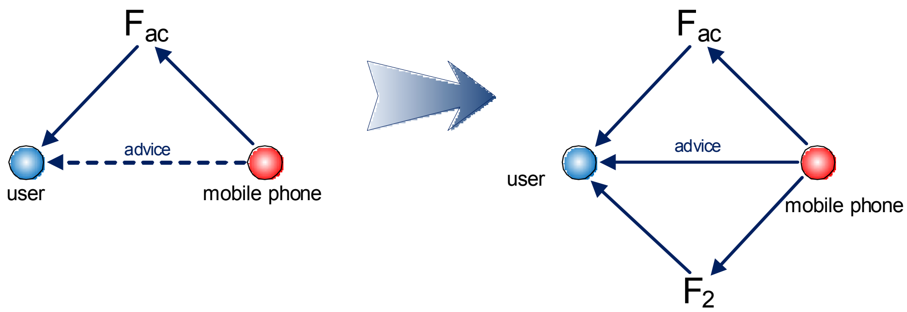
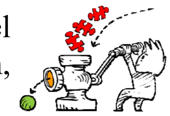


Fig. 2.1.1.i – Suggested transformation to improve the efficiency of alarm in a mobile phone



<u>Solution 1:</u>

In order to complement the vibration/acoustical field already present in the system a parallel optical signal can be added to the mobile phone (e.g. by blinking the light of the LCD screen, figure 2.1.1.j)

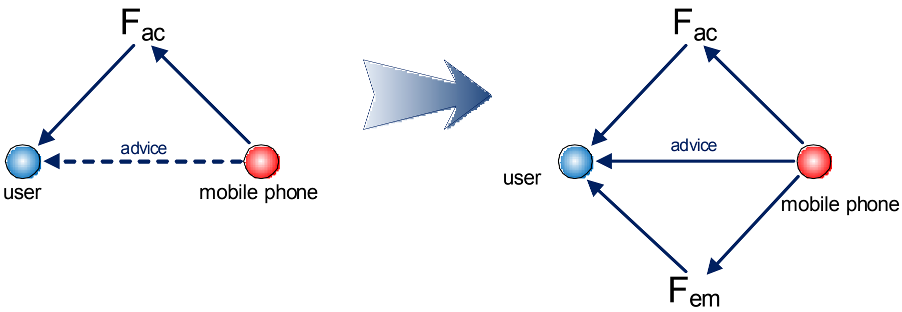


Fig. 2.1.1.j – Adoption of an optical signal as a complementary means to advice the user of an incoming phone call

4.2.2 - CLASSIFICATION OF STANDARD SOLUTIONS

Definition

In Classical TRIZ the Standard Solutions are grouped in 5 classes:
1. Improving interactions and eliminating harmful effects
2. Evolution of systems
3. Transition to macro and micro level
4. Detection and measurement problems
5. Meta-solutions, helpers

Theory

The Standard Solution were developed since the second half of the ‘70s by collecting “typical” solutions to technical problems. Originally they were just numbered sequentially, according to the order of discover.

In March 1979 Altshuller developed the first System of Standard consisting in three classes:
1. Standards for systems modification
2. Standards for detection and measurement
3. Standards for the application of the Standards

By the end of 1984 the majority of TRIZ schools in the former Soviet Union has adopted such a System of Standards for the solution of any “ordinary” problem, while ARIZ was applied for the analysis of non-standard, i.e. inventive, problems, as well as for the recognition of further Standards.

After the identification and formalization of the *Laws of Engineering System Evolution* (LESE, 1983-1986) Altshuller suggested a novel classification of the 76 Standard Solutions in five classes in order to harmonize them with the LESE:
1. Improving interactions and eliminating harmful effects
2. Evolution of systems
3. Transition to macro and micro level
4. Detection and measurement problems
5. Meta-solutions, helpers

Model

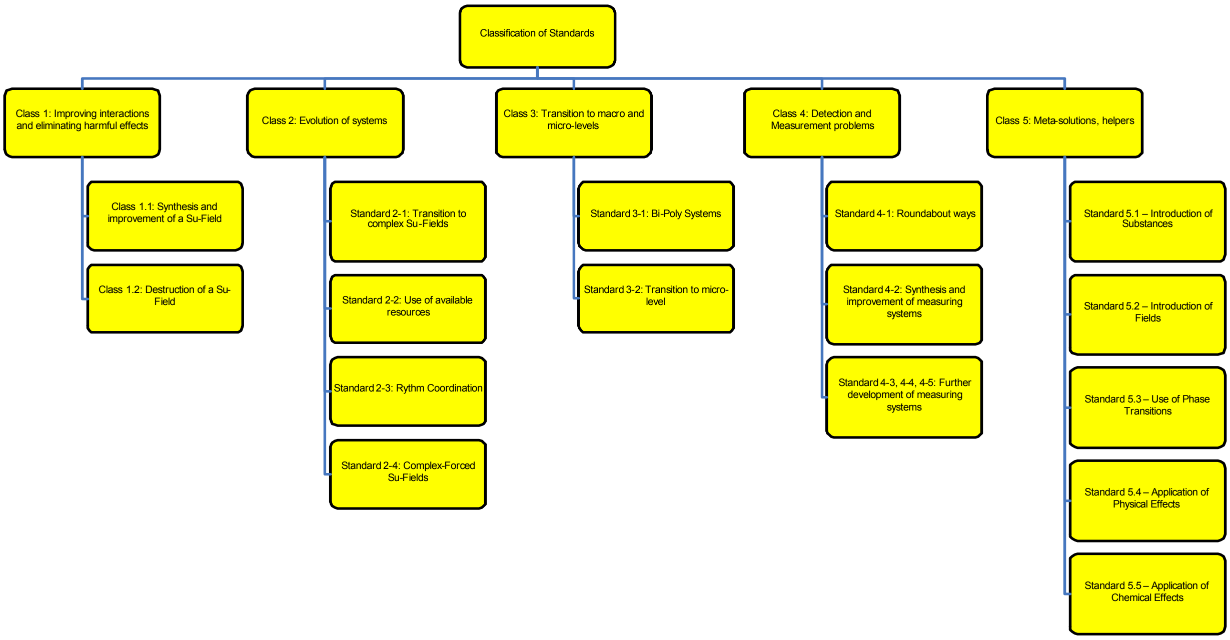


Fig. 2.2.a – Classification of the Standard Solutions

Instruments

The classification of the Standard Solutions is a guide for selection of the proper Standards to apply (figure 2.2.a):

* if a function is missing or an useful interaction between two elements of a *Technical System* should be improved, relevant Standards can be found in Class 1.1;
* if a problem is characterized by a harmful interaction between two elements of a Technical System, relevant Standards can be found in Class 1.2;
* in both cases, the modification of the existing substances/resources can be applied by following the Standards of Class 2;
* more critical problems require more radical changes of the Technical System, by an integration at *Super-System* level (Class 3.1) or by a transition to a smaller scale of interaction (Class 3.2).
* detection and measurement problems can be approached by eliminating the need of measurement (Class 4.1), building a new interaction for information deliver (Class 4.2), further evolving existing measurement elements (Class 4.3);
* whatever is the Standard to be applied, some special precautions can be adopted to prevent drawbacks while introducing a new substance (Class 5.1), a field (Class 5.2), a phase transition (Class 5.3), Physical and Chemical Effects (Class 5.4 and 5.5).

More detailed directions about the selection and use of Standards are provided in *section 3*.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

CLASS 1: IMPROVING INTERACTIONS AND ELIMINATING HARMFUL EFFECTS

Theory
The first class of Inventive Standards is dedicated to the synthesis of a Su-Field interaction, to the improvement of the positive effect of a Su-Field interaction or to the elimination of the negative effect of a Su-Field interaction, by means of a Su-Field transformation (*section 2.1.1*)

CLASS 1.1: SYNTHESIS AND IMPROVEMENT OF A SU-FIELD

Definition

The synthesis of a Su-Field consists in the creation of a complete triad Substance 1 – Field Substance 2, which is the *minimal model* of a technical system.
Improving a Su-Field means improving the positive effect of a functional interaction between Substance 2 (*Tool* or *Working Organ*) and Substance 1 (*Product* or *Object*).

Instruments

The first standard (1.1.1) is aimed at the creation of a new Su-Field interaction by introducing the missing elements of the system.
Besides, while applying the other standards of class 1.1 (1.1.2-1.1.8), the main field existing between the working organ S_2 and the object S_1 should be kept and the addition of substances should “boost” the existing interaction under the existing field.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 1-1-1: SYNTHESIS OF SUBSTANCE-FIELD SYSTEM

Definition

The synthesis of a Su-Field consists in the creation of a complete triad Substance 1 – Field Substance 2, which is the *minimal model* of a technical system.

Theory

If there is a need to provide a positive effect to an *object* (Substance 1) by delivering an *useful function*, i.e. by modifying a parameter or a feature of the object itself, and the conditions do not contain any limitations on the introduction of substances and/or fields, the problem is solved by synthesizing a complete Su-Field model: the object is subjected to the action of a physical field which produces the necessary change in the object.

Model

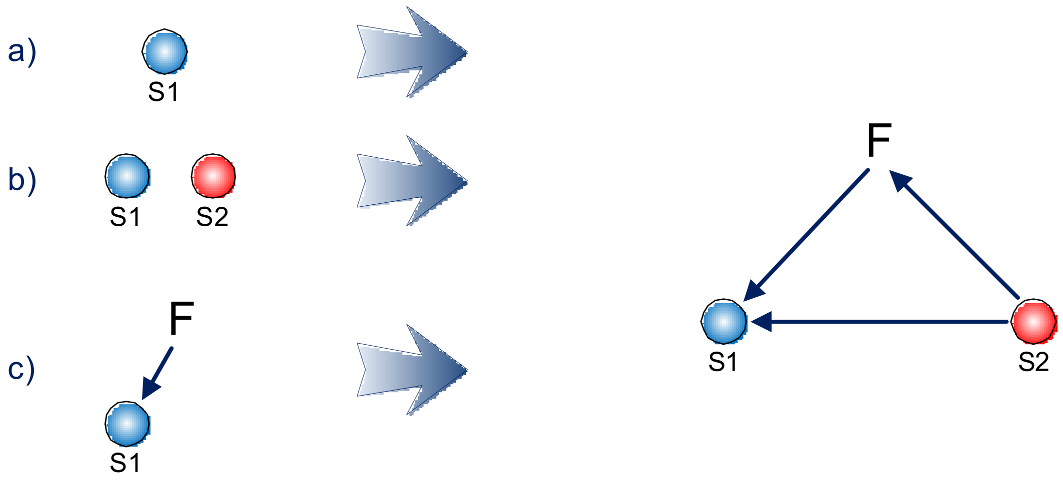


Fig. 2.2.1.1.1.a – STANDARD 1-1-1: Synthesis of substance-field system

Instruments

This standard is applied when an useful function should be performed on a given object (S_1), but an interaction capable to provide the expected modification of the object is missing.

Three different situations can be encountered (fig. 2.2.1.1.1.a, left):
no other elements are present;
a working element is present (S_2), but no fields make it interact with the object (S_1);
a field is present (F), but the working element is missing.
In order to deliver the useful function the system must be completed by adding the missing elements (fig. 2.2.1.1.1.a, right), i.e. by introducing a substance and/or a field in the system.
In order to perform a systematic search for the substance/field to be added to the system, it is suggested to browse the tables of *Substance/Field resources*.

Example

It is requested to keep the door of a freezer firmly closed in order to minimize heat exchanges.

First, it is necessary to determine the useful function to be delivered: keeping the door closed can be translated into the function “hold the door”, i.e. “stabilize its orientation in the closed position”. It is worth to notice that the function is properly expressed when the parameter of the object to be controlled (i.e. increased, decreased, changed, stabilized) is explicit.
The initial situation is thus constituted by just one object (the door), since no other elements have been mentioned (fig. 2.2.1.1.1.a, sub-case a).

According to the Standard 1.1.1, it is necessary to introduce a substance and a field (figure 2.2.1.1.1.b).

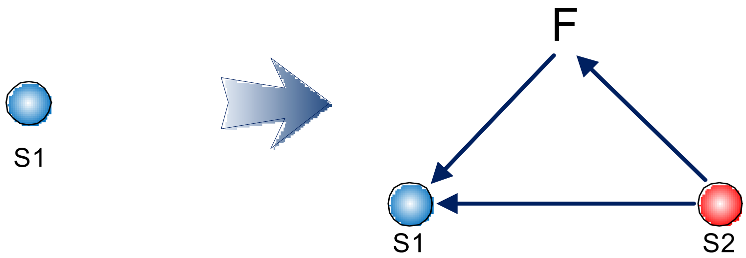


Fig. 2.2.1.1.1.b – STANDARD 1-1-1: Synthesis of substance-field system

Browsing the tables of Substance-Field resources or just focusing the attention on the problem solver experience, several solutions can be triggered: a mechanical field can be created by means of a hook (working element); a magnetic field can be applied by a magnet etc. (figure 2.2.1.1.1.c).

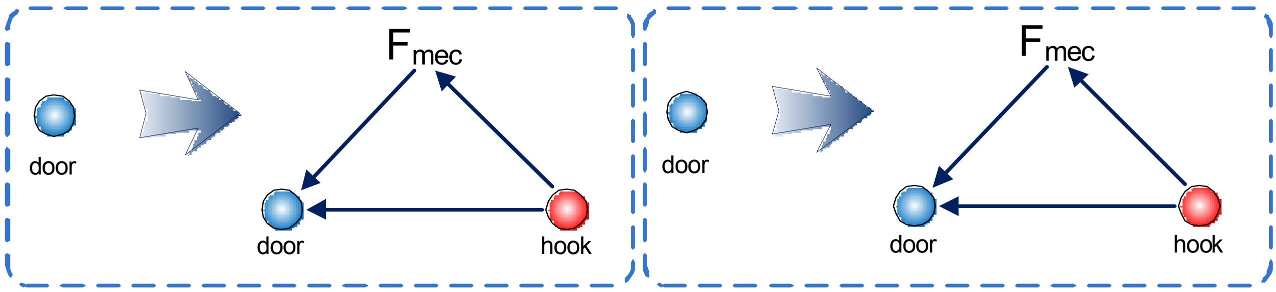
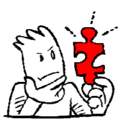


Fig. 2.2.1.1.1.c – Exemplary applications of standard 1.1.1 to deliver the function "hold the door"

Self Assessment



Exercise1:
Nina is in the kitchen, and with her mother she is making a cake for dinner. They need some cwhipped cream, so the mom prepared a bowl with the cream and a whisk, leaving them on the table. Obviously doing so, the cream remains liquid. When Nina arrives, she complete the S-Field model quickly. What does she do?

Answer1:
This problem is obviously very simple, but it is resolved going to complete a mini model that was incomplete (fig. 2.2.1.1.1.d left). On the table we have two substances: the cream, within the bowl, and the whisk. According to standard 1.1.1, it is easy to see that a field is missing. Unfortunately for Nina, a mechanical field could be a good solution, so she starts to shake the whish inside the cream in order to whip it (fig. 2.2.1.1.1.d right).

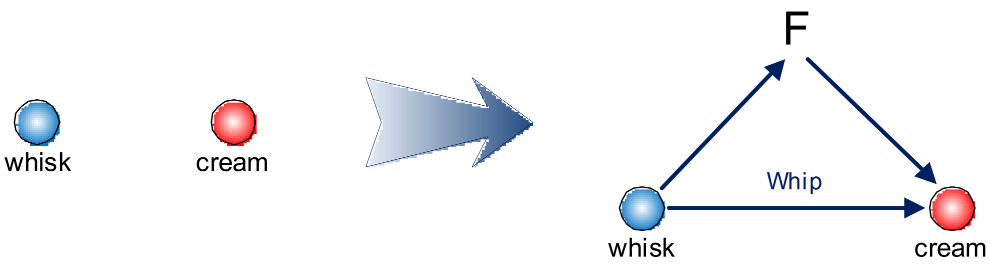


Fig. 2.2.1.1.1.d – an easy example of usage of standard 1.1.1: whipping the cream

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 1-1-2: IMPROVING INTERACTIONS BY INTRODUCING ADDITIVES INTO THE OBJECTS

Definition

Improving a Su-Field means improving the positive effect of a functional interaction between Substance 2 (*Tool* or *Working Organ*) and Substance 1 (*Product* or *Object*), without modifying the main field existing between the substances.
The interaction can be improved by introducing an internal additive to the substances.

Theory

If there is a need to improve the positive effect of an useful function to an object, and the conditions do not contain any limitations on the introduction of additives to the given substances, the problem can be solved by introducing foreign additives in the present substances to enhance controllability or impart the required properties to the Su-Field interaction.
The role of these additives is to amplify the effect of the existing interaction between the substances under the present field, or to increase the degree of control over the interaction. Therefore, it is not allowed to modify the nature of the field existing between the two substances.

Model

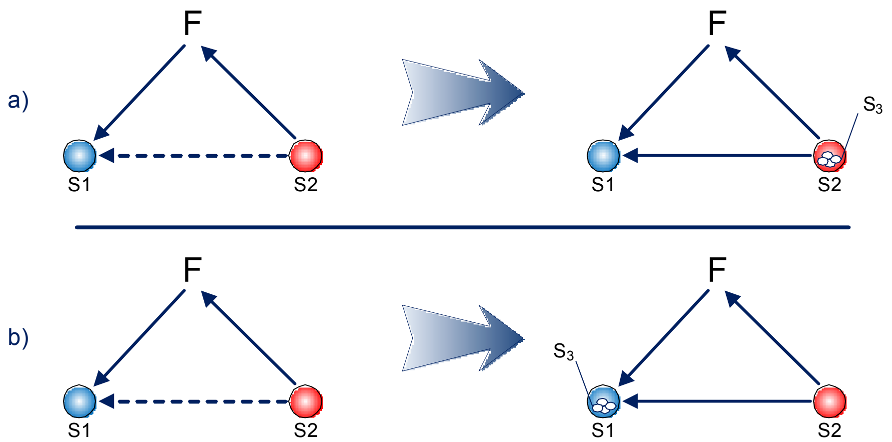


Fig. 2.2.1.1.2.a – STANDARD 1-1-2: Improving interactions by introducing additives into the objects

Instruments

This standard is applied when an useful function is not sufficient, i.e. the modification exerted on the object doesn't fit the expectations, and it is allowed to introduce additives in the working element (fig. 2.2.1.1.2.a, above) or in the object (fig. 2.2.1.1.2.a, below).
The following steps should be applied:

1. build a Su-Field model of the insufficient useful function; identify the parameter modification to be improved;
2. check whether it is possible to introduce additives in the working element and/or in the object;
3. search for substances which might improve the efficiency of the existing field;
4. check if there are any limitations to the introduction of such specific substance into the technical system.

Note: the third step can be driven by a table of substance resources.

Example

To clean the surface of a gas stove in a kitchen, we use a wet sponge, in order to dissolve dirt particles of food.
If the sponge contains just water, the process is very slow and some fat substances remain stuck to the stove. According to the Standard Solution 1.1.2, such an insufficient interaction can be improved by means of an internal additive (fig. 2.2.1.1.2.b).
In facts, while it is relatively complicated to introduce internal additives to the dirt, an ordinary solution is adding some detergent (S_3) to the water in order to increase its capability to dissolve the dirt.

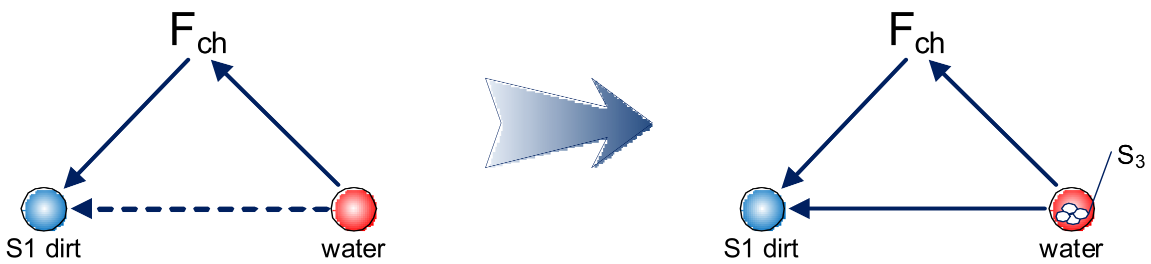


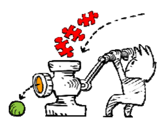
Fig. 2.2.1.1.2.b – Exemplary applications of standard 1.1.2 to improve the useful function "dissolve dirt"

Self Assessment

Exercise 1:

Driving a car when the road is covered by snow can be dangerous, since the adherence of the wheel is pretty low (example of section 2.2.1.1.3).
Generate a solution according to the Standard 1.1.2 (and not standard 1.1.3!!).

Answer 1:



A model representing the insufficient interaction between road and wheel is represented in fig. 2.2.1.1.2.c, left.
The parameter to be modified (increased) is the friction existing between wheel and road, in order to have higher grip the directions of standard 1.1.2 can be followed: introduce additives in the working element and/or in the object to improve the efficiency of the interaction (fig. 2.2.1.1.2.c, right).

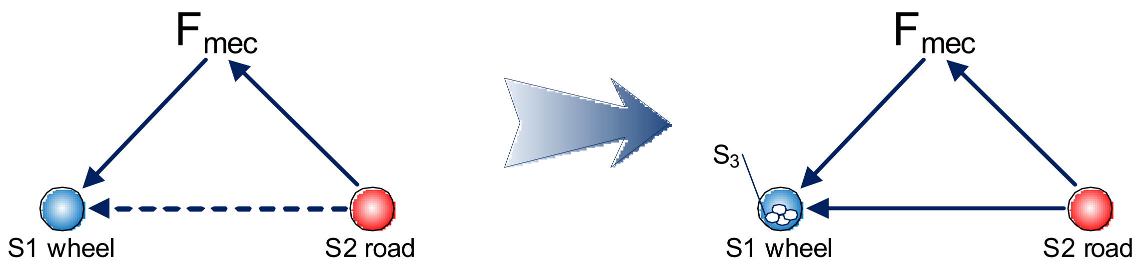


Fig. 2.2.1.1.2.c – Exemplary applications of standard 1.1.2 to improve the useful function "support wheel"

Instead of introducing internal additives in the road, it is more convenient to add a substance S_3 into the wheel.
A well known example is constituted by snow tyres with spikes (fig. 2.2.1.1.2.d)

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Fig. 2.2.1.1.2.d – Exemplary applications of standard 1.1.2 to snow tyres (internal additives = spikes)

<u>Exercise 2:</u>

Everyone today has a notebook. We can carry it from home to work or to school, for example. We use to have a canvas bag to hold the computer, but it may occur that this pouch falls down with the consequent breakdown of the pc. So sometimes protection offered by canvas bag is not sufficient. How could we improve it?

<u>Answer 2:</u>

In the initial situation we have S_1 represented by the bag which by way of a mechanical field contains and protects a second substance (the notebook) (see fig. 2.2.1.1.2.e left). The parameter that must be improved is the protective capability of the bag. so according to standard 1.1.2 we must add a new substance S_3 to make it sufficient. We can chose if putting something within the bag or into the notebook: in this case the first choice is more useful. This substance could be some foam rubber between the canvas layers (fig. 2.2.1.1.2.e. right).

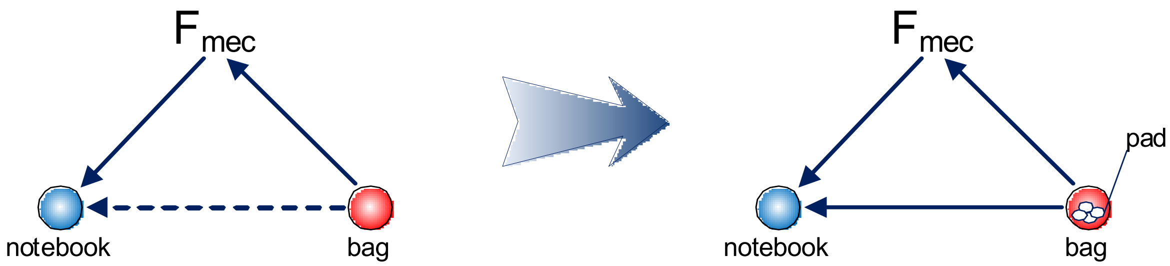


Fig. 2.2.1.1.2.e – the Su-Field model of a bag for the notebook.

References

[1]	VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 1-1-3: IMPROVING INTERACTIONS BY INTRODUCING ADDITIVES INTO A SYSTEM

Definition

Improving a Su-Field means improving the positive effect of a functional interaction between Substance 2 (*Tool* or *Working Organ*) and Substance 1 (*Product* or *Object*), without modifying the main field existing between the substances.
The interaction can be improved by introducing an external additive to the substances.

Theory

If there is a need to improve the positive effect of an useful function to an object, and the conditions do not contain any limitations on the introduction of additives to the given substances, the problem can be solved by attaching an external additive to the present substances to enhance controllability or impart the required properties to the Su-Field interaction.
The role of these additives is to amplify the effect of the existing interaction between the substances under the present field, or to increase the degree of control over the interaction. Therefore, it is not allowed to modify the nature of the field existing between the two substances.

Model

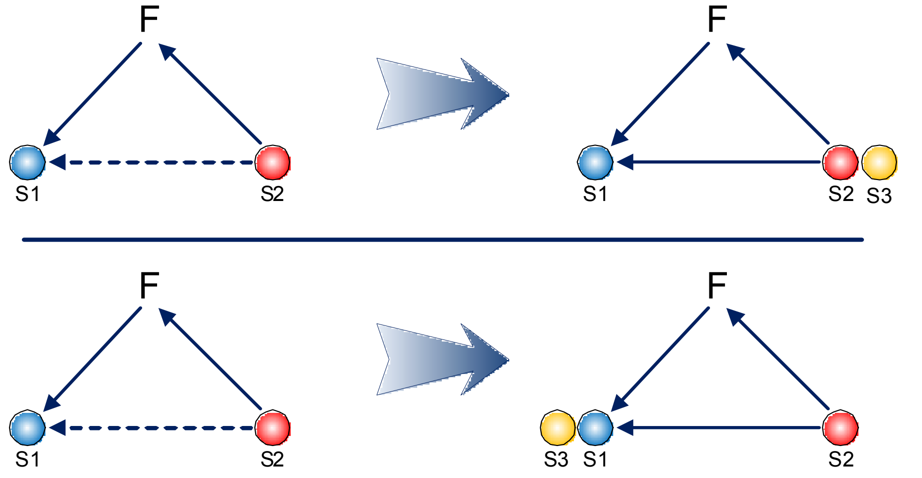


Fig. 2.2.1.1.3.a – STANDARD 1-1-3: Improving interactions by introducing additives into a system

Instruments

This standard is applied when an useful function is not sufficient, i.e. the modification exerted on the object doesn't fit the expectations, and it is allowed to add external substances to the working element (fig. 2.2.1.1.3.a, above) or to the object (fig. 2.2.1.1.3.a, below).

The following steps should be applied:

1. build a Su-Field model of the insufficient useful function; identify the parameter modification to be improved;
2. check whether it is possible to apply external additives to the working element and/or to the object;
3. search for substances which might improve the efficiency of the existing field;
4. check if there are any limitations to the introduction of such specific substance into the technical system.

Note: the third step can be driven by a table of substance resources.

Example

Driving a car when the road is covered by snow can be dangerous, since the adherence of the wheel is pretty low. A Su-Field model representing the situation is shown in fig. 2.2.1.1.3.b, left.
Nota: il passo 3 può essere sopportato dalla tabella Substance-Field.

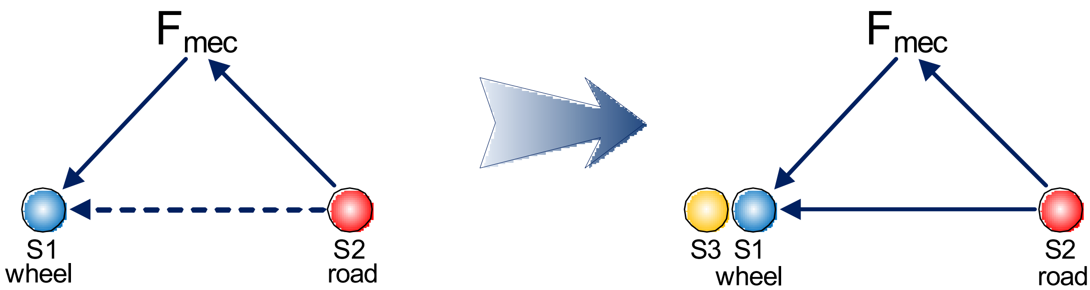
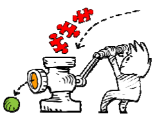


Fig. 2.2.1.1.3.b – Exemplary applications of standard 1.1.3 to improve the useful function "support wheel"

In order to improve the useful interaction between the road (covered by snow) and the wheel, the standard 1.1.3 suggest adding an external substance to the road or to the wheel (fig. 2.2.1.1.3.a). Despite it's possible in theory to apply an external substance to the road in order to improve its grip, it is clear that it is much more convenient to apply a the external additive to the wheel (fig. 2.2.1.1.3.b, right).
A well known solution is the adoption of snow chains.

Self Assessment

Exercise 1:
A plastic cover must be painted, but it is very smooth and porous by no means. So the paint doesn't stick and cover enough the plastic surface. Try to solve this problem by using the Standard 1.1.3.



Answer 1:
The initial situation shows another time an useful but insufficient action between S_2 (the paint) and S_1 (the part to be painted) as represented in fig. 2.2.1.1.3.c left.

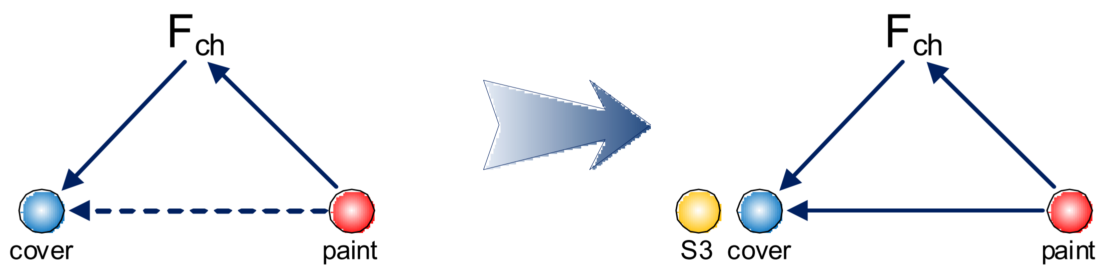


Fig. 2.2.1.1.3.c – how to paint a cover with a Su-Field model

The parameter to improve is the sticking of paint to the cover. To resolve this problem, following the standard solution 1.1.3 suggestions, we have to add an external substance S_3 or to the paint or to the cover, as modeled in fig 2.2.1.1.3.c left. Placing something inside the paint means following the standard 1.1.2 direction. Thus the external substance has to be placed near or over the cover. An explanatory solution could be a fixative spread over the cover before painting (fig. 2.2.1.1.3.c right).

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 1-1-4: USE OF ENVIRONMENT TO IMPROVE INTERACTIONS

Definition

Improving a Su-Field means improving the positive effect of a functional interaction between Substance 2 (*Tool* or *Working Organ*) and Substance 1 (*Product* or *Object*), without modifying the main field existing between the substances.
The interaction can be improved by using the environment as third substance which can increase the efficiency of the system.

Theory

If there is a need to improve the positive effect of an useful function to an object, and the conditions contain limitations on the introduction of additives to the given substances, the problem can be solved by using the environment as third substance to enhance the controllability or to impart the required properties to the Su-Field interaction. The role of the environment is to amplify the effect of the existing interaction between the substances under the present field, or to increase the degree of control over the interaction. Therefore, it is not allowed to modify the nature of the field existing between the two substances.

Model

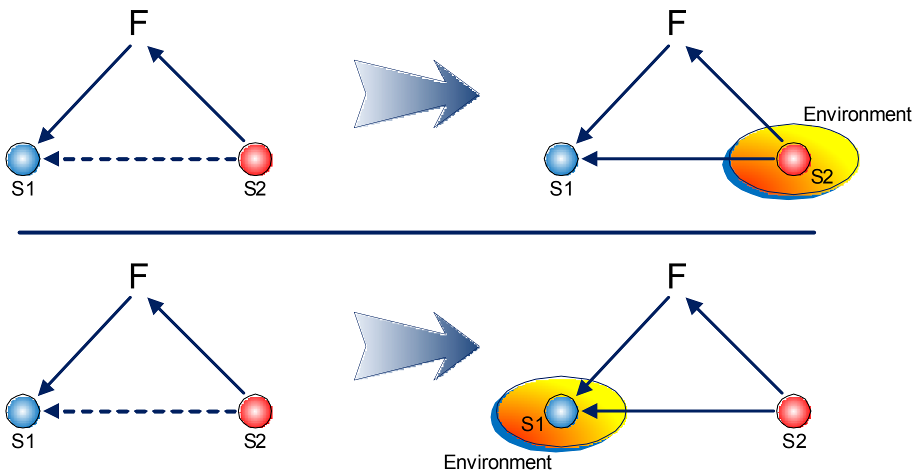


Fig. 2.2.1.1.4.a – STANDARD 1-1-4: Use of environment to improve interactions

Instruments

This standard is applied when an useful function is not sufficient, i.e. the modification exerted on the object doesn't fit the expectations, and it is not allowed to add external substances to the working element. In such a case, it must be checked if the environment surrounding any of the interacting substances can provide the expected properties to the field.
The following steps should be applied:

1. build a Su-Field model of the insufficient useful function; identify the parameter modification to be improved;
2. define candidate properties capable to improve the efficiency of the existing field;
3. analyze the characteristics of the environment surrounding the working tool (fig. 2.2.1.1.4.a, above) or the object(fig. 2.2.1.1.4.a, below) and check if any of the properties defined at step 2 are available;
4. check if there are any limitations to the adoption of the environment as the third substance of the Su-Field interaction.

Note: the second and third step can be driven by a table of substance resources.

Example

In order to improve the efficiency of an air-conditioning system, the outdoor fans are installed on the northern side of the building, thus taking advantage from the shady environment (Fig. 2.2.1.1.4.b).

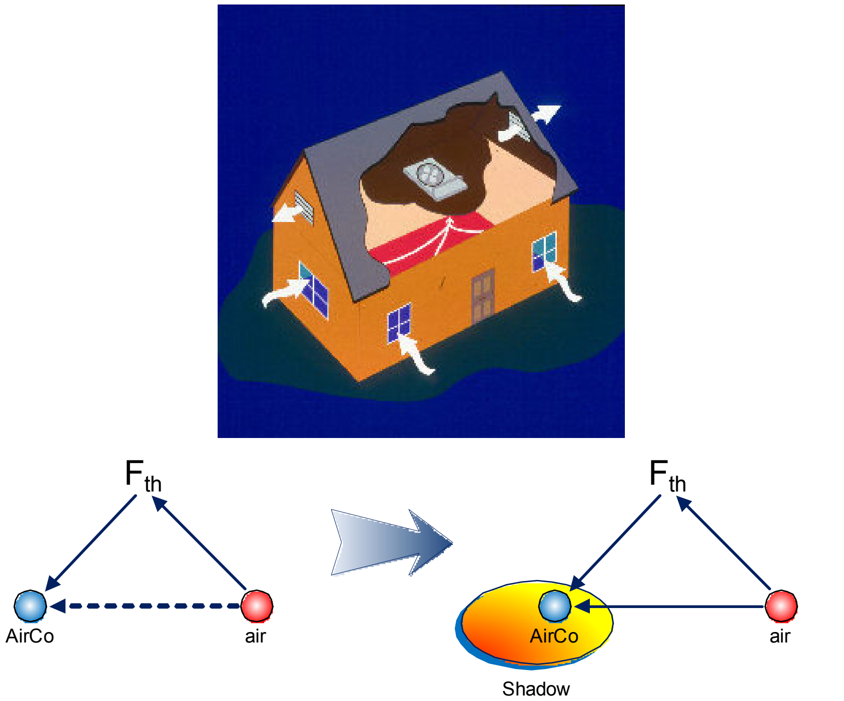
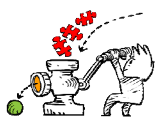


Fig. 2.2.1.1.4.b – Placement of an AirCo system on the shady side of a building

Self Assessment

<u>Exercise 1:</u>
How many times we have taken a slice of pizza in a fast food and it is bad because it is too cold? Too many. So how is it possible to avoid an excessive pizza cooling according to standard 1.1.4?



<u>Answer 1:</u>
The problem is very simple to represent with a minimal model. There are two substances, the pizza and the fast food counter. The field between them is a thermal one, in fact we can consider the insufficient action of insulating the pizza by the counter (fig. 2.2.1.1.4.c left). Obviously we can't build a counter with an hot floor, because it would be too expensive; so we should use some substance already present in pizza and counter environment as the standard solution suggests: the lamps over the floor could be a good solution (fig. 2.2.1.1.4.c right).

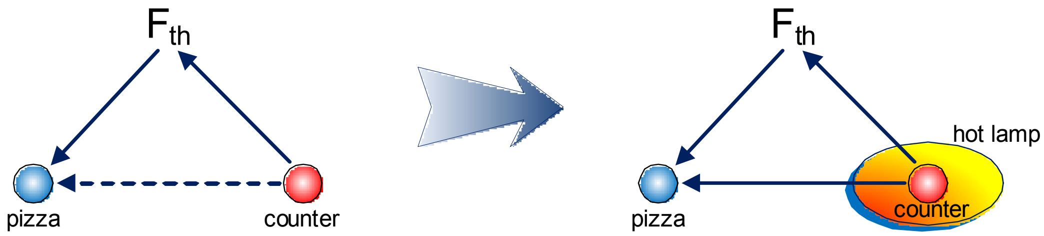


Fig. 2.2.1.1.4.c – the pizza counter modelled with Su-Field

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 1-1-5: MODIFICATION OF ENVIRONMENT TO IMPROVE INTERACTIONS

Definition

Improving a Su-Field means improving the positive effect of a functional interaction between Substance 2 (*Tool* or *Working Organ*) and Substance 1 (*Product* or *Object*), without modifying the main field existing between the substances.
The interaction can be improved by using a modification of the environment as third substance which can increase the efficiency of the system.

Theory

If there is a need to improve the positive effect of an useful function to an object, and the conditions contain limitations on the introduction of additives to the given substances, while the existing environment does not contain substances with suitable properties, the problem can be solved by replacing the existing environment with another one, or by decomposing the environment, or by introducing additives into the environment so that the modified environment can play the role of third substance to enhance the controllability or to impart the required properties to the Su-Field interaction.
The role of the modified environment is to amplify the effect of the existing interaction between the substances under the present field, or to increase the degree of control over the interaction. Therefore, it is not allowed to modify the nature of the field existing between the two substances.

Model

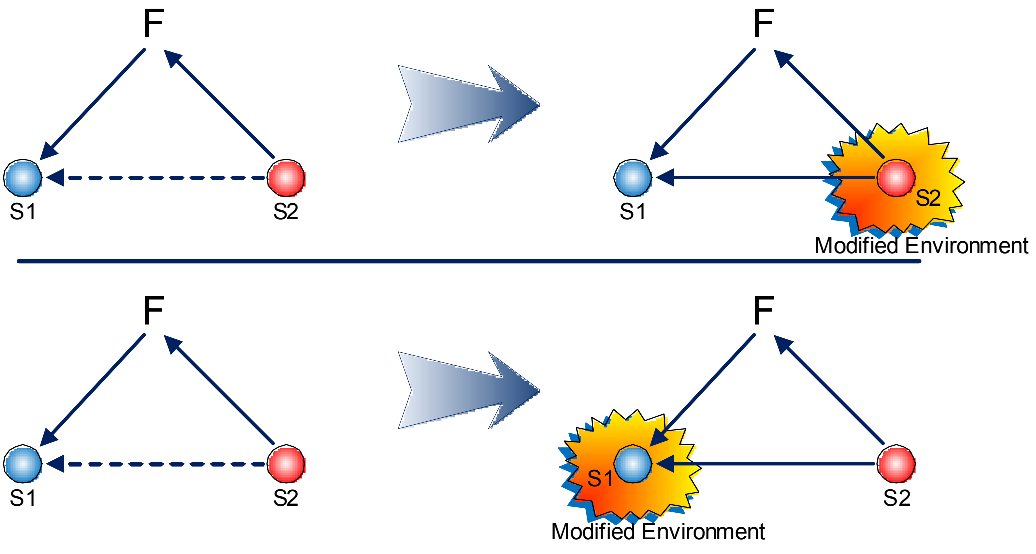


Fig. 2.2.1.1.5.a – STANDARD 1-1-5: Modification of environment to improve interactions

Instruments

This standard is applied when an useful function is not sufficient, i.e. the modification exerted on the object doesn't fit the expectations, it is not allowed to add external substances to the working element and the existing environment lacks of suitable properties to improve the interaction between the two substances. In such a case, it must be checked if a modification the environment surrounding any of the interacting substances can provide the expected properties to the field.

The following steps should be applied:

1. build a Su-Field model of the insufficient useful function; identify the parameter modification to be improved;
2. define candidate properties capable to improve the efficiency of the existing field;

* analyze the characteristics of the environment surrounding the working tool (fig. 2.2.1.1.5.a, above) or the object(fig. 2.2.1.1.5.a, below) and check if any of the properties defined at step 2 can be obtained by:
    * introducing a third substance into the environment;
    * decomposing the environment into its constituent substances;
    * replacing the environment;

4. check if there are any limitations to the selected modification of the environment.

Note: the second and third step can be driven by a table of substance resources.

Example

In a smoker room, even after short time, air becomes unbreathable even for chain smoker, because air surrounding smokers doesn't dissipate smoke adequately (fig. 2.2.1.1.5.b left).

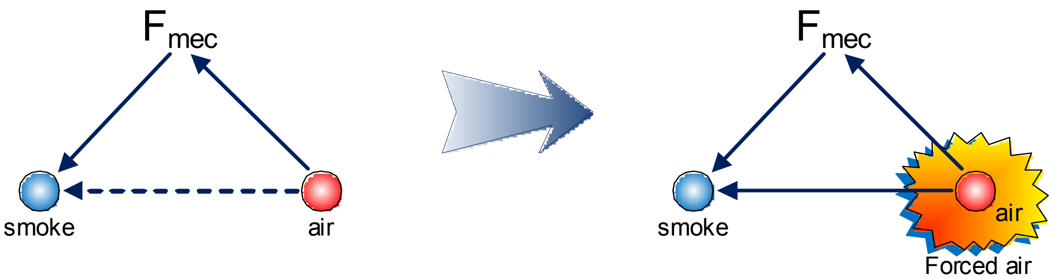
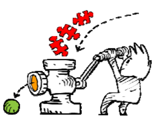


Fig. 2.2.1.1.5.b – an explanatory model of standard solution # 1.1.5

If we try to observe the environment we can find, for example clean air, that could help to dissolve smoke quickly. But if air, both the clean part and the polluted one, is immobile, the problematic situation doesn't change enough. So we could imagine to put into the room clean forced air in order to take away a lot of smoked air in a very short time (fig. 2.2.1.1.5.b right).

Self Assessment

Exercise 1:
Nina has invited her friends for dinner to eat homemade Italian pizza. She reads the recipe in a cookery book and prepares the dough, but just finished, she discovers that it doesn't rise quick enough for dinner, because the leavening time is quite long. Having just studied the Standard 1.1.5, how do you think to help our friend Nina?



Answer 1:
The initial stressful Nina's situation is represented in fig 2.2.1.1.5.c left, where the S_2, the leaven, through a chemical field is not able to rise sufficiently S_1, (the dough) in time.

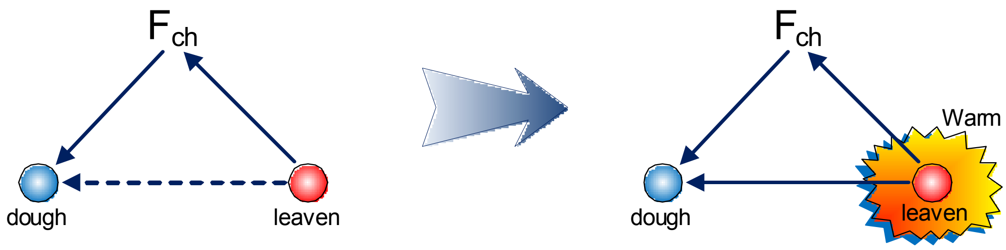


Fig. 2.2.1.1.5.c – the model to improve the leavening process

The parameter to improve is time of rising, and it depends, among the others, on temperature. According to standard 1.1.5 we must consider the impasto environment and try to change it somehow. So if the dough is invested by quite hot air the leaven rises dough quickly (fig. 2.2.1.1.5.c right).

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 1-1-6: PROVIDING MINIMUM EFFECT OF ACTION

Definition

Providing minimum effect of action is requested when a useful excessive action is delivered, thus it is necessary to reduce the impact of the Tool on the Object of a Su-Field interaction.

Theory

When there's an excess of a Substance or an excess of a Field and it is difficult or impossible to provide a controlled (measured, optimal) amount of it, it is recommended to keep the status of the excessive substance or field and to remove the superfluous secondarily. The excess of a substance is removed by a field (fig. 2.2.1.1.6.a, above), while excess of a field is removed by a substance (fig. 2.2.1.1.6.a, above).

Model

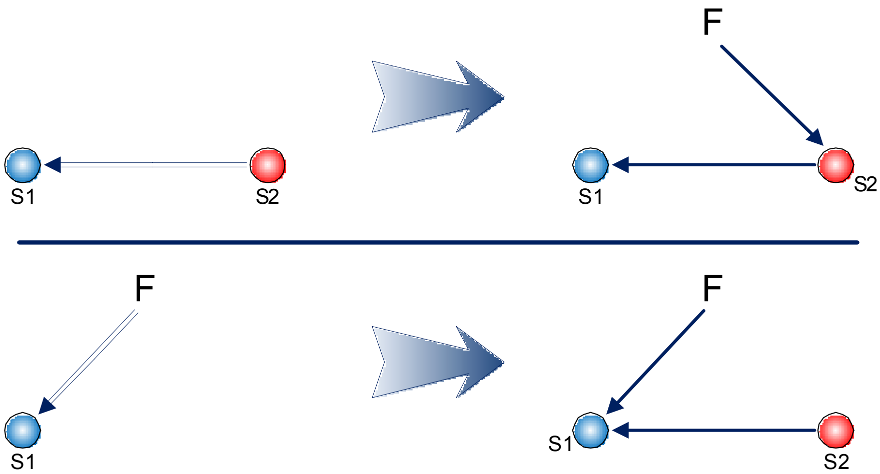


Fig. 2.2.1.1.6.a – STANDARD 1-1-6: Providing minimum effect of action

Instruments

This standard is applied when an excessive amount of substance is present in the system or when a useful interaction is excessive (*1.1.2 – Types of interactions and related symbols*).

If it is too difficult or even not possible to reduce and control the amount of substance/field, the following steps should be applied:

4. build a Su-Field model of the excessive useful interaction;
5. identify the parameter characterized by an excessive value;
6. introduce a modification capable to remove the excess:
   * if the excessive parameter is related to a substance S2, look for field resources to be applied to S2, capable to produce the desired value of S2 parameter;
   * if the excessive parameter is related to the impact of a field F on a substance S1, look for substance resources to be applied to S1, capable to produce the desired impact of the field F;

Note: the third step can be driven by a table of substance-field resources.

Example

Nina is at the beach, and she's sunbathing to become tanned and so prettier. But as it is known, too much sun is dangerous for our skin, especially the UV-B rays. She is a TRIZ student and immediately recognizes that she could apply a standard solution to solve her problem. The sun is the sun, e she has nothing to do, neither with the electromagnetic field which it produces even if it is excessive, but she wants to sunbathe. So the initial situation is like that reproduced in fig. 2.2.1.1.6.b left.

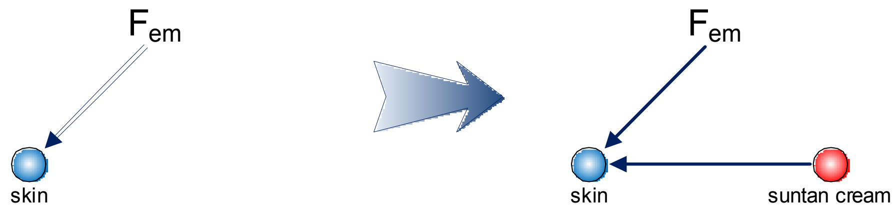


Fig. 2.2.1.1.6.b – to solve the problem of sun burns with Su-Field

Applying Standard solution 1.1.6 a second substance S_2 is needed to reduce the effect produced by sun. This substance is the suntan lotion that cuts down the intensity of sun rays reaching Nina' skin (fig. 2.2.1.1.6.b right).

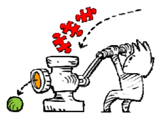
Self Assessment

<u>Exercise 1:</u>

Bill is at work, and he must design a device to fill with small pellets all the sixty holes that are disposed in a radial way on a spinning wheel. The wheel has a horizontal axis, and it rotates at a very high speed. The holes help to deliver a single pellet at a time to another mechanical device that pulls out the pellet and deposits it on a conveyor belt. The actual loading system of the wheel is composed by a tank full of pellets; the wheel goes through this tank, and pellets fall down into the hole aided by gravity and by an air stream. But at the given speed there is a high percentage of failures. How Bill can improve his device using standard 1.1.6?

<u>Answer 1:</u>

The first step toward the solution is to see that the wheel is filled with a number of pellets greater than necessary. In this way the initial situation to use standard 1.1.6 is obtained: an excessive number of pellets (S_2) is filing external portion of the wheel (S_1) as represented in fig. 2.2.1.1.6.c.



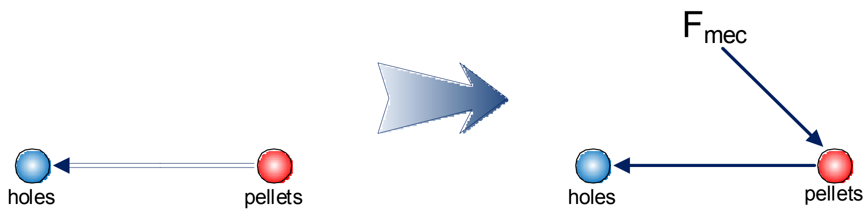
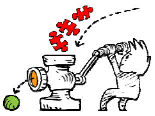


Fig. 2.2.1.1.6.c – a device improving using standard 1.1.6

The number of pellets is the parameter at its excessive value and it is provided by a substance to another one. So we have to find a field able to grant that the chosen parameter is at the right value. We have a wheel, rotating at a high speed: centrifugal forces could represent our resource to fulfill Standard's model.

Exercise 2:

Sometimes to clean bathroom surfaces from limestone or other kind of blemish some acids are needed. But its chemical effect could be excessive for pottery that may be eroded. According to standard 1.1.6 how could you resolve this problem?



Answer 2:

Start with modeling the initial state: we have only a field (F_{ch}) that performs an excessive action toward the pottery (S_1), as represented in fig.2.2.1.1.6.d left. In this case we can choose as parameter at an excessive value the pH of the cleaner. According to standard 1.1.6 suggestion we have to find a second substance (S_2) in such a way that the action becomes useful and sufficient. This second substance could be a diluting agent inside the bottle of acid that absorbs some of its corrosive power and lows solution pH values (fig. 2.2.1.1.6.d right).

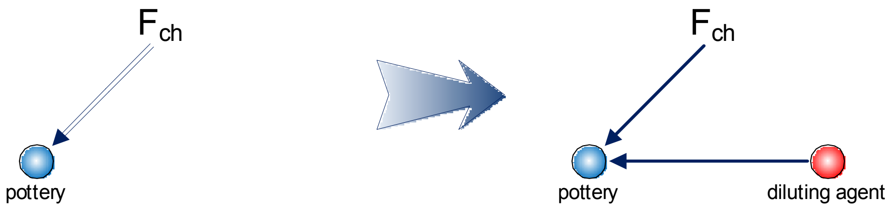
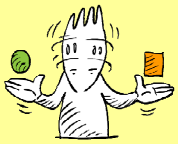


Fig. 2.2.1.1.6.d – a possible solution for an excessive active field

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3



See also:
4.1.1.2 – Types of interactions and related symbols

STANDARD 1-1-7: PROVIDING MAXIMUM EFFECT OF ACTION

Definition

If a maximum effect of action on a substance (Object) is required and this is not allowed, the maximum action has to be preserved but directed to another substance attached to the object itself.

Theory

When it is desired to exert the maximum effect on a certain object, but the conditions of the system determine some impediments to the direct action of such a strong field on the object itself (fig. 2.2.1.1.7.a, left), it is suggested to address the same field on another substance linked to the object, in order to keep the benefits, without violating any constraint of the system and7or introducing any harm (fig. 2.2.1.1.7.a, right).

Model

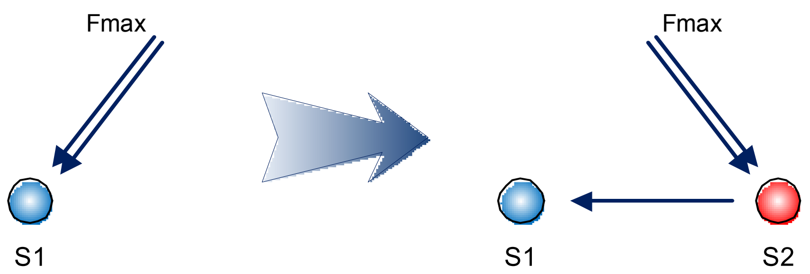


Fig. 2.2.1.1.7.a – STANDARD 1-1-7: Providing maximum effect of action

Instruments

This standard is applied when a useful interaction is desired at its maximum extent, but cannot be applied at the same time, and thus results excessive (*1.1.2 – Types of interactions and related symbols*).

If it is not desired to reduce and control the amount of field, the following steps should be applied:

1. build a Su-Field model of the excessive useful interaction;
2. identify the parameter characterized by an excessive value;
3. look for substances which can be submitted to the same useful interaction and tolerate its maximum effect;
4. Identify possible resources (properties, characteristics) of the substance S1 which can be linked to the added substance S2.

Note: the third and the fourth steps can be driven by a table of substance-field resources.

Example

Frequently a right torque is required to tighten screws. If a little force is applied on the wrench, it is impossible to reach the required result. If a too strong force is applied the limit of desired torque on screw could be overtaken, causing also risk of breaking screw's head. Translating this situation in Su-field language, there is a substance S_1, the screw, on which a mechanical field is applied, (fig. 2.2.1.1.7.b left).

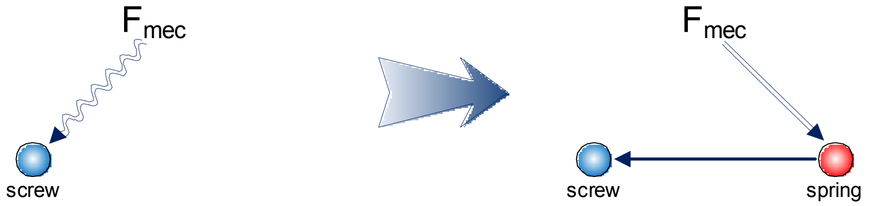


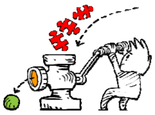
Fig. 2.2.1.1.7.b – the model of a mechanical problem solved with standard 1.1.7

This field must be at its maximum level to reach the goal, but it is impossible to apply it because of risk to pass screw yield stress. So a second substance S_2 is required between the F_{mec} and S_1: this substance could be a spring that lets transfer the torque till a certain given value, then it warps, in such a way even with a maximum force screw is safe (fig. 2.2.1.1.7.b right).

Self Assessment

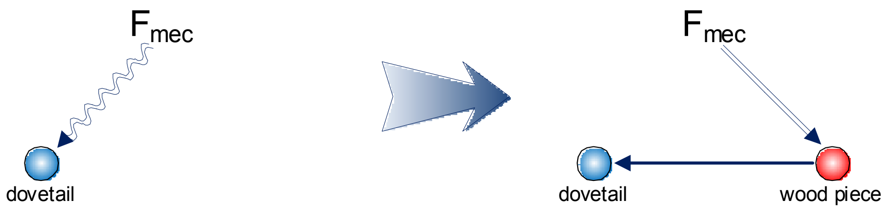
Exercise 1:

Nina's grandfather is a joiner. He is realizing a wood closet, and he has to force a dovetail. To do this he must hit the wood piece with an hammer, because a lot of force is needed, but the hammer bruise the wood. Can you help the joiner?



Answer 1:

The initial situation could be modeled with a field, developed by the hammer so a mechanical one, that interact in a excessive harmful way toward the wooden dovetail (S_1), see fig. 2.2.1.1.7.c left. According to standard 1.1.7, we have to find a second substance attached to the first one which preserve the maximum effect of the field, fig. 2.2.1.1.7.c right. This could be a wood piece over the dovetail that transmit the hammer hit force to the joint avoiding any harmful consequence of the hit distributing the force in a larger surface.



*F**Fig. 2.2.1.1.7.c – a standard solution applied in a joinery***

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

Education and Culture DG
Lifelong Learning Programme

STANDARD 1-1-8: PROVIDING SELECTIVE EFFECT

Definition

A selective effect of action is required when the effect of a certain field on a substance (object) is required to have different values in different regions of the object itself.

Theory

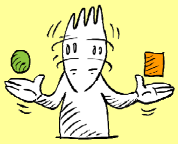
When an useful field is applied to a certain object, but it is desired a different impact of such a field on different regions of the object itself, two options are possible:

apply a maximal field, then a protective substance is introduced in places where a minimum effect is required (see 2.2.1.1.8.1);

apply a minimal field, then introduce a new substance capable to amplify the local effect where the maximum effect is required (see 2.2.1.1.8.2).

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3



See also:
4.1.1.2 – Types of interactions and related symbols

STANDARD 1-1-8-1: PROVIDING SELECTIVE EFFECT BY MAXIMUM FIELD AND PROTECTIVE SUBSTANCE

Definition

A selective effect of action is required when the effect of a certain field on a substance (object) is required to have different values in different regions of the object itself.

Theory

When an useful field is applied to a certain object, but it is desired a different impact of such a field on different regions of the object itself, it is possible to apply a maximal field to the whole object and then a protective substance is introduced in places where a minimum effect is required.

Model

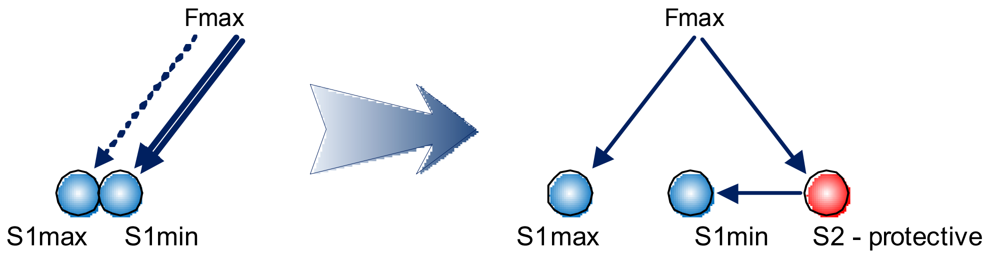


Fig. 2.2.1.1.8.1.a – STANDARD 1-1-8-1: providing selective effect by maximum field and protective substance

Instruments

This standard is applied when a useful interaction is desired at its maximum extent, but cannot be applied to the whole object, and thus results excessive on a portion of the object itself (*1.1.2 – Types of interactions and related symbols*).

If it is not desired to reduce and control the amount of field, the following steps should be applied:

1. build a Su-Field model of the excessive useful interaction;
2. identify the operational space of the interaction and distinguish the regions of the Substance s1 where different values of the same parameter are required;
3. look for substances which can play a protective role for the Substance S1, and more precisely for its region where a minimum effect is required;
4. Identify possible resources (properties, characteristics) to link the substances S1 and s2.

Note: the third and the fourth steps can be driven by a table of substance-field resources.

Example

Modern cars have wide widows and windshields to maximize the visibility of the external environment. Nevertheless, especially in summer time, when the sun is high and its light very bright, a large windshield lets pass too much light on the face of drivers and passengers.

Let's build a model of the situation: there is the sun light, that is an electromagnetic field, which impacts the whole passenger compartment through the windshield (fig. 2.2.1.1.8.1.b left)

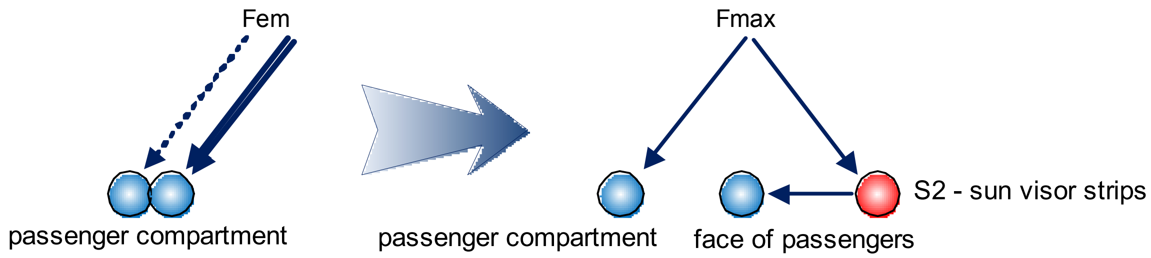


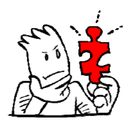
Fig. 2.2.1.1.8.1.b – to solve an everyday problem Standard solution 1.1.8.1 has been used

Since the light is excessive for a portion of the passenger compartment (where the faces of driver and passengers are positioned), according to standard 1.1.8.1 we have to add an external substance between the field and the eyes when we are driving, that absorbs the excessive field effect where it could be inconvenient. The solution can be a windshield sun visor strip on the top of the windshield as showed in fig. 2.2.1.1.8.1.b right and 2.2.1.1.8.1.c, which it lets see through but stops the excessive brightness of the sun light.

Fig. 2.2.1.1.8.1.c– on the top of the windshield the sun strip is visible; it lets see through but the sun is no more inconvenient because it is darker than transparent windshield glass.

Self Assessment

<u>Exercise 1:</u>



We are at the hospital. Nina's brother had an accident, and he has to be submitted to an X-ray analysis. However the doctor must examine not all body but only some interesting and critical parts of it. Like everybody knows X-rays aren't healthy at all, so Nina proposes an inventive solution. Have you any idea, according to Standard 1.1.8.1?

Answer 1:

The initial situation could be modeled as follows: a strong electromagnetic field hits Nina's brother body, but in some zones it is useful, in other ones it could be very dangerous. See fig. 2.2.1.1.8.1.d left.

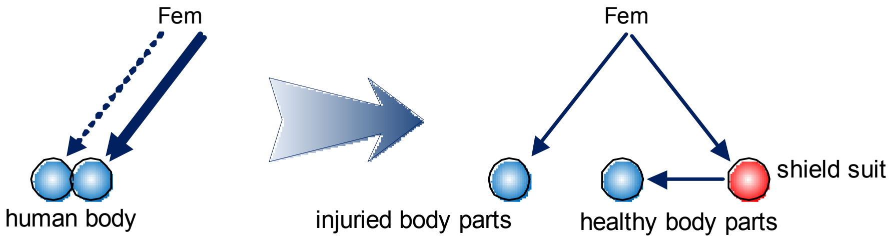
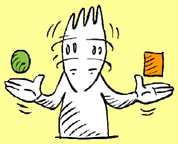


Fig. 2.2.1.1.8.1.d – an application of standard 1.1.8.1 in a sanitary environment

The same field is expected in some areas but it is unwished in others. So, following standard 1.8.1 suggestions, we need a substance S_2 that is hit by electromagnetic field and affords protection by X-rays in all non interesting zones (fig 2.2.1.1.8.1.d right). This second substance could be a special suit, made with an X-rays absorber or reflecting material, with holes in correspondence of interesting diagnosis zone.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3



See also:
4.1.1.2 – Types of interactions and related symbols

STANDARD 1-1-8-2: PROVIDING SELECTIVE EFFECT BY MINIMAL FIELD AND ACTIVE SUBSTANCE

Definition

A selective effect of action is required when the effect of a certain field on a substance (object) is required to have different values in different regions of the object itself.

Theory

When an useful field is applied to a certain object, but it is desired a different impact of such a field on different regions of the object itself, it is possible to apply a minimal field, then introduce a new substance capable to amplify the local effect where the maximum effect is required.

Model

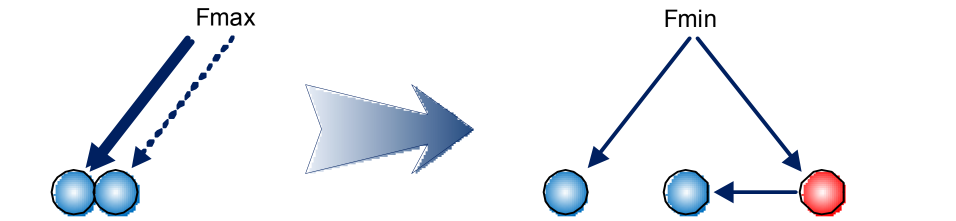


Fig. 2.2.1.1.8.2.a – STANDARD 1-1-8-2: providing selective effect by minimum field and active substance

Instruments

This standard is applied when a useful interaction is desired at its maximum extent, but cannot be applied to the whole object, and thus results excessive on a portion of the object itself (*1.1.2 – Types of interactions and related symbols*).

If it is not desired to reduce and control the amount of field, the following steps should be applied:

build a Su-Field model of the excessive useful interaction;

identify the operational space of the interaction and distinguish the regions of the Substance s1 where different values of the same parameter are required;

look for substances which can play an active (amplification) role for the Substance S1, and more precisely for its region where a maximum effect is required;

Identify possible resources (properties, characteristics) to link the substances S1 and s2.

Note: the third and the fourth steps can be driven by a table of substance-field resources.

Example

It could be strange, but some devices producing cool air, called direct-fired absorption chillers, need water at a temperature above 100 degrees Celsius. Air conditioning systems are used especially in summer time, when we have a lot of sunny days. So why don't use sun to warm water? As it is known a swimming pool, even if it remains a whole day under a hot summer sun doesn't reach boiling temperature. It is much easier warms up a bit of water by time, like in a boiler pipe, but sun itself can't reach this result. So we have an electromagnetic field, given by the sun that it is sufficient for earth life, but it is insufficient to warm a pipe fill of water till 100 degree Celsius. This is the initial model of standard, as is modeled in figure 2.2.1.1.8.2.b left.

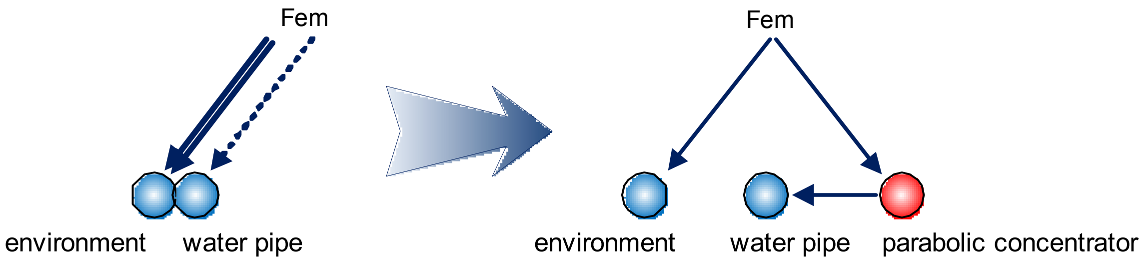


Fig. 2.2.1.1.8.2.b – an example of standard 1.1.8.2: parabolic concentrator

Since irradiation power of the sun cannot be increased, a substance S_2 doing that must be found (fig. 2.2.1.1.8.2.right). A parabolic mirror with the pipe in the focus could multiply sun effect a lot of time, warming water within the pipe in a very short time and also at temperature over 100 degrees Celsius.

Self Assessment

Exercise 1:

Nina's grandfather is 91 years old, and by now his hearing has some problem, so all the relatives are constrained to speak aloud to be heard. Nina doesn't like this situation and so she has studied the problem and she has found a good solution according to standard 1.1.8.2. Can you guess her solution?

Answer 1:

The first step Nina did was modeling the initial situation. We have a field, an acoustic field, generated by people speaking, that is sufficient to be heard from all (S_2) but insufficient for Nina's grandfather (S_1), see fig. 2.2.1.1.8.2.c left. Standard solution 1.1.8.2 states that if a field is needed to be high in certain zones, and low in others, it must be at its lower level and an external substance, interacting with the field, has to be introduced where the maximum effect is needful. An hearing aid is the right solution: it is put in grandfather ear and it amplify external acoustical field with no need for other people to shout to be understood.

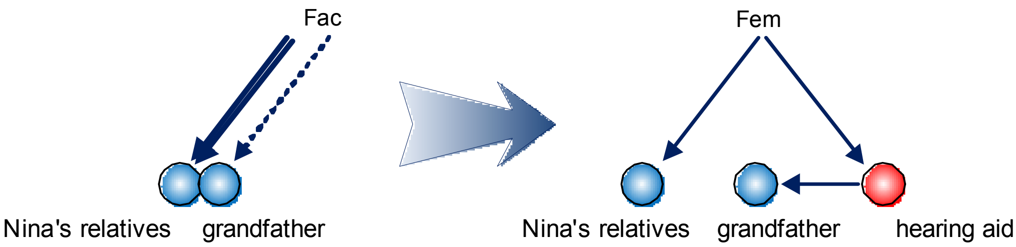


Fig. 2.2.1.1.8.2.c – standard solution could be used everywhere, with our grandfather too. In the picture the model of a problem with a deaf person.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

CLASS 1.2: ELIMINATION OF A HARMFUL INTERACTION

Definition

The elimination of a harmful interaction consists in the modification of a Su-Field system in order to avoid that a negative Tool exerts any undesired effect on the Object of the interaction.

Instruments

The standards 1.2.1-1.2.5 provide directions to eliminate, or at least minimize the harmful effect of un undesired functional interaction between two substances.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

4.

STANDARD 1.2.1 – Elimination of a harmful interaction by a foreign substance

Definition

The elimination of a harmful interaction consists in the modification of a Su-Field system in order to avoid that a negative Tool exerts any undesired effect on the Object of the interaction.

Theory

If useful and harmful effects appear between two substances in a SFM and there is no need to maintain a direct contact between the substances, the problem is solved by introducing a third substance between them.

Model

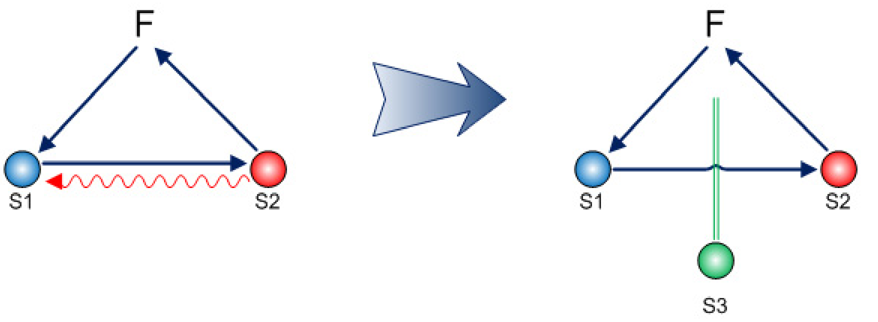


Fig. 2.2.1.2.1.a – STANDARD 1-2-1: Elimination of a harmful interaction by a foreign substance

Instruments

This standard is applied when two substances exchange both positive and negative interactions (i.e. useful and harmful functions are delivered), and it is allowed to introduce additives between the elements (fig. 2.2.1.2.1.a).

The following steps should be applied:

1. build a Su-Field model of the harmful function; identify the parameter modification to be eliminated;
2. check whether it is possible to introduce additives between the tool and the object, i.e. it is not mandatory to keep the two substances in contact with each other;
3. search for substances which might be interposed to interrupt the existing harmful interaction;
4. check if there are any limitations to the introduction of such specific substance into the technical system.

Note: the third step can be driven by a table of substance resources.

Example

Nina's mother, sometimes, cooks some dishes within the oven, but she doesn't like this kind of cuisine because the baking tin becomes very dirty with encrusted oil. If we try to model this situation the result could be like represented in fig 2.2.1.2.1.b left, that is a baking tin (S_1) performs the useful action through a mechanical field of containing dish (S_2), but at the same time dish dirties the tin. We should find an external substance able of interrupting the harmful action. The solution could be a baking release paper under the dish that preserves clean the pan (fig. 2.2.1.2.1.b right).

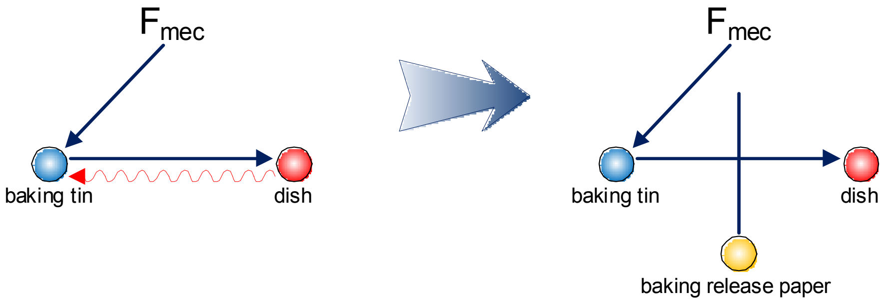
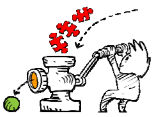


Fig. 2.2.1.2.1.b – Exemplary applications of standard 1.2.1 to remove the secondary harmful effect generated by S_2: a third substance has been introduced between S_1 and S_2.

Self Assessment

Exercise 1:
We are in our car, and outside it is raining. To clean the windshield we can use the windscreen wiper. Yet the friction force between the rubber and the glass, useful for cleaning, is harmful because of wasting of the blade. Try to solve this problem following the standard solution 1.2.1.



Answer 1:
The initial situation could be represented with a mini model composed by a first substance S_1, the rubber windscreen wiper blades, that by a mechanical field cleans a second substance S2, that is the windscreen. But in addition to the cleaning function, useful, we have to represent the harmful action too, given by the wasting of the rubber blade caused by the glass by means of same the friction forces helpful to clean fig. 2.2.1.2.1.c left. Standard solution 1.2.1 suggests to provide our system of a third substances able to stop the harmful effect of the mechanical field; see fig. 2.2.1.2.1.c right. The practical solution adopted is to cover the rubber with a graphite coating.

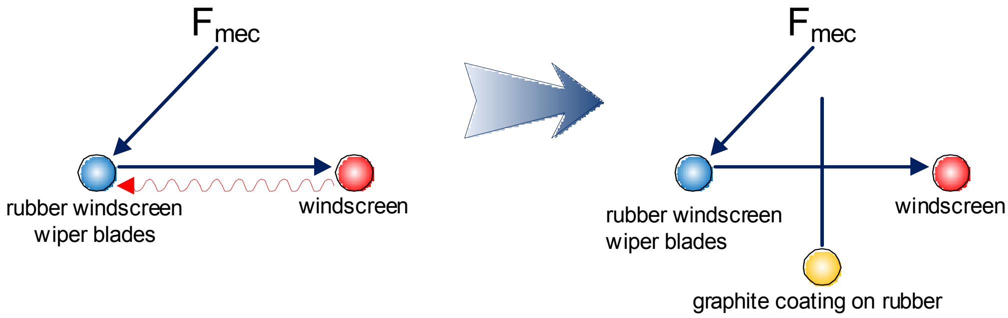


Fig. 2.2.1.2.1.c – how to use standard 1.2.1 to solve a problem with a windscreen wiper

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 1.2.2 – Elimination of a harmful interaction by modification of an existing substance

Definition

The elimination of a harmful interaction consists in the modification of a Su-Field system in order to avoid that a negative Tool exerts any undesired effect on the Object of the interaction.

Theory

If useful and harmful effects appear between two substances in a SFM and there is no need to maintain a direct contact between the substances, the problem is solved by introducing a third substance between them, which is a modification of the first of the second substance..

Model

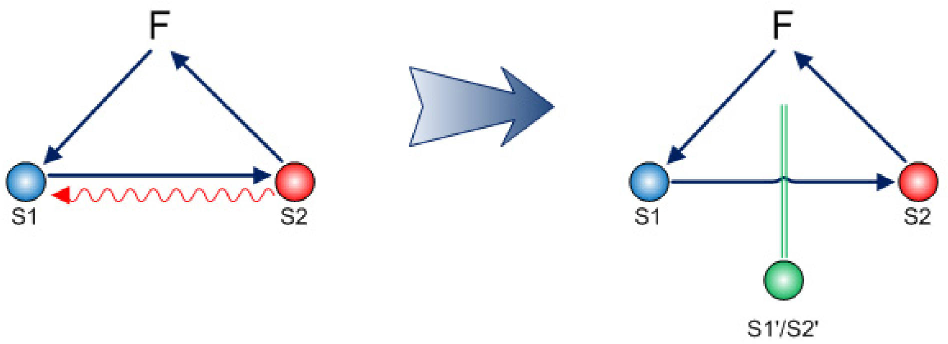


Fig. 2.2.1.2.2.a – STANDARD 1-2-2: Elimination of a harmful interaction by modification of an existing substance

Instruments

This standard is applied when two substances exchange both positive and negative interactions (i.e. useful and harmful functions are delivered), and it is allowed to introduce additives between the elements (fig. 2.2.1.2.2.a).

The following steps should be applied:

1. build a Su-Field model of the harmful function; identify the parameter modification to be eliminated;
2. check whether it is possible to introduce additives between the tool and the object, i.e. it is not mandatory to keep the two substances in contact with each other;
3. search for allowable modifications of the interacting substances S1 and S2, which might be used as a third substance to be interposed to interrupt the existing harmful interaction;
4. check if there are any limitations to the introduction of such specific substance into the technical system.

Note: the third step can be driven by a table of substance resources.

Example

When one rides a motorbike can feel the air pressure given by speed. So sometimes it uses to mount a small windshield that breaks air in place of rider helmet, but at the same time it creates troublesome turbulences. Going to model this initial state we have the windshield (S_1) that by a mechanical field protect from air pressure rider head (S_2), but at the same time it creates turbulences. According to standard 1.2.2 S_1 or S_2 have to be modified in order to remove the harmful action of the windshield. A way to solve the problem is to create a hole in the windshield lower part so that the air can follow the windshield profile from both its sides and reduces whirls formation at the upper part of the glass.

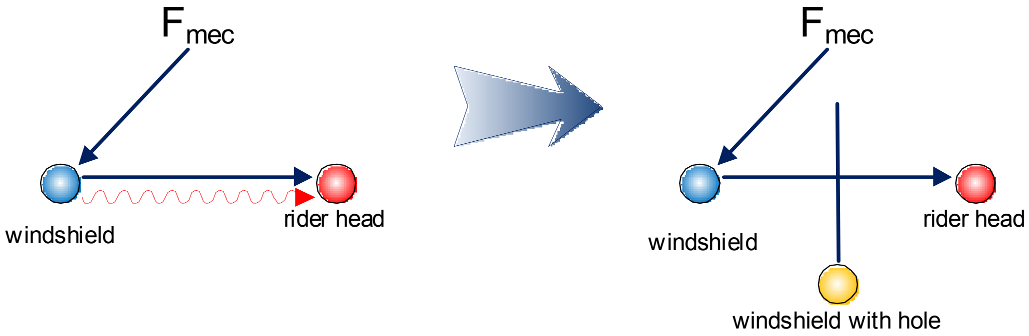
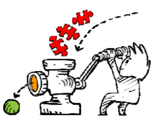


Fig. 2.2.1.2.2.b – Exemplary applications of standard 1.2.2 to remove the secondary harmful effect generated by S_1.

Self Assessment

Exercise 1:

When outside it is cold, we usually wear jackets, raincoats etc. Our body in fact is a good heat source and the jacket has the function of insulating from cold external air. But in particular situations it may occur that internal temperature increases, for example caused by a physical effort, and so also the formation of sweat. This moisture remains trapped in the zone where the jacket is closer to the body. Is it possible to solve this problem aided by standard solution 1.2.2?



Answer 1:

In this case we have the jacket which performs two action: the first, useful, is to insulate the body from the external air, and the second one, this time harmful, is to avoid that moisture goes away. In Su-Filed terms, this could be translated as represented in fig. 2.2.1.2.2.c left, where the jacket is S1 which by a thermal field insulates and wets body. Seeing that is quite difficult change some body properties, we can work only on the S_1, and we have to find its modification in order to break the making of moisture (fig. 2.2.1.2.2.c right). Knowing that warm air goes up, a special membrane on jacket shoulder could solve our problem (fig. 2.2.1.2.2.d).

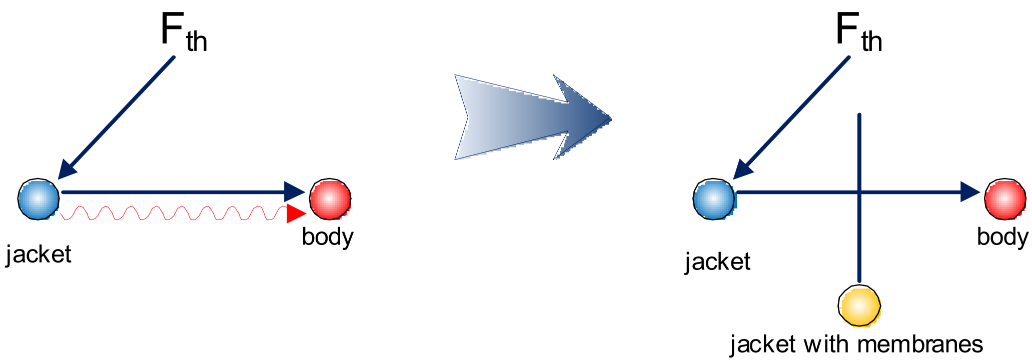


Fig. 2.2.1.2.2.c – Exemplary applications of standard 1.2.2 to remove the secondary harmful effect generated by S_1.

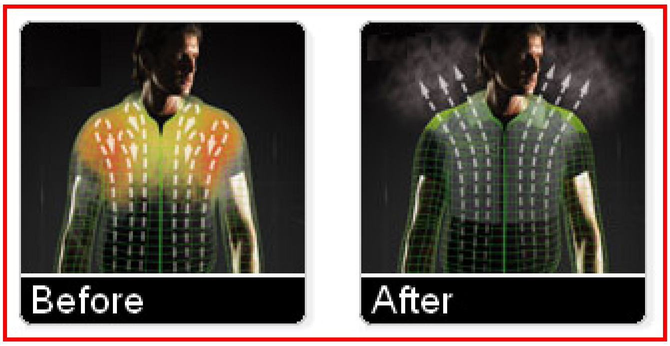


Fig. 2.2.1.2.2.d – The commercial solution of previous exercise.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 1.2.3 – Elimination of a harmful effect of a field

Definition

The elimination of a harmful field consists in the modification of a Su-Field system in order to avoid that an undesired effect impacts a certain substance.

Theory

If it is required to eliminate the harmful effect of a field upon a substance, the problem can be solved by introducing a second substance that draws off upon itself the harmful effect of the field

Model

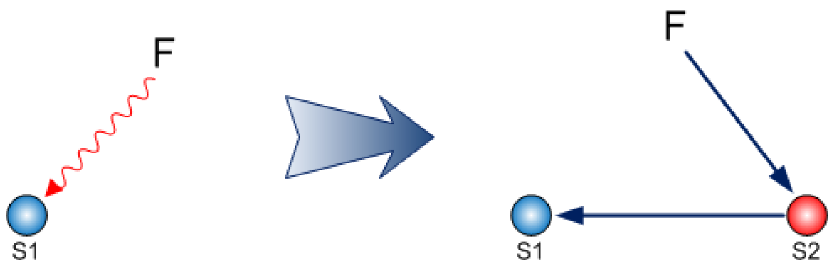


Fig. 2.2.1.2.3.a – STANDARD 1-2-3: Elimination of a harmful effect of a field

Instruments

This standard is applied when a harmful function is delivered to certain object, and it is allowed to introduce additives in the system (fig. 2.2.1.2.3.a).

The following steps should be applied:

1. build a Su-Field model of the harmful function; identify the parameter modification to be eliminated;
2. check whether it is possible to introduce additives in the system;
3. search for a further substance S2, capable to attract the existing harmful interaction and to preserve the system;
4. check if there are any limitations to the introduction of such specific substance into the technical system.

Note: the third step can be driven by a table of substance resources.

Example

Our car body is made up of metal and it may be attacked by rust. If we build a Su-Field model, we have a chemical field (F_{ch}) that performs a harmful action toward the body car (S_1), see fig. 2.2.1.2.3.b left. This is properly the effect we have to remove. According to the Standard Solution 1.2.3 we have to add another substance to remove the harmful effect of the field. Obviously the desired substance is the paint that cover the car body, which protect the car against moisture attack (fig. 2.2.1.2.3.b right).

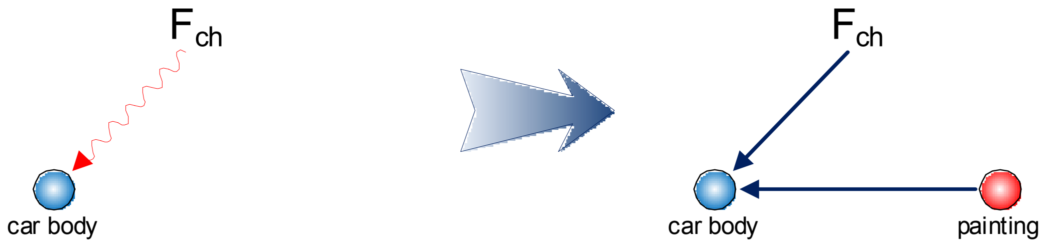
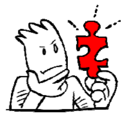
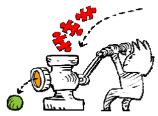


Fig. 2.2.1.2.3.b – Exemplary applications of standard 1.2.3 to remove the harmful effect of the field "chemical attack".

Self Assessment



Exercise 1:
When it is a sunny day, sunlight may be too bright for eyes. Try to model this easy situation and find a solution according to Standard 1.2.3.



Answer 1:
In the problem description we have just the elements to build a Su-Field model. In fact there is the sunlight which we can consider as an electromagnetic field; it performs an harmful effect toward our eyes, which represent the substance (S_1) (fig. 2.2.1.2.3.c left). A second substance is requested to break the effect of the field. The solution is played by dark sunglasses that allows eyes to see through, but reduce the brightness of sunlight (fig. 2.2.1.2.3.c right).

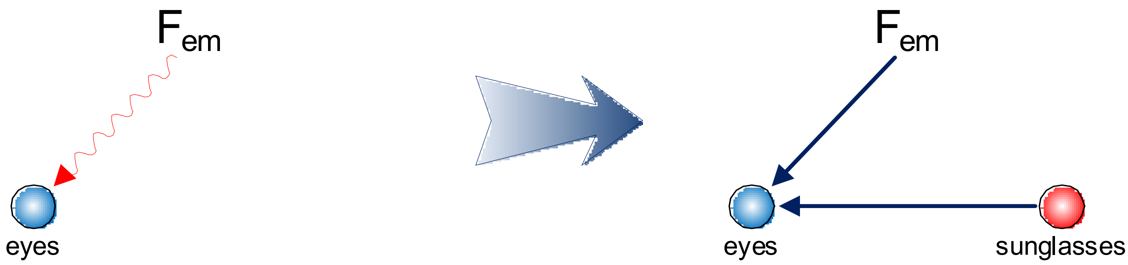


Fig. 2.2.1.2.3.c – Exemplary applications of standard 1.2.3 to remove the harmful effect of the electromagnetic field "to dazzle".

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 1.2.4 – Elimination of a harmful effect by a new field

Definition

The elimination of a harmful field consists in the modification of a Su-Field system in order to avoid that an undesired effect impacts a certain substance.

Theory

If useful and harmful effects appear between two substances in a Substance-Field System, and a direct contact between the substances must be maintained, the problem can be solved by transition to a dual Substance-Field System, in which the useful effect is provided by the existing field while a new field neutralizes the harmful effect (or transforms the harmful effect into a useful effect).

Model

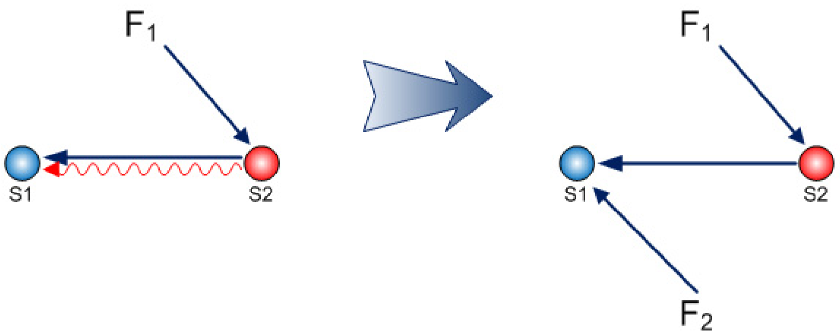


Fig. 2.2.1.2.4.a – STANDARD 1-2-4: Elimination of a harmful effect by a new field

Instruments

This standard is applied when a harmful effect impacts a certain object, and it is allowed to introduce a new field in the system (fig. 2.2.1.2.4.a).
The following steps should be applied:

1. build a Su-Field model of the harmful function; identify the parameter modification to be eliminated;
2. check whether it is possible to introduce a new field in the system;
3. search for a further field F2, capable to neutralize the existing harmful effect and to preserve the system;
4. check if there are any limitations to the introduction of such specific field into the technical system.

Note: the third step can be driven by a table of substance resources.

Example

Matt works in a joinery. Very often he has to make some straight cut with a pendulum jigsaw, so at first he draws a straight line with a pencil on the wood part to cut as reference. Yet, when he starts to cut, sawdust covers the line near the saw and Gino is forced to blow to remove the dust. Is it possible helping Gino using standard 1.2.4?
At first we have to build the substance-field model: extracting from the description there is the saw (S_1) which by a mechanical field (F_{mech}) performs the useful action of cutting the wood piece (S_2), see fig. 2.2.1.2.4.b left. Yet, the saw executes also a harmful action: the dust covers the reference line on the wood. The parameter damaged from the harmful effect is the

possibility of seeing the sign, so, according to standard 1.2.4 we have to find a second field in order to clean the line from the dust or to overcome its presence. An electromagnetic field could be a good answer, in fact laser beam projecting a straight line could solve the problem (fig. 2.2.1.2.4.b right).

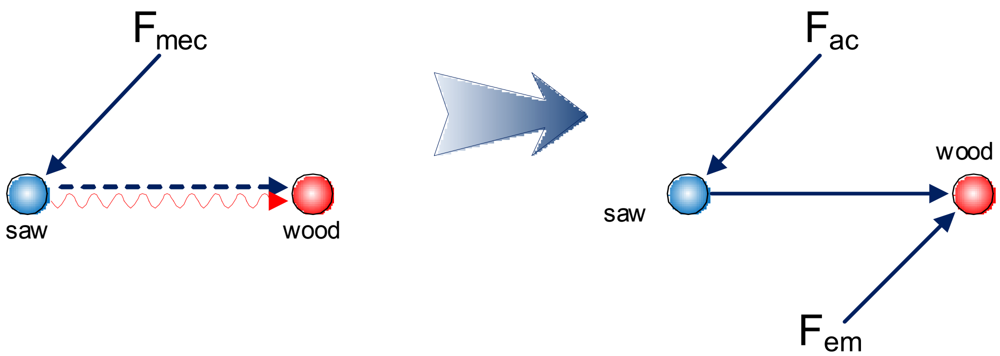


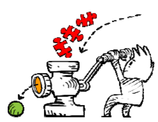
Fig. 2.2.1.2.4.b – Exemplary applications of standard 1.2.4: a second Su-Field model has been built to overcome the harmful effect generated by the first field.

Self Assessment

Exercise 1:

In a mechanical workshop there are a lot of machines tool. One of them works very well at high RPM but the friction between the tool and the working object may cause an overheating and so possible deformation of the object making the work not so precise. Try to solve this problem aided by standard solution 1.2.4.

Answer 1:



We have to start with building the initial model of the situation. We have the tool of the machine (S_1) that works the object (S_2) by a mechanical field, developing an useful and sufficient function. But the description states that the friction between S_1 and S_2, the same useful for the tooling function, causes an overheating of the object: this one is obviously an harmful action, because it generates object's deformation and so the loss of accuracy of manufacture (fig. 2.2.1.2.4.c left). Standard 1.2.4 suggest to introduce a new field (fig. 2.2.1.2.4 right) with the aim to neutralize the harmful effect of the field developing also the useful function of the system. This field for example could be a thermal one, acting only on the object or on both tool and object, in order to cool down them to avoid object deformation and loss of accuracy.

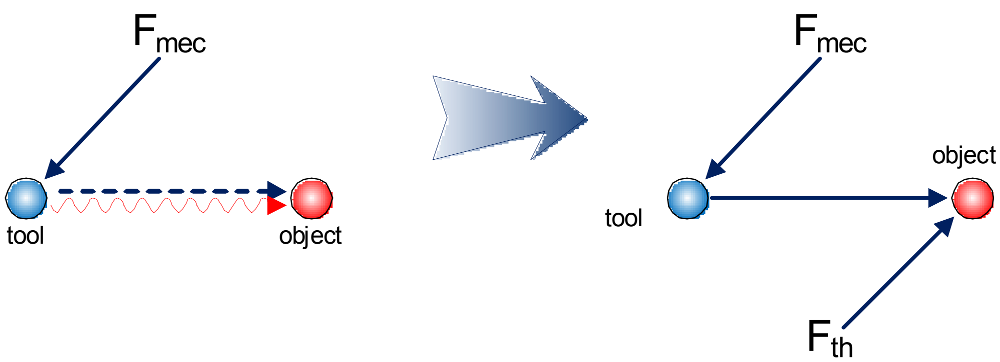


Fig. 2.2.1.2.4.c – the initial situation and the solved one of a machine tool system

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 2.1.1 – Synthesis of a Chain Substance-Field System

Definition

A Chain Substance-Field System is a complex systems where at least a substance generates and is subject to two different fields.

Theory

The efficiency of Su Field model can be improved by transforming one of the parts of the Su Field interaction into an independently controllable Su-Field, thus forming a chain Substance-Field system.

Model

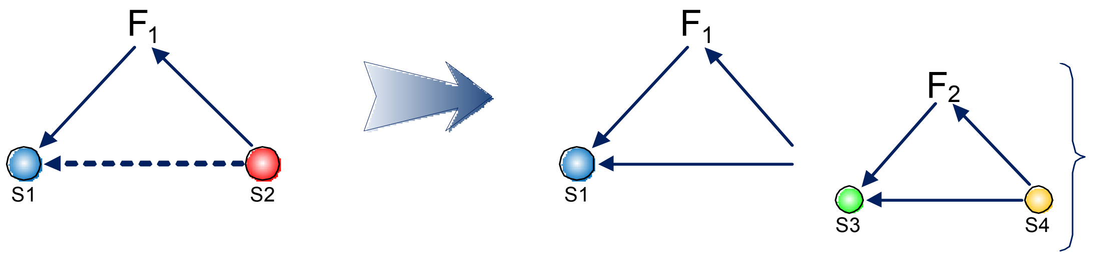


Fig. 2.2.2.1.1.a – STANDARD 2-1-1: Synthesis of a Chain Substance-Field System

Instruments

This standard is applied when an useful function is not sufficient, i.e. the modification exerted on the object doesn't fit the expectations, and it is not allowed to introduce additives in the system.

The following steps should be applied:

build a Su-Field model of the insufficient useful function; identify the parameter modification to be improved;

check whether it is possible to substitute the working element or the object with an independently controllable Su-Field subsystem;

search for resources which might improve the efficiency of the existing field;

check if there are any limitations to the introduction of such specific substances and field into the technical system.

Note: the third step can be driven by a table of substance resources.

Example

Nina has to prepare a lot of sandwich for a party. When she cuts the bread slice from the whole baguette with a knife she realizes that the knife could be improved, because with her arm she has to make both the alternating horizontal movement and the vertical one to slice the bread, and often the cut is not perfect. Building the Su-Field model of this initial situation we have the bread baguette (S_1), the knife (S_2) and the interacting mechanical field fig. 2.2.2.1.1.b left. The function is developed by the knife that by means of a mechanical field slices or cut the bread; this function is useful but insufficient. According to standard solution 2.1.1 to improve the initial model we have to transform the tool, in this case the knife, in a new separate Su-Field model. So we have to add another substance (S_3) and another field bounded to blade, fig 2.2.2.1.1.b right. We can add a motor (S_3) that provide to the blade by a mechanical field the alternating movement in order to leave to Nina only the task of guiding the new knife (fig. 2.2.2.1.1.c).

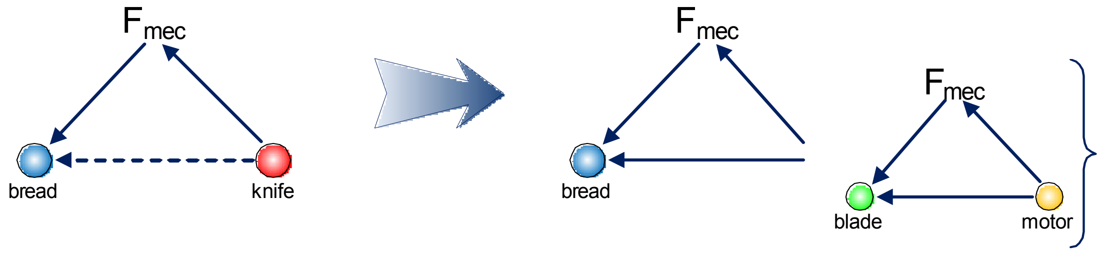
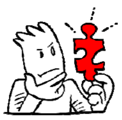


Fig. 2.2.2.1.1.b – the Su-Field model of the problem

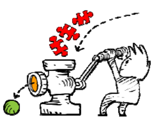
Fig. 2.2.2.1.1.c – electrical knife

Self Assessment



Exercise 1:

Nina is at the shopping center to buy some stuff. While she comes back home by feet, it starts raining. So she takes out her umbrella from the handbag: when she tries to open the umbrella she is in trouble because with one hand she holds the shopping bag and unfolding is not easy only with the other hand. Try to solve this problem making evolve the umbrella according with standard 2.1.1.



Answer 1:

The first step understands the problem e building its Su-Field model. The initial situation could be represented with a mini model composite by: the umbrella (S_1) and a generic hand (S_2) which by means of a mechanical field has some difficulties to unfold S_1. So the function of opening is naturally useful but insufficient fig (2.2.2.1.1.d left). Now, to follow the standard 2.1.1 suggestion, we have to transform one of the substances in a new separated Su-Field model. On the hand side is difficult to operate, but it easier working on the umbrella side. So we have to add another substance and a new field, in order to improve the actual system. We can imagine the third substance as a spring that when it is requested by hand, by means of the new field, also in this case mechanical, opens the umbrella (fig. 2.2.2.1.1.d right).

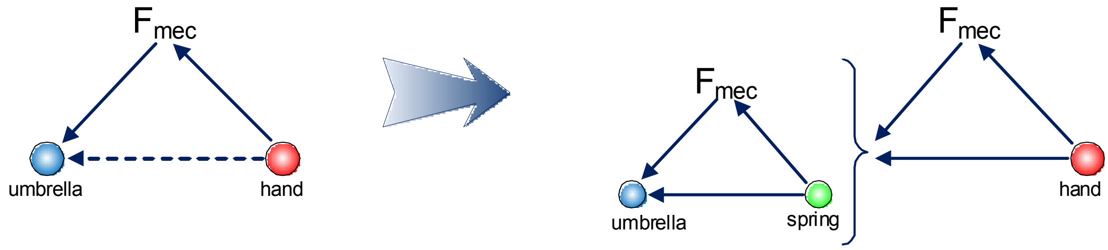


Fig. 2.2.2.1.1.d – standard solution 2.1.1 applied to un umbrella

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 2.1.2 – Synthesis of a Dual Substance-Field System

Definition

A Dual Substance-Field System is a complex systems where the substances interact through two parallel fields.

Theory

If it is necessary to improve the efficiency of Substance-Field System, and replacement of Substance-Field System elements is not allowed, the problem can be solved by the synthesis of a dual Substance-Field System through introducing a second field which is easy to control.

Model

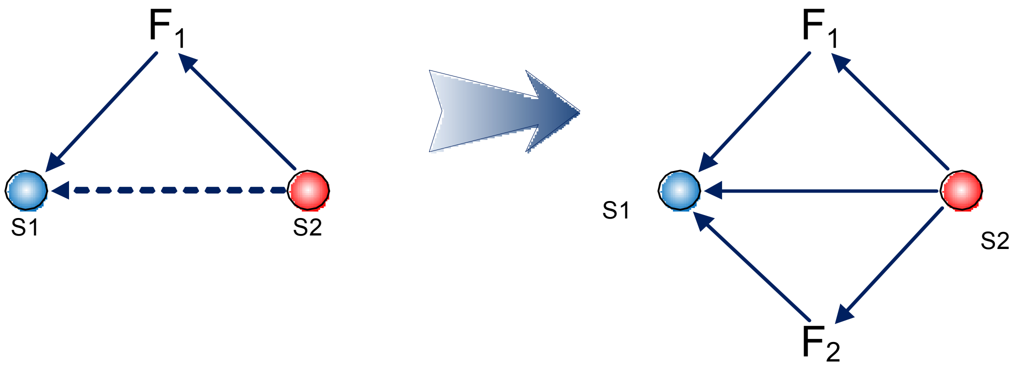


Fig. 2.2.2.1.2.a – STANDARD 2-1-2: Synthesis of a Dual Substance-Field System

Instruments

This standard is applied when an useful function is not sufficient, i.e. the modification exerted on the object doesn't fit the expectations, and it is not allowed to introduce additives in the system.

The following steps should be applied:

build a Su-Field model of the insufficient useful function; identify the parameter modification to be improved;

check whether it is possible to add a new field in the system;

search for new fields to be established between the original substances which might improve the efficiency of the existing interaction;

check if there are any limitations to the introduction of such specific field into the technical system.

Note: the third step can be driven by a table of substance resources.

Example

Nina went on holiday with her boyfriend Matt. When they arrived in the hotel, they found a nice room, with all comforts as minibar, air conditioning, sat-tv and trouser press (see fig. 2.2.2.1.2.c left). Before to go to sleep, Luca wanted to try to stretch his trousers with the press to be perfect the next day. The following morning he took out the trousers from the press yet they were stretcher than the night before but not as he has imagined. So he thought: "Why not improve this comfortable but unsatisfactory system ?".

The first step to do is building the model: in this case there are the trousers press (S_2), which by means of a mechanical field stretches in a useful but insufficient way the trousers (S_1), see fig. 2.2.2.1.2.b left. The standard solution 2.1.2 suggests to introduce in the initial model a new field in parallel with the existent in order to make the insufficient action as sufficient (fig 2.2.2.1.2.b right). Taking the list of all the possible field to add, the thermal one seems to be the more convenient. So to stretch the trousers instead using only a pressure that is a mechanical field, introduce in parallel also a thermal one to improve the useful action of the hotel trousers press (fig. 2.2.2.1.2.c right).

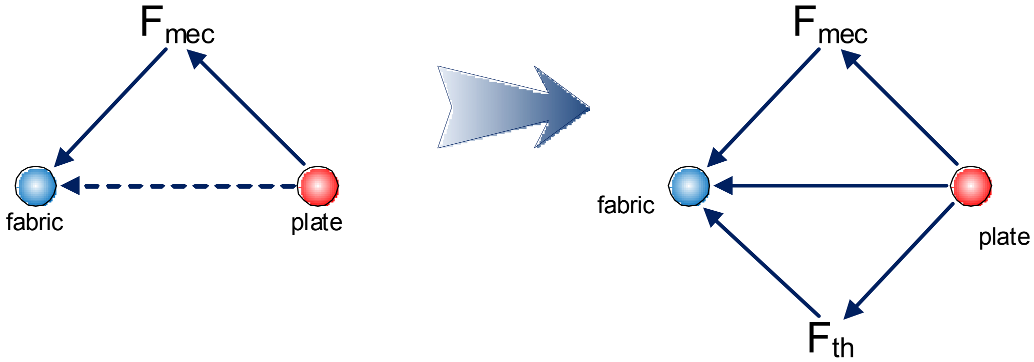


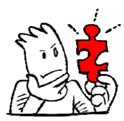
Fig. 2.2.2.1.2.b – the model of the problem

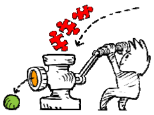
Fig. 2.2.2.1.2.c – on the left the first model of a trouser press, which works with a mechanical field. On right the evolved solution, which contains also a thermal field coupled with the mechanical one.

Self Assessment

Exercise 1:

To warm a room, usually a radiator is used. It heats up the air of the room by convectional movement: hot air leaves the radiator from its upper part, winds for all the room and in the meantime it cools down, and then it enters again in the radiator zone from its lower part. With this system warming up of the room is assured, but it needs a lot of time. How could you improve the radiator following the standard solution 2.1.2 suggestions?





Answer 1:

Start with building the Su-Field model of the initial situation. We can consider as a first substance the room we want to warm (S_1), as second the radiator (S_2), that is the tool of the system useful action, and as field a thermal one (fig. 2.2.2.1.2.d left). We have to improve this model by adding a new field working in parallel with the existent (fig. 2.2.2.1.2.d right). The time to warm the room must be decreased: actually hot air is shoved just by convectional movement, thus we have to find a way to speed up its motion. A mechanical field developed by a fan could be a good solution, (fig. 2.2.2.1.2.e).

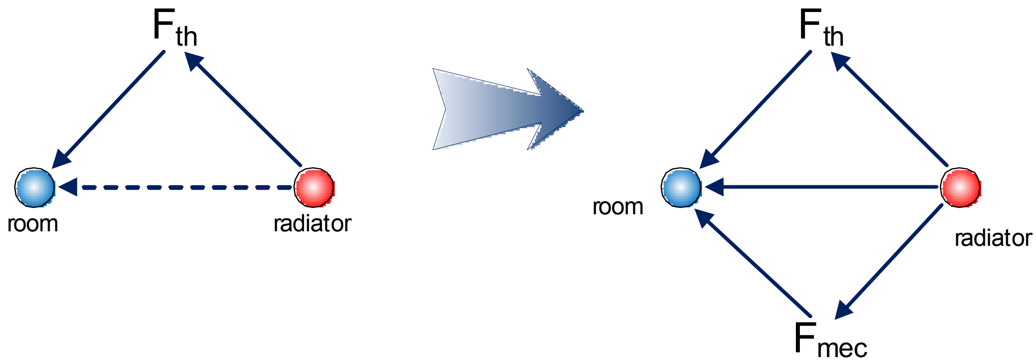


Fig. 2.2.2.1.2.d – the initial situation and the final solution modelled with Su-Field

Fig. 2.2.2.1.2.e – on the left a radiator; on the right a convector: within there is a radiator and a fan to move quickly warmed air.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 2.2.2 –- Increasing a degree of fragmentation of substance components

Theory
Efficiency of a Substance-Field System can be improved by increasing the degree of fragmentation of the object which acts as a "tool" in Substance-Field System, which in the end of its evolution will be replaced with a new field that can deliver a function of the tool.

Model

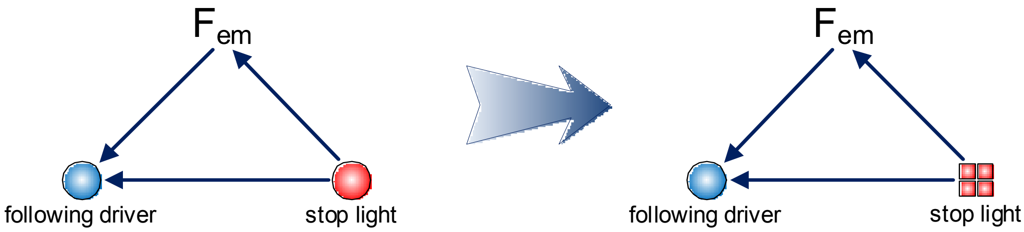


Fig. 2.2.2.2.2.a – STANDARD 2-2-2: Increasing a degree of fragmentation of substance components

Example
When we are driving a car, and we press the brake pedal, on the rear side of our car stop lights switch on to advise the following driver we are braking. Usually there are two stop light at the left and right part of the car and a central one. To improve this system by the suggestions of standard 2.2.2, start with build the mini model representing the initial situation. The function of the stop lights is to inform the following driver: so we have S1 represented by the driver, the object of the function, S2 are the stop lights, the tool, and the field of interaction is electromagnetic, fig. 2.2.2.2.2.b left. Standard 2.2.2 suggests increasing the degree of fragmentation of the substance which acts as a tool in the model, so we have to fragment the stop lights. It means that instead a single lamp by side, stop light may be composed by a set of small lamps like led, which allows to give different shape to the stop light, fig. 2.2.2.2.2.b right.

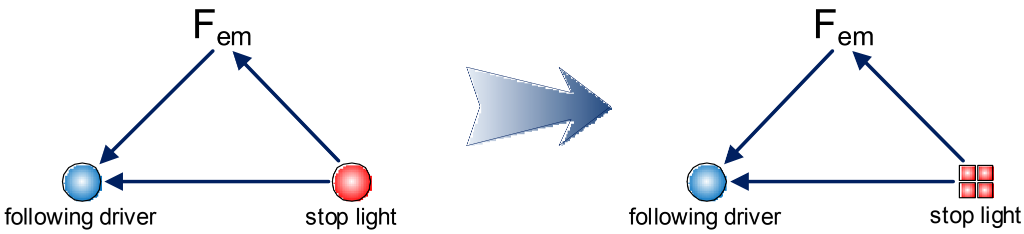
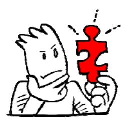


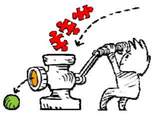
Fig. 2.2.2.2.2.b – the representative model of the system and its improving

Self Assessment

Exercise 1:
Nina's father is lover of bricolage, and in his garage he has a lot of instruments: keys, screwdrivers, drills, hammers, screws, nails, saws, and so on. A lot of them are hanged at the wall, in order to be taken easily. Until he works in garage or near the wall supplied with accessories, he doesn't have any problem, but when he has to repair something around for the house he has to bring all the needed tools, or to go to and fro to take the necessary. Taking into account for example the screwdrivers, how could you improve them according to standard 2.2.2?



Answer 1:



The building of the mini model is very easy: we have to consider the screwdrivers. In their action they interact obviously with screws, so in the model there are: the first substance "the screw", the second substance "the screwdriver" and the field of interaction that in this case is a mechanical one (fig. 2.2.2.2.2.c left). Now, the given suggestion said that we have to increase fragmentation of the tool of the model, so of the screwdriver, fig. 2.2.2.2.2.c right. What does increasing the fragmentation of a screwdriver mean? A possible solution could be separate the haft from the head and make the tools interchangeable.

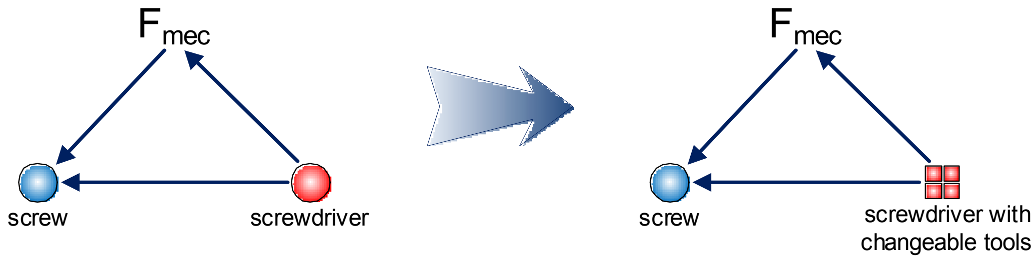


Fig. 2.2.2.2.2.c – the Su-Field model for a screwdriver

Fig. 2.2.2.2.2.d – on the left a set of screwdrivers with different head; on the right a single screwdrivers wit a set

of interchangeable heads for the different usages.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 2.2.3 – Transition to capillary porous objects

Theory

Efficiency of a Substance-Field System can be improved by replacing a solid object in the Substance-Field Mode with a capillary porous one.

Model

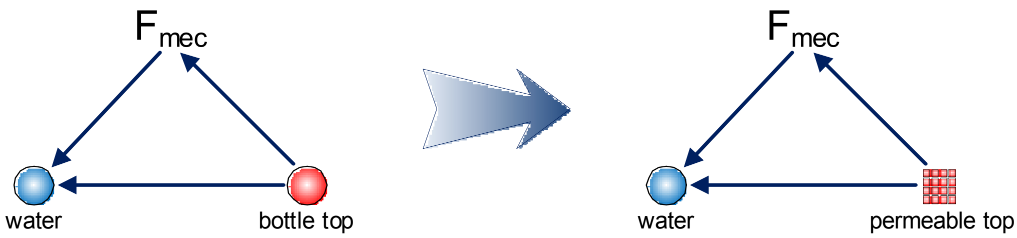


Fig. 2.2.2.2.3.a – STANDARD 2-2-3: Transition to capillary porous objects

Example

When Nina goes on bike, she takes always a water bottle to drink. This bottle must be closed in order to prevent that the water leaks. Yet, when Nina wants to drink she has to stop to open the bottle. If we want to improve the system “water bottle” following the standard 2.2.3, at first we have to model the original situation: the *tool* substance is the bottle top (S2), while the object is the water. The field of interaction is a mechanical one (fig. 2.2.2.2.3.b left); indeed we can say that the top stops the water and it is a mechanical action. Standard 2.2.3 suggests passing from a solid object to a porous one (fig. 2.2.2.2.3.b right). It means that the cap must be porous, that is it must be composed by a membrane that stops the water if the pressure is under a certain value, but it lets pass the water if the pressure overcome a certain threshold. The pressure could be increased for example squeezing the bottle.

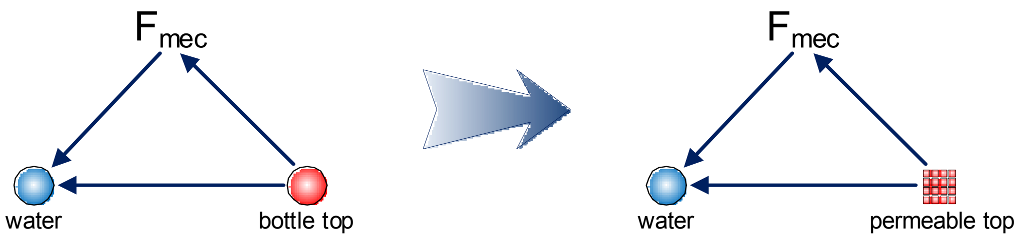
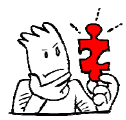


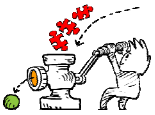
Fig. 2.2.2.2.3.b – improving a system increasing its porosity

Self Assessment

<u>Exercise 1</u>:



Nina is in the kitchen, and her mother is frying frozen fish and there is a problem with the hot oil. In fact, when the fish is put into the pan, the oil starts to spatter, dirtying the entire cooking plane and with the risk of burning Nina and her mother. The clear solution is covering the pan with a cap, but if there is the cap the smokes of the frying remains within and they give a bad taste to the fish. Is possible to improve the actual system with a new one according to standard solution 2.2.3?



Answer 1:

The first step must be focusing the system to improve: we have a cover to avoid that hot oil leak from the frying pan. So a substance is the frying oil (S_1), the other is the cover (S_2); they interact by means of a mechanical field (fig. 2.2.2.2.3.c left). The standard suggests to make a solid object before with a cavity, then with multiple cavities and so perforated, or at the end completely porous (fig. 2.2.2.2.3.c right). Now we have to translate this concept to our tool that is the cover. A good solution could be a cover made up of a very thick net, in order to stop the hot droplets of oil but at the same time let that the smoked pass through (fig. 2.2.2.2.3.d).

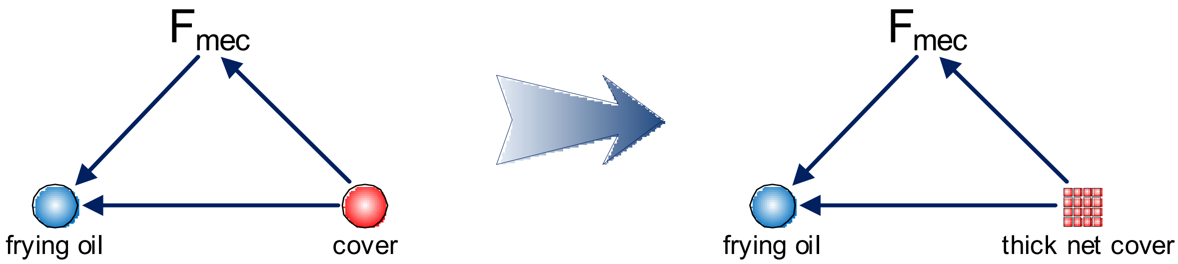


Fig. 2.2.2.2.3.c – the initial and final Su-Field model for a cover of a frying pan

Fig. 2.2.2.2.3.d – the first image represent a classic glass cover; on the right the cover made up of thick net

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 2.2.4 – Increasing a degree of system dynamics

Theory

Efficiency of a Substance-Field System can be improved by increasing the degree of dynamics (i.e. the degrees of freedom) of Substance-Field System, thus by a transition to a more flexible, rapidly changing structure of the system.

Model

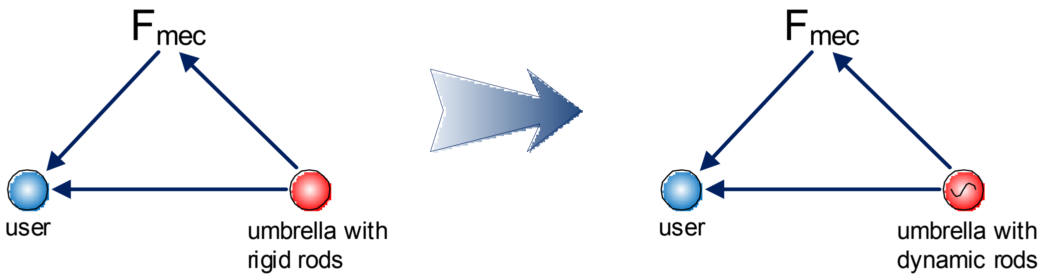


Fig. 2.2.2.2.4.a – STANDARD 2-2-4: Increasing a degree of system dynamics

Example

Nina is walking under the rain protected by an umbrella. While she’s walking, she looks to the umbrella structure. It is made by a long haft connected with a set of rigid rods that have the function to maintain tight the impermeable canvas. When the umbrella is opened a large surface is needed to protect mostly, but this imply also a big encumbrance when it is closed. The function of the umbrella is to protect the user from the rain droplets, and when Nina starts to build the Su-Field Model she has to consider: as first substance the user, as second one the umbrella and the field of interaction obviously mechanical. At this point, she wants to improve this model using the standard 2.2.4: the tool of the system has to increase its of dynamics. The umbrella, as already said, is made of two rigid parts, the haft and the rods, and a flexible one, and so already dynamic, the canvas. So she has to make dynamic or the haft, or the rods or both. To make dynamic a rigid body means give it a degree of freedom, so instead of rigid rod she can imagine a rod with one or more joints in order to occupy less when the umbrella is closed. The same concept could be used for the haft.

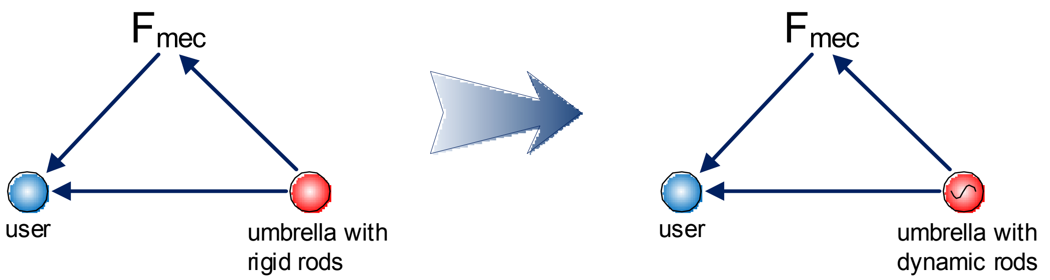
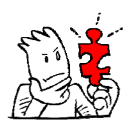


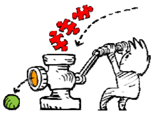
Fig. 2.2.2.2.4.b – increasing dynamics to a rigid umbrella

Self Assessment

<u>Exercise 1</u>:



If we look at the windows of houses in a lot of them we can find the wood shutters to avoid the sunlight enters in the room. Following suggestion of standard 2.2.4 try to find some solutions that increase shutter's degree of dynamics.



Answer 1:
The starting point is typically the building of the Su-Field model. The first substance is the sun light, the second one the wood shutters that by means of an electromagnetic field block the passing of the light (fig. 2.2.2.2.4 c left and fig. 2.2.2.2.4.d.1). The standard suggests making the model more dynamic and so more flexible. Obviously we can work with the sunlight, it is already at its maximum degree of flexibility, and it is a field! So we have to look a solution for the shutter. It is a rigid wooden blind, so the first step it to give it one more degree of freedom. This could mean that can be opened (fig. 2.2.2.2.4.d.2) in order to let pass a little bit of light more. But this is not enough; in fact we increase the dynamics degree, making all the bar of the shutter inclinable (fig. 2.2.2.2.4.d.3). The next step conveys toward a venetian blind, in which all the bars are moveable and the degree of darkening could be better chosen (fig. 2.2.2.2.4.d.4). The following degree of dynamics is to make the shutter completely flexible, as that represented in fig. 2.2.2.2.4.d.5 by a roller blind; the last step of the dynamic increasing process is the jump toward a field, that is the darkening capability is transferred to the glass of the window creating a self-diming window with the help of an electric filed (fig. 2.2.2.2.4.d.6).

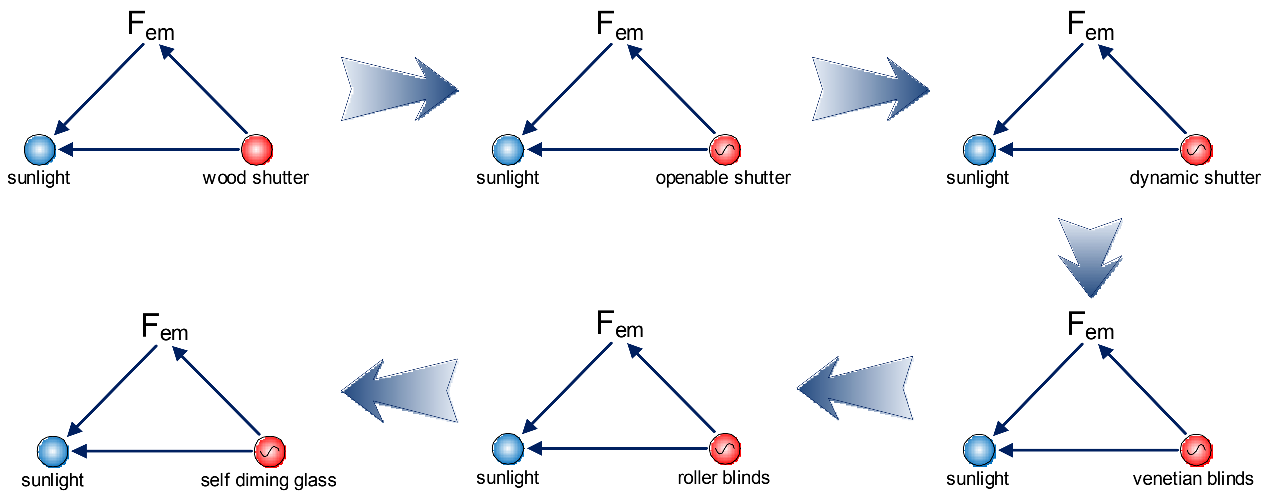


Fig. 2.2.2.2.4.c – how to improve a shutter by several Su-field models

Fig. 2.2.2.2.4.d – the process of the rise of dynamic degree for a shutter: 1) the classical rigid wooden shutter; 2) a shutter with the capability to be open in half; 3) a shutter with all the bars dynamic; 4) a venetian blind; 5) a roller blind; 6) a self diming glass.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 3.1.1 - Formation of bi and poly-systems

Theory
System efficiency at any stage of its evolution can be improved by combining the system with another system (or systems) to form a bi- or poly-system.

Instruments
For a simple formation of bi- and poly-systems, two and more components are combined. Components to be combined may be substances, fields, substance-field pairs and whole Substance-Field Systems.

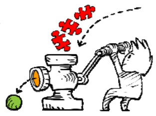
Example
Think to the lorries: they can carry very heavy weight, but sometimes these one are so weighty that the axles of the trailer could have some problems to sustain the load. So accordingly to the standard 3.1.1, the system can evolve passing to a poli-system, thus we can build a trailer with a lot of axles and small wheels to distribute the weight (fig. 2.2.3.1.1.b).

Fig. 2.2.3.1.1.b – in the image a trailer with axles evolved toward a poli-system

Self Assessment

Exercise 1:
On the Nina’s desk, at office, there is all she needs for: the computer, the phone, the fax, the printer, the scanner and so on. Yet sometimes Nina needs more empty space on the desk to manage her documents. How can you help her following the statements of standard 3.1.1?

Answer 1:



To increase the efficiency of a system it must be combined with another one o with more of one in order to create a bi- or a poli-system. So in the Nina’s desk instead of having a lot of different office tools, some of them could be merged in a single poli-system: for instance the printer, the scanner and the fax could be substituted by a multifunctional printers able to perform all the function of the single instrument (fig. 2.2.3.1.1.c).

Fig. 2.2.3.1.1.c – a multifunctional printer: it is a poli-system composed by a printer, a scanner and a fax.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 3.1.2 - Developing links in bi and poly-systems

Theory
Efficiency of bi- and poly-systems can be improved by developing links between system elements.

Instruments
Links between elements of a bi- and poly-system may be made either more rigid or more dynamic.

Example
In the last generation car, a lot of electronic gadgets are assembled as optional. A classic bi-system is composed by the car stereo with the Bluetooth connection to receive cell phone and use the same speaker as hands-free kit. The evolution of this system, following the suggestion of standard 3.1.2, has to be realized developing some links between the elements of the system. One interaction could be to decrease the playing music volume when a calling is arriving.

Self Assessment

<u>Exercise 1</u>:
If you pay attention to the motorcycle, you can see that some of them have the stand system composed by two stands: a center and a side one. So there is a bi-system. Try to make evolve this system according to standard 3.1.2.

<u>Answer 1</u>:
The standard 3.1.2 suggests developing a link, an “interaction” between the components of the bi-system, which are two stands of the motorbike. An explanatory solution could be this one: when the motorcycle is over the center stand, opening the side one prevent the closure of the first (fig. 2.2.3.1.2.b).

Fig. 2.2.3.1.2 – in the picture the two stands: the first (the center stand) sustain the motorcycle, while the second could avoid the first closure.

References
[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 3.1.3 - Increasing the difference between system components

Theory

Efficiency of bi- and polysystems can be improved by increasing the difference between system components. The following line of evolution is recommended:
similar components
components with biased characteristics
different components
combinations of the "component + component with opposite function"

Example

All know the rechargeable battery, for example the one within a cell phone. Their charge could be restored by a battery charger. If we try to make evolve the battery charger in accord with standard 3.1.3 we have to create a bi- or a poli- system in which the component must be very different or even with opposite function. We could imagine a battery charger enclosed with a battery discharger (fig. 2.2.3.1.3.b).

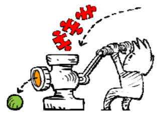
Fig. 2.2.3.1.3 – a system enclosed with its opposite: a battery charger/discharger.

Self Assessment

<u>Exercise 1</u>:

When the cars were equipped with the first car radio, two front speakers were provided, one on the left and one on the right. So this system was born as a bi-system. Subsequently other speakers are set in the car, for example in the rear seats. Try to improve this poli-system according to standard 3.1.3.

<u>Answer 1</u>:



The steps followed by car audio speakers have been: two speaker (bi-system), four speakers (poli-system), six speakers and so on. But, independently from the number of the speakers, they are identical. Standard 3.1.3 proposes to differentiate the elements, or, if they are already different, increase their difference. So we can realize a sound system in which every speaker or every pair plays a different sounds: for example 2 speaker for the higher frequencies (tweeter), two for the lower frequencies (woofer) and two for the middle.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 3.1.4 - Integration of several components into a single component

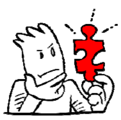
Theory
Efficiency of bi- and poly-systems can be improved by "convolution" (integration of several components into a single component) by reducing auxiliary components. Completely convoluted bi- and poly-systems become mono-system again, and integration can be repeated at another level of the system.

Example

Nina has a party with her friend, so she wants to be nice for her boyfriend. So she goes to buy some make-ups: lipstick, blusher, mascara, eyeliner and so on. When she is in the lipstick area of the shop, she notices a nice tool: a kind of pen with the lipstick at one side, and a lip liner at the other (fig. 2.2.3.1.4.b left). So she decides to purchase it. She remains very amazed with her shopping, but while she comes back home she has an idea to improve this bi-system: why not improve it following the advice of standard 3.14? A convolution of the bi-system is possible, making a lipstick with the lip liner included in (fig. 2.2.3.1.4.b right)

Fig. 2.2.3.1.4.b –on the left the bi-system lipstick & lip liner; on the right the convoluted bi-system

Self Assessment



<u>Exercise 1</u>:
Still few years ago, only desktop Pc existed, and like now, they were composed by the monitor, the case, the keyboard and the mouse. When usage of computer has become indispensable and the need to use the pc also over the office, a poly-system has been created: i.e. the idea of a portable Pc was born. This new system contains old previous separated element in a new one system. Accepting suggestion of standard 3.1.4 try to make evolving this system.

<u>Answer 1</u>:

Standard solution 3.1.4 suggests that to improve the efficiency of an existing bi or poli-system a convoluting process is needed. It means that we have to find a new system which is able to develop all the functions developed by the single component of the poli-system. So we need a black box able to be a monitor, a mouse, a keyboard and a case for the cpu. A good solution to this task are the latest generation tablet pc, in which all the actions could be performed on the touch screen monitor put on the top of the box containing all the electronic part of the pc (fig. 2.2.3.1.4.c).

Fig. 2.2.3.1.4.c – the latest generation portable tablet pc: all the input function are performed on the touch-screen monitor.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 3.1.5 – Distributing incompatible properties among the system and its parts

Theory

Efficiency of bi- and poly-systems can be improved by distributing incompatible properties among the system and its parts. This is achieved by using a two-level structure in which all the system as a whole has a certain property A, while its parts (particles) have property anti-A.

Example

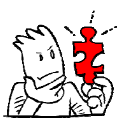
Nina is going to buy something for dinner, and she goes also in a butcher's shop. When she enters she finds the butcher which is removing bones from a big piece of meat. Suddenly yet the butcher loses the control of the knife and he hurts itself in a hand. So Nina asks him how is it that she doesn't use a protecting glove with some iron inserts. He answers that some rigid parts, although it is protective it isn't comfortable to work at all because of their obstruction to moving. Then Nina explains him that a glove with iron inserts is a bi-system, and to increase its efficiency of this a distribution of incompatible properties among the parts of the system could be done: the system in its entirety has a certain property but the single components parts could have the opposite one. So a special glove that is macroscopically flexible in order to facilitate the work but microscopically rigid in order to prevent injury to the worker is needed (fig. 2.2.3.1.5.b left).

This solution has been already adopted long time ago by the medieval soldiers to protect themselves from blade attacks at the place of a rigid armour (fig. 2.2.3.1.5. right).

Fig. 2.2.3.1.5.c – on the left a special glove for the butchery activities; on the right a chainmail armour.

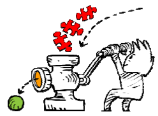
Self Assessment

<u>Exercise 1</u>:



In the old black and white television an high-energy electron beam, properly collimated and focused, excited a layer of phosphorescent coating on the screen that emitted light creating the image. But obviously this created image was in gray scale and not colored. According to standard 3.1.5 how is it possible rendering the image fully colored?

Answer 1:



The first step to use the standard 3.1.5 is to have a bi or a poli-system. Hot it is known all colors could be obtained by summating with different weight the three primary colors, red green and blue. So we can build a screen composed of three overlapping layer, each one creating an image in their own color scale, or a one layer with a special colored matrix able to be excited by three single electron beams, one for each color. In both cases, we have that the whole image, looked from outside the television is fully colored, but its parts (its pixel) are monochromatic (try to see TV from a very close distance, you will see RGB points clearly).

References

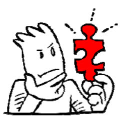
[1]	VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 3.2.1 – Transition to microlevel

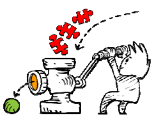
Theory
Efficiency of a system at any stage of its evolution can be improved by transition from a macrolevel to a microlevel: the system or its part is replaced by a substance capable of delivering the required function when interacting with a field.
It is worth to note that there is a multitude of microlevel states of a substance (crystal lattice, molecules, ions, domains, atoms, fundamental particles, fields, etc.). Therefore, various options of transition to a microlevel and various options of transition from one microlevel to another, lower one, should be considered when solving a problem.

Example
Take an electric device, for example an electric car. To perform some action it needs of some energy supplied by an electric storage cell (a battery). Obviously little by little that the cell provides energy to the tool it power runs down and so it needs to be recharged. Standard 3.2.1 suggests that to improve a system all of it or only one of its components must be changed and substituted by a new substance able to perform the desired function in interaction with a field. So in our case we have to find a new substance to introduce in our car to supply the energy needed by the engine looking at the microlevel. Einstein discovered that some material, if they are hit by wave light produce electrical energy. So using this principle we can provide the car of some solar cell to feed the engine.

Self Assessment



Exercise 1:
Nina is cleaning her room using a simple vacuum cleaner. While she is working she thinks how this tool works. Then she's got an idea to improve the cleaning system using the standard solution 3.2.1. And you, have you got any idea?



Answer 1:
The standard that Nina applied to find a solution suggests a transition from a macro to a micro level, i.e. we have to find a substance able to perform the function of removing dust and other small and light particles of dirty when it is subjected to some field. Some fabrics like wool or other synthetic ones could be electrostatically charged if rubbed, and so as polishing, in order to be able of develop the function of collect powder.

References
[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

STANDARD 5.1.1.1 - Introducing substances to a system under restricted conditions

Theory
If it is necessary to introduce a substance in the system, and it is not allowed, a "void" can be used instead of the substance.

Instruments
Note: A "void" is usually gaseous substance, like air, or empty space formed in a solid object.
In some cases a "void" may be formed by other substances, such as liquids (foam) or loose bodies.

Example
In every house, windows are present. They have the function of letting the possibility of changing air of the room and of letting pass through light from outside. But if there is a delta of temperature from outside to inside, windows must have also the function of insulating the room. But sometimes, their glass is not sufficient to this aim. A possible way to solve the problem is to grow the thickness of the glass, but doing so the windows become more expensive and heavier. Another way to reach the solution is to introduce a layer of thermal insulating material, for example a wood layer, but the windows are no more transparent. Standard solution number 5.1.1.1 suggests that when to introduce a new substance in a system to reach some goal is not allowed, void could be the right solution. In our problem we have to introduce another substance (glass or wood or other one), but it isn't allowed because of some negative consequences, so we have to find a way to solve the problematic situation with void, or air or empty space and so on. A good solution could be two thin sheets of glass but with a gap between them full of air for example: air is a good thermal insulator and the window remains light and transparent (fig. 2.2.5.1.1.b left).

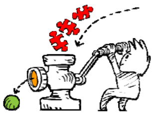
Fig. 2.2.5.1.1.b – a window section with an insulating hollow glass

Self Assessment

Exercise 1:

Nina is drinking a very hot coffee, insomuch that also the cup burns. So she starts thinking how and if is possible to improve the system to avoid that the user could burn his fingers to simply drink a cup of coffee. And you, have you got some idea to solve this problem using the standard solution 5.1.1.1?

Answer 1:



This standard suggests to introduce some void if any other substance is forbidden for any reasons. Nina's cup of coffee is very hot also in its outer part. The standard thinking for instance is to introduce a new substance more insulating then the pottery of the cup. But it is more expensive and besides it complicate the production process. So we could follow the standard suggestion, and try to introduce void in some way. We know that air is a good thermal insulator, so we have to introduce air between the inner surface that is in contact with the hot coffee and the outer one in contact with user fingers. A simple solution could be a cup like that showed in figure 2.2.5.1.1.c.

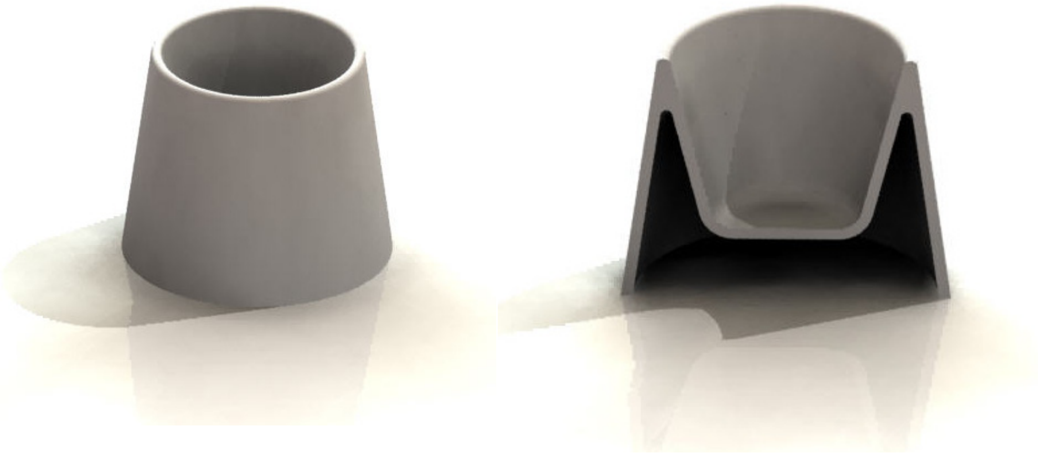


Fig. 2.2.5.1.1.c – a coffee cup that prevent finger burning. On the right its section.

References

[1] VV.AA.: A thread in the labyrinth (in Russian). Petrozavodsk: Karelia, 1988. ISBN 5-7545-0020-3

See also
1.3 OTSM Triz

5 Techniques to Resolve Contradictions / Resources / Effects

5.1 - Definition Contradictions

Definition

A contradiction literally means saying "No" but more generally refers to the proposition that assert apparently incompatible or opposite things.

Theory

TRIZ can be summarized as the result of a huge empirical study and can be presented as 3 main postulates – one of these postulates states the importance of "contradictions" in the field of problem solving and invention: These three postulates are:

- the existence of a set of Laws of evolution
- the concept of contradiction as the key barrier limiting system evolution until an invention appears
- the concept of the specific situation which determines the specific conditions and resources impacting the evolution of a technical system

The most effective inventive solution of a problem, according to TRIZ, is the one that overcomes some contradictions.

Instruments

A contradiction shows where (in the TRIZ so-called operative zone) and when (in the TRIZ so-called operative time) a conflict happens.

Contradictions occur when improving one parameter or characteristic of a technique negatively affects the same or other characteristics or parameters of the technique.

Examples

Presence of contradictions / dialectics can be shown in various fields:

- Mathematics: plus and minus, differential and integral
- Physics: mechanic action and reaction, positive and negative electrical charges
- Chemistry: combination and dissociation of atoms

5.1.1 – Types of Contradictions

Definition

Altshuller and his coworkers distinguished the following three types of contradictions:

- Administrative Contradiction - we speak about administrative contradiction when it is necessary to do something, but we do not know how to do it.
- Technical Contradiction - we speak about a technical contradiction when we improve one part (an evaluation parameter) of the technical system with the help of known methods, but that entails the worsening of other part (another evaluation parameter) of the technical system.
- Physical Contradiction - we speak about a physical contradiction when we impose mutually opposed requirements on the same control parameter of the system.

Further definitions of these 3 types are given in the following paragraphs

Theory
According to Altshuller, an inventive situation typically hides a number of contradictions. Identifying the contradictions which prevent the achievement of the Most Desirable Result is the first step from an inventive situation to the beginning of problem solution.
Usually, a successful formulation of the physical contradiction shows the problems nucleus. When the contradiction is extremely intensified, often the problems solution will be straightforward.

Instruments
See Chapter 2 "Techniques to resolve Technical Contradiction" & Chapter 3 "Techniques to resolve a Physical Contradiction"

Examples

Administrative Contradiction:
- It is necessary to detect the number of small particles in a liquid with very high optical purity.
- The particles reflect light poorly even if we use a laser.
- What to do?

Technical Contradiction:
- If the particles are very small the liquid stays optically pure, BUT the particles are invisible.
- OR if the particles are very big they are detected, BUT the liquid is not optically pure.

Physical Contradiction:
- The particle size must increase to be viewed AND-NOT increase to keep the optical purity of the liquid.

5.1.1.1 – Administrative Contradiction
Definition

The Administrative Contradiction states that there is a problem with an unknown solution.

Model
Something is required to make or receive some result, to avoid the undesirable phenomenon, but it is not known how to achieve the result.

Example

We want to increase quality of production and decrease the cost of raw materials.
Such a form of a problem recalls an inventive situation.
The administrative contradiction itself is provisional, has no heuristic value, and does not show a direction to the answer.

Notes
Most TRIZ practitioners completely ignore the Administrative Contradiction due to its lack of tangible meaning.

5.1.1.2 – Technical Contradiction

Definition

A technical contradiction occurs when two different Evaluation Parameters are in conflict with each other.
An Evaluation Parameter represent the desired domain for solutions.
The Evaluation Parameters and their required values define the objective of resolutions.
That means that these parameters represent what the customer or problem owner wants from the solution. That can be a better performance, an increased use of resources, a decreased amount of harmful effects, etc … (see OTSM model of a contradiction)

Theory

The technical contradiction represents a conflict between "two subsystems" or between a sub-system and the external environment.
Such technical contradictions occur if:

- Creating or intensifying the useful function in one subsystem creates a new harmful or intensifies an existing harmful function in another subsystem (or in the environment)
- Eliminating or reducing the harmful function in one subsystem deteriorates the useful function in another subsystem
- Intensifying the useful function or reducing the harmful function in one subsystem causes the unacceptable complication of other subsystems or the whole technique. Or even „just“ a not acceptable consumption of resources.

Model

There are different models for defining a technical contradiction:

- The OTSM model of a contradiction (described subsequently – Section Physical Contradiction)
- An action is simultaneously useful and harmful
- An action causes useful and harmful functions
- The introduction of the useful action or the recession of the harmful effect leads to deterioration of some subsystems or the whole system

Instruments

See Chapter 2 "Techniques to resolve Technical Contradiction"

Example

As a container becomes stronger it becomes heavier.
We want high strength and low weight.
We want to increase the penetration depth of ions into a semiconductor and decrease the electrical power (energy source) that is necessary for the ion implanter operation.

5.1.1.3 – Physical Contradiction

Definition

A physical contradiction defines a situation where there are conflicting values of one "Control Parameter".
Control Parameters impact a system and so represent the possible domain of variables. Control Parameters and their values define means to act on the problem.
That means that these parameters represent what we are able to change within the system.

Theory
Such physical contradictions occur if:

- Intensifying the useful function in a subsystem simultaneously intensifies the existing harmful function in the same key subsystem
- Reducing the harmful function in a subsystem simultaneously reduces the useful function in the same key subsystem
- it could be also useful against another useful function, harmful against harmful etc

See also "The OTSM Model of a contradiction"

Model

- See "The OTSM Model of a contradiction" (described subsequently)
- A given subsystem (element) should have property A to execute a necessary function and property non-A or anti-A to satisfy the condition of a problem.

A physical contradiction implies inconsistent requirements to a physical condition of the same subsystem (element) of the technical system.

Instruments
See Chapter 3 "Techniques to resolve a Physical Contradiction"

Example
We want high weight and low weight.
We want the insulator in semiconductor chips to have low dielectric constant k in order to reduce parasitic capacities – and we want that insulator also to have high dielectric constant k in order to store information better.

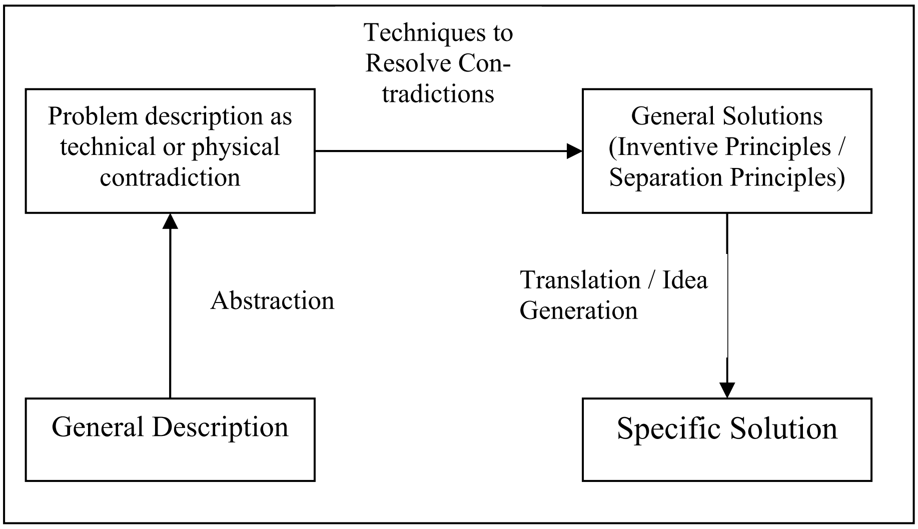
5.1.1.4 – TRIZ & Technical & Physical Contradictions

Definition

TRIZ states that inventive solutions eliminate contradictions rather than looking for tradeoffs , and that there is a defined set of inventive principles to help eliminate such contradictions.
The research of Altshuller discovered that not only it is possible to resolve contradictions, but there are a finite number of ways to resolve them.
Engineering solutions are mostly found by searching ‘randomly’ for the answer (trial-and-error problem solving) or drawing on personal knowledge and analogies. TRIZ offers a systematic process based on the concept of abstraction in which a problem-solver maps a specific problem to a generic framework out of which comes a generic solution requiring translation back to the specific.
Identifying, understanding and resolving contradictions within a system is a powerful way to improve that system. The way how to identify **and resolve technical and physical contradictions** and within a system will be described subsequently.

Theory & Model
The "Hill"-Model illustrates very well the overall steps of the application process:

- General description of the problem
- Abstraction the problem – problem definition as a technical or physical contradiction
- Application of the TRIZ techniques to resolve (technical or physical) contradictions - general solutions
- Idea generation for specific solutions of the specific problem



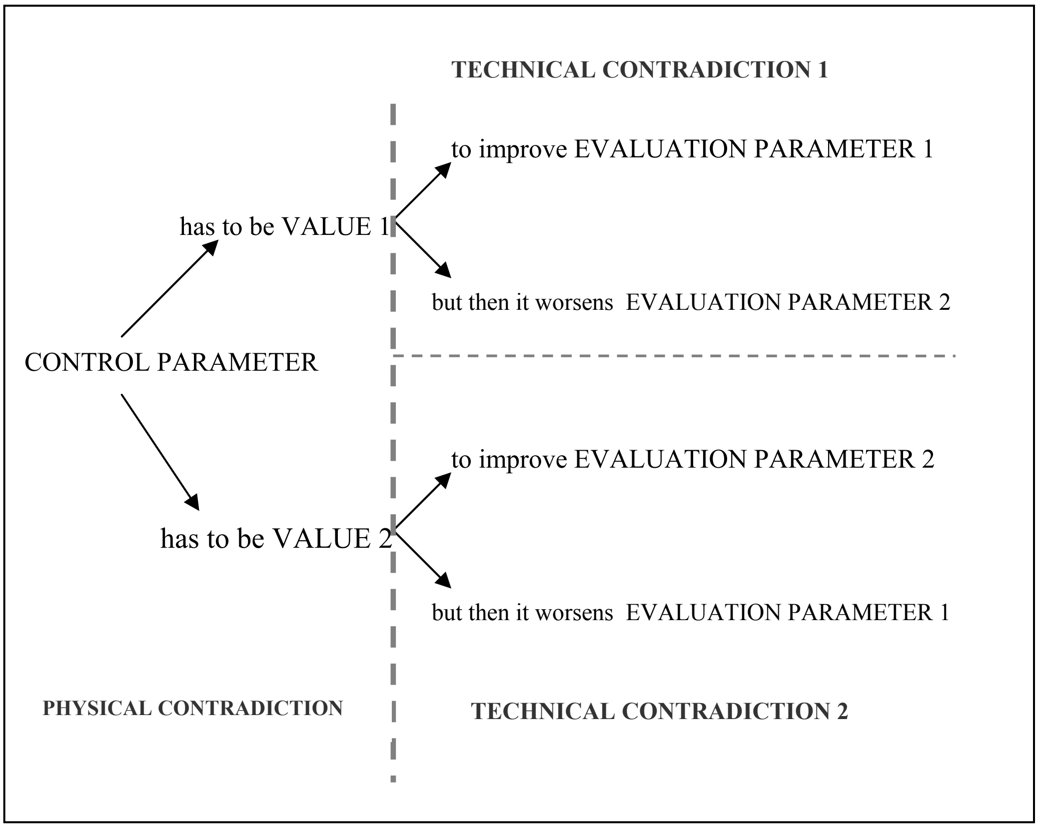
Instruments
See Chapter 2 & 3

5.1.2 The OTSM model of a contradiction:

This system of contradictions is based on the existence of a physical contradiction and two technical contradictions. These technical contradictions justify the need of the two different states of the physical contradiction.

The two technical contradictions are complementary as they correspond to the increasing of the first evaluation parameter that implies the decreasing of the second evaluation parameter. And of the increasing of the second that implies the decreasing of the first.

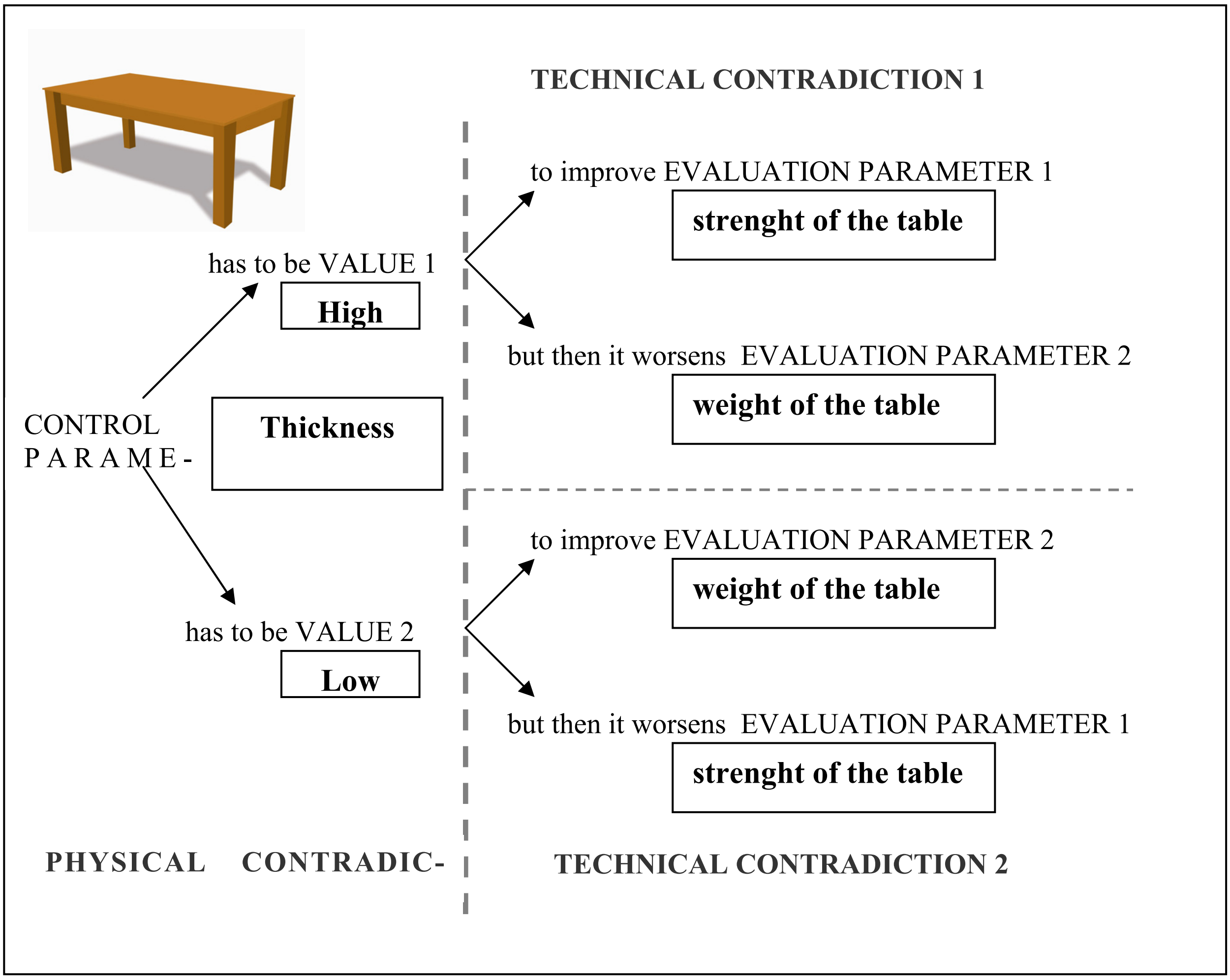
The two evaluation parameters of the technical contradictions are defined as taking part in describing the objective, whereas the control parameter of the physical contradiction is a mean to make the situation change.



The graphical representation of the OTSM model of contradiction makes it much more clear. We have to define / find one Control Parameter and two Evaluation Parameters of the system. The graphic representation is an easy to use template where on the "right part" we have the two Technical Contradictions, and on the "left part" there is the Physical Contradiction.

Model:
A certain Control Parameter should have a Value1 in order to improve a certain Evaluation Parameter1, but this worsens a certain Evaluation Parameter2, and the Control Parameter should have a Value2 in order to improve a certain Evaluation Parameter2, but this worsens a certain Evaluation Parameter1;
It is clear that V1 and V2 can assume also extremely opposite values like “present”/”absent”, or “true”/”false”, …..

<u>Example for Contradictions - OTSM Model</u>



Technical Contradiction 1: We want to improve the strength of a table but normally than the weight of the table worsens,
Technical Contradiction 2: If we improve the weight (make it lighter) the will worsens,

So we can define two Evaluation Paameters:
EP1: strength of the table
EP2: weight of the table

The next step is to look for a Control Parameter: Thickness of the table
Value of thickness can be "big" or "small"
If the thickness is big then the strength will be high (good) but the weight will also be high (bad).
If the thickness is small then the weight will be little (good) but the strength will also be low (bad).

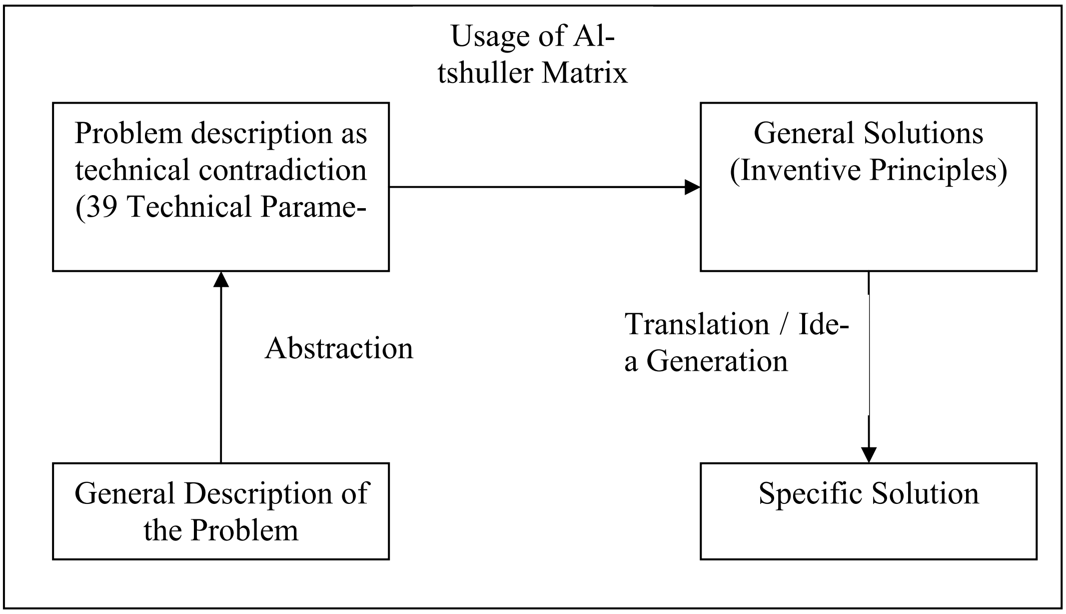
So we are looking for solutions to get a "big" AND "small" thickness!

5.2 – Techniques to resolve Technical Contradictions

Definition

A technical Contradiction is a conflict between characteristics within a system when improving one parameter of the system causes the deterioration of other parameter.
Altshuller identified 40 Principles that could be used to eliminate technical contradictions. He also identified 39 characteristics of Technical Systems – so called Technical Parameters - that can be used to develop and describe a technical contradiction.
How to structure the problem as a contradiction is an essential step of the analysis of the problem. The formulation of the technical contradiction helps to understand the root of the problem better and to find out the right solutions faster. TRIZ states that if there is no (technical) contradiction then it is not an inventive problem. (see 2.2.3.1 Description of the Problem)

Model



Example:
Increasing the power of the motor (a desired effect) may cause the weight of the motor to increase (a negative effect).

5.2.1 – The 40 Inventive Principles

Definition

The Inventive Principles are a very simple tool within TRIZ to look for ideas and resolve technical contradictions.
The application of the 40 Inventive principles does not require any special knowledge and children as well as professionals may use them.
The Altshuller Matrix was designed to formalize and to facilitate the usage of this TRIZ tool in practical activity. So the usage of the Inventive principles in combination with the Altshuller Matrix (contradiction table) requires some practical skills.

Theory
Genrich S. Altshuller offered an approach to the development of inventive principles in the late 50's. He selected the most often occurring strong principles based on the analysis of a large number of the patents. Each of these principles efficiently "worked" at least in 80-100 inventions. As a result, 40 most often used inventor's Principles were published.

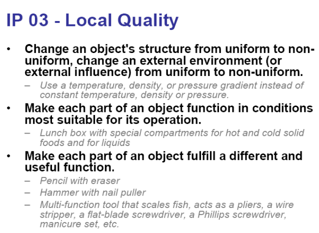
Model
The 40 Inventive Principles:
1. Segmentation
2. Extraction (Extracting, Retrieving, Removing, Taking out)
3. Local Quality
4. Asymmetry
5. Consolidation (Merging)
6. Universality
7. Nesting (Matrioshka, "Nested doll")
8. Counterweight (Anti-weight)
9. Prior Counteraction (Preliminary anti-action)
10. Prior Action (Preliminary action)
11. Cushion in Advance (Beforehand cushioning)
12. Equipotentiality
13. Do it in Reverse ("The other way round")
14. Spheroidality (Curvature)
15. Dynamics
16. Partial or Excessive Action
17. Transition into a New Dimension (Another Dimension)
18. Mechanical Vibration
19. Periodic Action
20. Continuity of Useful Action
21. Rushing Through (Skipping)
22. Convert Harm into Benefit ("Blessing in disguise" or "Turn Lemons into Lemonade")
23. Feedback
24. Mediator („Intermediary")
25. Self-service
26. Copying
27. Dispose (Cheap Short-living Objects)
28. Replacement of Mechanical System (Mechanics Substitution)
29. Pneumatic or Hydraulic Constructions (Pneumatics and Hydraulics)
30. Flexible Membranes or Thin Films (Flexible Shells and Thin Films)
31. Porous Material
32. Changing the Color (Color Changes)
33. Homogeneity
34. Rejecting and Regenerating Parts (Discarding and Recovering)
35. Transformation of Properties (Parameter Changes)
36. Phase Transition
37. Thermal Expansion
38. Accelerated Oxidation (Strong Oxidants)
39. Inert Environment (Inert Atmosphere)
40. Composite Materials

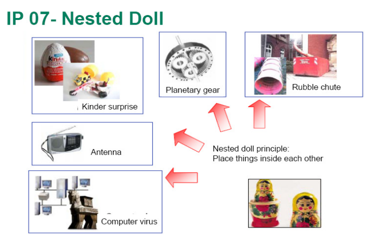
Instruments
For each of the 40 Inventive Principles a detailed description was provided by Altshuller and his colleagues. (see Annex).
The model of each Principle is constituted by:
1. a title
2. a number of guidelines
3. (possibly) a number of examples

Inventive Principle 01 - Segmentation
A. Divide an object into independent parts.
B. Make an object easy to disassemble.
C. Increase the degree of fragmentation or segmentation.

Several exemplified descriptions have been published afterwards. During the last years also exemplified descriptions for an application of the Inventive Principles in a lot of different fields (architecture, biology, chemistry, construction, busineness & management / finance, ..) are available.

Example
Principle 1. Segmentation
A. Divide an object into independent parts.
- *Replace mainframe computer by personal computers.*
- *Replace a large truck by a truck and trailer.*
- *Use a work breakdown structure for a large project.*
- Make an object easy to disassemble.
- *Modular furniture*
- *Quick disconnect joints in plumbing*
- Increase the degree of fragmentation or segmentation.
- *Replace solid shades with Venetian blinds.*
  1. *Use powdered welding metal instead of foil or rod to get better penetration of the joint.*Rejecting and Regenerating Parts (Discarding and Recovering) = Scarto e rigen-erazione delle parti (scartare e ricuperare)
  2. Transformation of Properties (Parameter Changes) = Trasformazione di proprietà
  3. Phase Transition = Transizione di fase
  4. Thermal Expansion = Espansione termica
  5. Accelerated Oxidation (Strong Oxidants) = Ossidazione accelerate (elevata ossidazio-ne)
  6. Inert Environment (Inert Atmosphere) = Ambiente inerte (atmosfera inerte)
  7. Composite Materials = Materiali composite





Examples for TRIZ – Playing Cards: (Text and Illustrations)

The Usage of the Inventive Principles

In general there are two methods to apply the 40 Inventive Principles during the problem solving process:

- The simplest method is what we can call familiarization of the principles. Here we are trying to apply each of the principles or their combinations to solving the technical contradiction in the specific problem.
(Note: this is just a suggestion for getting acquaintance with the inventive principles, because it doesn't fit with the main purpose of Altshullers work , i.e. avoiding trial and errors)
- The second way is the formulation of a technical contradiction and utilization of Altshuller's Matrix in order to get a set of recommended principles for solving your problem. (see 2.2.)

Another suggestion is to browse the Inventive principles more strictly related to separation in space strategies, because they enlarge the view on possible resources to adopt (moreover they start reducing the generalization level from the ideal solution to the technical solution)

Familarization / Brainstorming with the Principles

Instrument

The simplest method is what we can call familiarization of the principles. Here we are trying to find applications of each of the principles or their combinations to see where they are used in products and processes.
The more ones become familiar with these principles, the more ones will see them in action everywhere around us and can apply them in a problem solution process.
The second step is that we are using principles and/or their combinations as catchwords for successive brainstorming sessions. A good and helpful suggestion for a previous step is the definition of the so called "operational space" and "operational time", that means where and when exactly is the problem.

The Contradiction or Altshuller Matrix

(see 2.2 The Altshuller Matrix)

Definition

The contradiction matrix was one of the first outcomes of the work of Altshuller and his colleagues.
Altshuller abstracted and classified inventive solutions (inventive principles) and also identified 39 technical parameters that can describe all the different contradictions solved. (see 2.2.2. the 39 technical parameters)
These technical parameters were laid out in a 39x39 matrix where the x-axis is the parameter that worsens in the contradiction, whilst the parameter described on the y-axis is the one that improves.

Model

↓ Useful Parameter / Feature to improve / Characteristics to be improved
→ Harmful Parameter / Undesired Result / Characteristic that is getting worse

	harmful parameter → / useful parameter ↓	1 weight of mobile object	2 weight of stationary object	3 length of mobile object	4 length of stationary object	5 area of mobile object	6 area of stationary object	7 volume of mobile object	8 volume of stationary object	9 velocity	10 force	11 tension/ pressure	12 shape	13 stability of composition	14 strength	15 durabilty of mobile object	16 durability of stationary object	17 temperature	18 lumination
1	weight of mobile object	+	-	15, 8, 29,34	-	29, 17, 38, 34	-	29, 2, 40, 28	-	2, 8, 15, 38	8, 10, 18, 37	10, 36, 37, 40	10, 14, 35, 40	1, 35, 19, 39	28, 27, 18, 40	5, 34, 31, 35	-	6, 29, 4, 38	19, 1, 32
2	weight of stationary object	-	+	-	10, 1, 29,35	-	35, 30, 13, 2	-	5, 35, 14, 2	-	8, 10, 19, 35	13, 29, 10, 18	13, 10, 29, 14	26, 39, 1, 40	28, 2, 10, 27	-	2, 27, 19, 6	28, 19, 32, 22	19, 32, 35
3	length of mobile object	8, 15, 29, 34	-	+	-	15, 17, 4	-	7, 17, 4, 35	-	13, 4, 8	17, 10, 4	1, 8, 35	1, 8, 10, 29	1, 8, 15, 34	8, 35, 29, 34	19	-	10, 15, 19	32
4	length of stationary object		35, 28, 40, 29	-	+	-	17, 7, 10, 40	-	35, 8, 2,14	-	28, 10	1, 14, 35	13, 14, 15, 7	39, 37, 35	15, 14, 28, 26	-	1, 10, 35	3, 35, 38, 18	3, 25
5	area of mobile object	2, 17, 29, 4	-	14, 15, 18, 4	-	+	-	7, 14, 17, 4		29, 30, 4, 34	19, 30, 35, 2	10, 15, 36, 28	5, 34, 29, 4	11, 2, 13, 39	3, 15, 40, 14	6, 3	-	2, 15, 16	15, 32, 19, 13
6	area of stationary object	-	30, 2, 14, 18	-	26, 7, 9, 39	-	+	-		-	1, 18, 35, 36	10, 15, 36, 37		2, 38	40	-	2, 10, 19, 30	35, 39, 38	
7	volume of mobile object	2, 26, 29, 40	-	1, 7, 4, 35	-	1, 7, 4, 17	-	+	-	29, 4, 38, 34	15, 35, 36, 37	6, 35, 36, 37	1, 15, 29, 4	28, 10, 1, 39	9, 14, 15, 7	6, 35, 4	-	34, 39, 10, 18	2, 13, 10
8	volume of stationary object	-	35, 10, 19, 14	19, 14	35, 8, 2, 14	-		-	+	-	2, 18, 37	24, 35	7, 2, 35	34, 28, 35, 40	9, 14, 17, 15	-	35, 34, 38	35, 6, 4	
9	velocity	2, 28, 13, 38	-	13, 14, 8	-	29, 30, 34	-	7, 29, 34	-	+	13, 28, 15, 19	6, 18, 38, 40	35, 15, 18, 34	28, 33, 1, 18	8, 3, 26, 14	3, 19, 35, 5	-	28, 30, 36, 2	10, 13, 19

Extract of the Altshuller Matrix

Example
Usage of the Altshuller Matrix: see 2.2.

Other Selection Approaches of the Inventive Principles
Some other selection approaches of the Inventive Principles appeared during the last years:
Selection regarding the frequency of occurrence on the Altshuller Matrix
Selection regarding the approach from S. Fayer

Selection regarding the frequency of occurrence on the Altshuller Matrix
Inventive Principles listed according to their frequency of occurrence (FoO) on the Altshuller Matrix (starting with the most often listed principle)

Inventive Principles FoO 1- 10	**Inventive Principles FoO 11-20**	**Inventive Principles FoO 21-30**	**Inventive Principles FoO 31-40**
35	*26*	*14*	*38*
10	*03*	*22*	*08*
01	*27*	*39*	*05*
28	*29*	*04*	*07*
02	*34*	*30*	*21*
15	*16*	*37*	*23*
19	*40*	*36*	*12*
18	*24*	*25*	*33*
32	*17*	*11*	*09*
13	*06*	*31*	*20*

<u>Selection regarding the approach from Mr. S. Fayer</u>
S. Fayer recommends 4 groups of problems, where the inventive principles can be related to:

Group 1: Changing something about substances (quantity, quality, structure, shape) Inventive Principles: 1, 2, 3, 4, 7, 14, 17, 30, 31, 40

Group 2: How to deal with harmful factors Inventive Principles: 9, 10, 11, 12, 13, 19, 21, 23, 24, 26, 33, 39

Group 3: How to increase effectiveness and ideality Inventive Principles: 5, 6, 15, 16, 20, 25, 26, 34

Group 4: Using scientific effects, special fields and substances Inventive Principles: 8, 18, 28, 29, 32, 35, 36, 37, 38, 30, 31, 40

5.2.2. – The Altshuller Matrix / Contradiction Matrix

5.2.2.1. – The Design of the Altshuller Matrix

Definition

The Contradiction Matrix or Altshuller Matrix, developed by G. S. Altshuller, suggests Inventive Principles to solve contradictions arising while trying to improve a feature or a characteristic of any product, process or system. The contradiction matrix was one of the first outcomes of the work of Altshuller and his colleagues. Though this is one of the oldest components of TRIZ, it is still useful in preliminary problem solving.
Altshuller abstracted and classified inventive solutions (inventive principles) and also created 39 technical parameters that can describe all the different contradictions solved. (see 2.2.2. the 39 technical parameters)
These technical parameters were laid out in a 39x39 matrix where the x-axis is the parameter that worsens in the contradiction, whilst the parameter described on the y-axis is the one that improves.
The Altshuller Matrix (contradiction table) was designed to formalize and to facilitate the usage of this TRIZ tool in practical activity. The Matrix presents you with 39 system characteristics or "technical parameters", which represent the cionflicting Evaluation Parameters (OTSM).
The pairs of contradictory characteristics form a Matrix. The first item in the pair is located in the left column of Matrix and called Useful Parameter (or Feature to improve, Improving Feature, ..) . The other item of the pair is placed in the top row of the Matrix and called the Harmful Pasrameter (or Worsening Feature, Undesired Result, ..) . Not every contradictory pair of features has a set of principles associated with them.

Model

↓ Useful Parameter / Feature to improve / Characteristics to be improved
→ Harmful Parameter / Undesired Result / Characteristic that is getting worse

harmful parameter → / useful parameter ↓		1 weight of mobile object	2 weight of stationary object	3 length of mobile object	4 length of stationary object	5 area of mobile object	6 area of stationary object	7 volume of mobile object	8 volume of stationary object	9 velocity	10 force	11 tension/ pressure	12 shape	13 stability of composition	14 strength	15 durabilty of mobile object	16 durability of stationary object	17 temperature	18 illumination
1	weight of mobile object	+	-	15, 8, 29,34	-	29, 17, 38, 34	-	29, 2, 40, 28	-	2, 8, 15, 38	8, 10, 18, 37	10, 36, 37, 40	10, 14, 35, 40	1, 35, 19, 39	28, 27, 18, 40	5, 34, 31, 35	-	6, 29, 4, 38	19, 1, 32
2	weight of stationary object	-	+	-	10, 1, 29,35	-	35, 30, 13, 2	-	5, 35, 14, 2	-	8, 10, 19, 35	13, 29, 10, 18	13, 10, 29, 14	26, 39, 1, 40	28, 2, 10, 27	-	2, 27, 19, 6	28, 19, 32, 22	19, 32, 35
3	length of mobile object	8, 15, 29, 34	-	+	-	15, 17, 4	-	7, 17, 4, 35	-	13, 4, 8	17, 10, 4	1, 8, 35	1, 8, 10, 29	1, 8, 15, 34	8, 35, 29, 34	19	-	10, 15, 19	32
4	length of stationary object		35, 28, 40, 29	-	+	-	17, 7, 10, 40	-	35, 8, 2,14	-	28, 10	1, 14, 35	13, 14, 15, 7	39, 37, 35	15, 14, 28, 26	-	1, 10, 35	3, 35, 38, 18	3, 25
5	area of mobile object	2, 17, 29, 4	-	14, 15, 18, 4	-	+	-	7, 14, 17, 4		29, 30, 4, 34	19, 30, 35, 2	10, 15, 36, 28	5, 34, 29, 4	11, 2, 13, 39	3, 15, 40, 14	6, 3	-	2, 15, 16	15, 32, 19, 13
6	area of stationary object	-	30, 2, 14, 18	-	26, 7, 9, 39	-	+	-		-	1, 18, 35, 36	10, 15, 36, 37		2, 38	40	-	2, 10, 19, 30	35, 39, 38	
7	volume of mobile object	2, 26, 29, 40	-	1, 7, 4, 35	-	1, 7, 4, 17	-	+	-	29, 4, 38, 34	15, 35, 36, 37	6, 35, 36, 37	1, 15, 29, 4	28, 10, 1, 39	9, 14, 15, 7	6, 35, 4	-	34, 39, 10, 18	2, 13, 10
8	volume of stationary object	-	35, 10, 19, 14	19, 14	35, 8, 2, 14	-		-	+	-	2, 18, 37	24, 35	7, 2, 35	34, 28, 35, 40	9, 14, 17, 15	-	35, 34, 38	35, 6, 4	
9	velocity	2, 28, 13, 38	-	13, 14, 8	-	29, 30, 34	-	7, 29, 34	-	+	13, 28, 15, 19	6, 18, 38, 40	35, 15, 18, 34	28, 33, 1, 18	8, 3, 26, 14	3, 19, 35, 5	-	28, 30, 36, 2	10, 13, 19

5.2.2.2. – The 39 Technical Parameters

Definition

In order to find a descriptive and clearly arranged tool for the application of the Inventive Principles Altshuller also has to define and abstract characterictics of technical systems. In TRIZ these abstracted characteristics are called 39 Technical Parameters or 39 Characteristics (sometimes also Features).
For each of the 39 technical parameters a more detailed description was provided by Altshuller (Annex).
One of the questions behind was to find out if there are several Inventive Principles that have been used more often than others solving specific inventive problems.

Instruments

The 39 Technical Parameters

1. Weight of moving object
2. Weight of non-moving object
3. Length of moving object
4. Length of non-moving object
5. Area of moving object
6. Area of non-moving object
7. Volume of moving object
8. Volume of non-moving object
9. Speed
10. Force
11. Tension, pressure
12. Shape
13. Stability of object
14. Strength
15. Durability of moving object
16. Durability of non-moving object
17. Temperature
18. Brightness
19. Energy spent by moving object
20. Energy spent by non-moving object
21. Power
22. Waste of energy
23. Waste of substance
24. Loss of information
25. Waste of time
26. Amount of substance
27. Reliability
28. Accuracy of measurement
29. Accuracy of manufacturing
30. Harmful factors acting on object
31. Harmful side effects
32. Manufacturability
33. Convenience of use
34. Repairability
35. Adaptability
36. Complexity of device
37. Complexity of control
38. Level of automation
39. Productivity

Examples

TP 01 - Weight of moving object
The measurable force, resulting from gravity, that a moving body exerts on the surface which prevents it from falling.
A moving object is one which changes position on its own or as a result of some external force.

TP 02 - Weight of non-moving object
The measurable force, resulting from gravity, that a stationary object exerts on the surface on which it rests.
A stationary is one which cannot change position on its own or as a result of some external force

TP 17 -Temperature
The loss or addition of heat to an object or system during required functions, which may cause potentially undesirable changes to objects, system or productions.

TP 18-Brightness
The ratio of light energy to heat the area which is being lit by or in a system. Brightness includes the quality of light, degree of illumination, and other characteristics of light.

5.2.2.3. – Usage of the Altshuller Matrix

Theory

The usage of the Matrix requires a proper analysis of the problem, because a (technical) contradiction - there could be some more than one - has to be defined within the system.
The main steps using the Altshuller Matrix are:

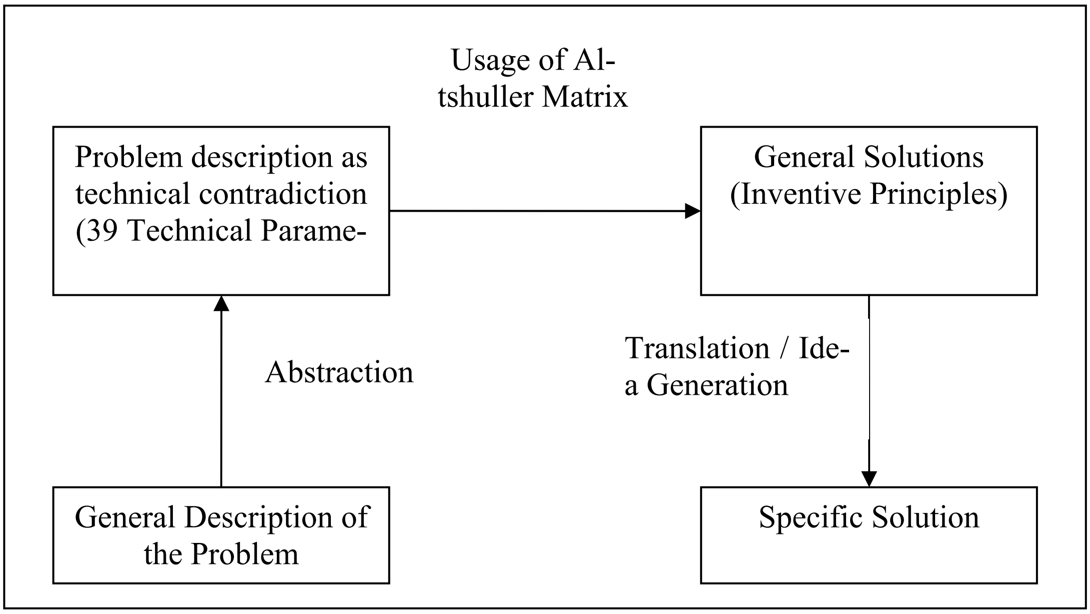
- Description of the Problem
- Defining the Technical Contradiction
  (Ways of Modelling the Problem - Finding technical contradictions)
- Translation into Technical Parameter (improving & worsening features)
- Identifying Inventive Principles from the Altshuller-Matrix
- Idea Generation with the Inventive Principles

The first step here is to summarise the problem to be solved and the problem context.
During this stage it may be helpful to note your problem and keep asking yourself what is stopping you from solving it. Either you will come up against a constraint to be evaluated or you will discover a contradiction that needs to be solved.
Then translate your problem analysis into separate contradiction statements. The desired state can't be reached because something else in the system prevents it. In other words, when something gets better, something else gets worse.

For example:
The bandwidth increases (good) but requires more power (bad).
The service is customized to each customer (good) but the service delivery system gets complicated (bad)
The next step is to translate the statement into a technical contradiction by matching the features to the particular Technical Parameters.
Note: This step may not be that easy initially, it is important to become familiar with the parameters, this means studying the parameters and beginning to collect your own examples of them.

Then look up your improving features to the worsening features on the Altshuller Matrix. Identify the numbers for the Inventive Principles that may help solve this technical contradiction. The numbers are contained in the cell at the intersection of that row and column
Look up the principles and use each principle to generate and record some solution ideas. The description of each Principle and additional hints will gives you a clue to a possible solution.

Model



Example
Usage of the Altshuller Matrix: see 2.2

Usage Matrix: Description of the Problem
Theory
Professional problem solvers say that a well defined problem is half solved.
There should be a good understanding of the system around the problem. Accordingly, different aspects related to the problem should be systematically documented.
For a detailed description of the problem and the problem surroundings TRIZ offers the so called "Innovation-Situation-Questionnaire®" (ISQ) or innovation checklist. The ISQ was developed by the Kishinev School of TRIZ in Moldova. (owned by Ideation International Inc.)
The ISQ is not an imperatively necessary when working with the Altshuller Matrix. However it assists by the findings and definition of important contradictions in the system.

Important Note:
ARIZ includes and defines a step-by-step process to work out technical contradictions and translate them into a physical contradiction (see Chapter ARIZ)

Instruments
"Innovation-Situation-Questionnaire®" – Structure:

Information about the system you would like to improve / create and its environment
- Systems name
- System´s primary useful function
- Current or desired system structure

Functioning of the system
System environment
Available resources (see Substance-Field-Resources)
Information about the problem situation
desired improvement to the system or a drawback you would like to eliminate
Mechanism which causes the drawback to occur, if it is clear
Other problems to be solved
Changing the system
Allowable changes to the system
Limitations to changing the system
Criteria for selecting solution concepts
Desired technological characteristics
Desired economic characteristics
Desired timetable
Expected degree of novelty
other criteria
History of attempted solutions to the problem
Previous attempts to solve the problem
Other system(s) in which a similar problem exists

Examples for ISQ: In "Systematic Innovation – an Introduction to TRIZ", John Terninko, Allo Zusman, Boris Zlotin, (also available on books.google.com)

Usage Matrix: Defining the Technical Contradiction (Ways of Modelling the Problem - Finding technical contradictions)
There are several ways and models described in TRIZ how to find out contradictions in the system.
Defining "What gets better – what gets worse"
OTSM Model of Contradictions (see Chapter 1.1.4)
ARIZ (see chapter ARIZ)

Theory & Instruments
<u>Defining "What gets better – what gets worse" or "if-then-but"</u>
The simplest way to look for contradicting parameters in a system is – after a one-sentence - summary of the problem - to answer the following two questions:

Summarise the problem to be solved and the problem context

What gets better (what is "good")	What gets worse (What is "bad")
this aspect of the system gets better….	at the expense of this aspect…
	‘

<u>OTSM Model of Contradictions</u>
See Chapter 1.1.4

Example
Ex 1: "Increase the durability of a product"

<u>Defining "What gets better – what gets worse" or "if-then-but"</u>

Summarise the problem to be solved and the problem context
Most design strategies for durability involve over-specifying the material type or its quantity. The most common durability solution is to add material to make something stronger.

What gets better (what is "good")	What gets worse (What is "bad")
this aspect of the system gets better….	at the expense of this aspect…
A product gets stronger…	*…but its weight increases*

Result:
If I want to get the product "stronger" the "weight" would get worse. (technical contradiction)

Translation into Technical Parameter
Model
The next step is to translate the general contradiction statement into a technical contradiction using the defined 39 Technical Parameters.
This step may not be that easy initially, it is important to become familiar with the parameters, this means studying the parameters and beginning to collect your own examples of them.
(see Annex)

Instruments
List of 39 Technical Parameters (with explanations)

Example
Ex 1: "Increase the durability of a product"

Summarise the problem to be solved and the problem context
Most design strategies for durability involve over-specifying the material type or its quantity. The most common durability solution is to add material to make something stronger.

What gets better (what is "good")	What gets worse (What is "bad")
that aspect of the system gets better….	at the expense of this aspect…
A product gets stronger…	*…but its weight increases*

Technical Parameter - Improving Feature	Technical Parameter - Improving Feature
A product gets stronger…	*…but its weight increases*
Strength – TP 14	***Weight of a non-moving object – TP 02***

Identifying Inventive Principles from the Altshuller Matrix
Look up the improving parameters to the worsening parameters on the Altshuller Matrix provided. Identify numbers for the Inventive Principles that may help solve this technical contradiction. The numbers are contained in the cell at the intersection of that row and column.
If the Altshuller Matrix contains a blank box at that intersection, try out the reversed contradiction or redefining your parameters.

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Instruments
Altshuller Matrix (Annex)

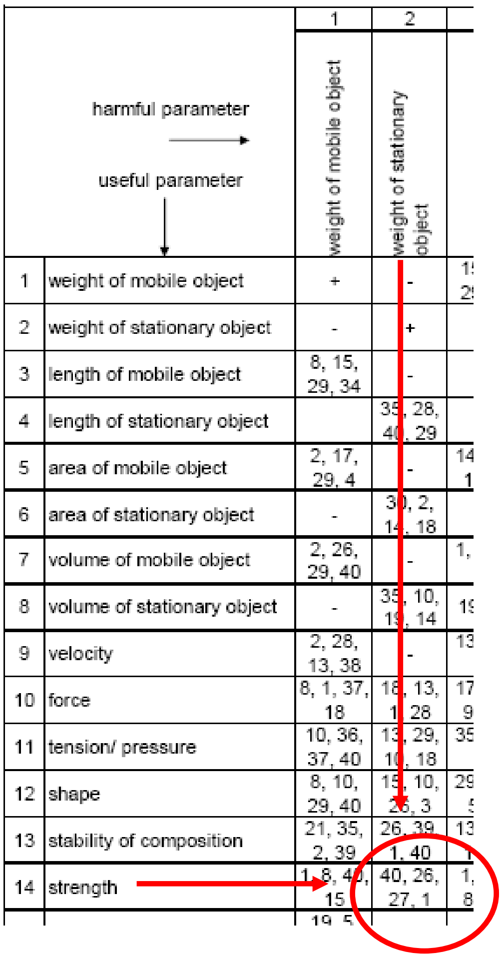
Example
Ex 1: "Increase the durability of a product"

Summarise the problem to be solved and the problem context
Most design strategies for durability involve over-specifying the material type or its quantity. The most common durability solution is to add material to make something stronger.

What gets better (what is "good")	What gets worse (What is "bad")
that aspect of the system gets better….	at the expense of this aspect…
A product gets stronger…	*…but its weight increases*

Technical Parameter - Improving Feature	Technical Parameter - Improving Feature
A product gets stronger…	*…but its weight increases*
Strength – TP 14	***Weight of a non-moving object – TP 02***

Inventive Principle Numbers from intersection of the Technical Parameters on the Altshuller Matrix:
(row 14) vs. (column 2 à)Inventive Principles: 40, 26, 27, 1



	harmful parameter → / useful parameter ↓	1 weight of mobile object	2 weight of stationary object
1	weight of mobile object	+	-
2	weight of stationary object	-	+
3	length of mobile object	8, 15, 29, 34	-
4	length of stationary object		35, 28, 40, 29
5	area of mobile object	2, 17, 29, 4	-
6	area of stationary object	-	30, 2, 14, 18
7	volume of mobile object	2, 26, 29, 40	-
8	volume of stationary object	-	35, 10, 19, 14
9	velocity	2, 28, 13, 38	-
10	force	8, 1, 37, 18	18, 13, 1, 28
11	tension/ pressure	10, 36, 37, 40	13, 29, 10, 18
12	shape	8, 10, 29, 40	15, 10, 26, 3
13	stability of composition	21, 35, 2, 39	26, 39, 1, 40
14	strength	1, 8, 40, 15	40, 26, 27, 1

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Idea Generation with the Inventive Principles

In the last step ideas have to be generated with the identified Innovative Principles.

Notes:

The inventive principle must be used as a precise direction to overcome the corresponding technical contradiction.

> **Typical mistake:** often it happens that beginners apply the Inventive Principles to the whole system (and not to the specific elements where the technical contradiction occurs).

The interpretation of the inventive principle guidelines should be as literal as possible in order to avoid their usage just as a confirmation of an ideal already conceived by the user.
The directions suggested by the different principles proposed by the same cell of the matrix can be combined, because they sometimes provide complementary suggestions.

Instruments & Example

Ex 1: "Increase the durability of a product"

Summarise the problem to be solved and the problem context
Most design strategies for durability involve over-specifying the material type or its quantity. The most common durability solution is to add material to make something stronger.

What gets better (what is "good")	What gets worse (What is "bad")
that aspect of the system gets better….	at the expense of this aspect…
A product gets stronger…	*…but its weight increases*

Technical Parameter - Improving Feature	Technical Parameter - Improving Feature
A product gets stronger…	*…but its weight increases*
Strength – TP 14	***Weight of a non-moving object – TP 02***

Inventive Principle Numbers from intersection of the Technical Parameters on the Altshuller Matrix:
(row 14) vs. (column 2 à)Inventive Principles: 40, 26, 27, 1

Solution ideas	
IP 40 - Composite materials	***Use lightweight composite materials in products that are likely to have a long-life and benefit from being very lightweight or create new composite materials from waste.***
IP 26 – Copying	***Dematerialize the mechanical parts of electronic interfaces by using screen prompts and fewer keys or use software only with robust touch screens.***
IP 27 - Cheap short lived products	***Evaluate whether products should be long lived. Use existing logistics and incentives to enhance product take-back, then design products and components for re-use, upgrade or recycling.***
IP 1 – Segmentation	***Make the object sectional for easy assembly and disassembly at the end of its life. almost all end-of-life strategies rely on easy separation of components and materials.***

5.3. Techniques to resolve Physical Contradictions

Definition

A physical contradiction is a conflict between two mutually exclusive physical requirements to the same parameter of an element of the system. More precisely, according to the ENV model (see chapter 1c) a physical contradiction occurs when different values are required for a given control parameter.

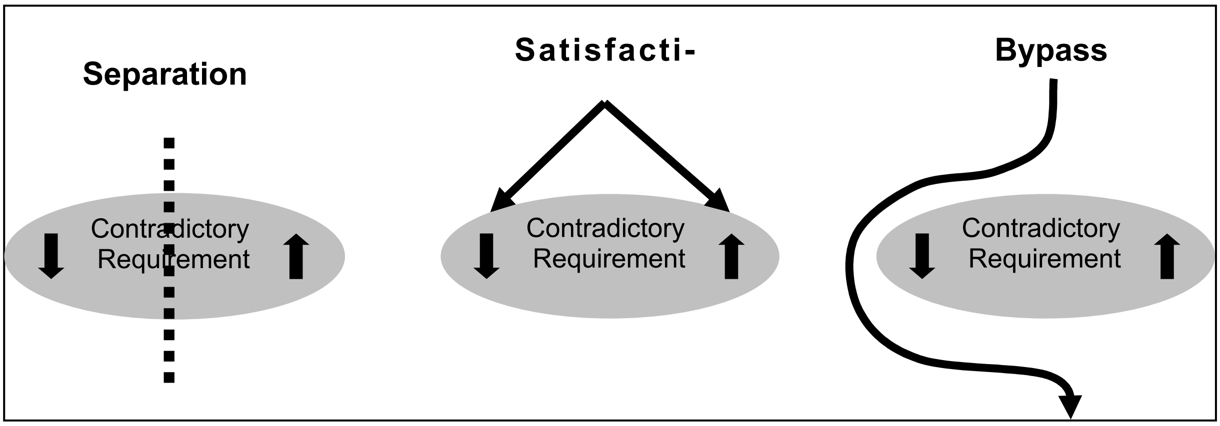
For problem solving, Contradiction formulation has the format: "A given element of the system should have characteristic A in order to realize a required function (to solve problem) AND this element should have characteristic NON-A in order to satisfy existent limitations and requirements".

Example: Element should be hot and cold...
Element should be hard and soft...

As a matter of principle a physical contradiction can be resolved by three concepts:

- Separation of the contradictory requirements (see 4 Separation Principles)
- Satisfaction of the contradictory requirements
- Bypass the contradictory requirements

Model



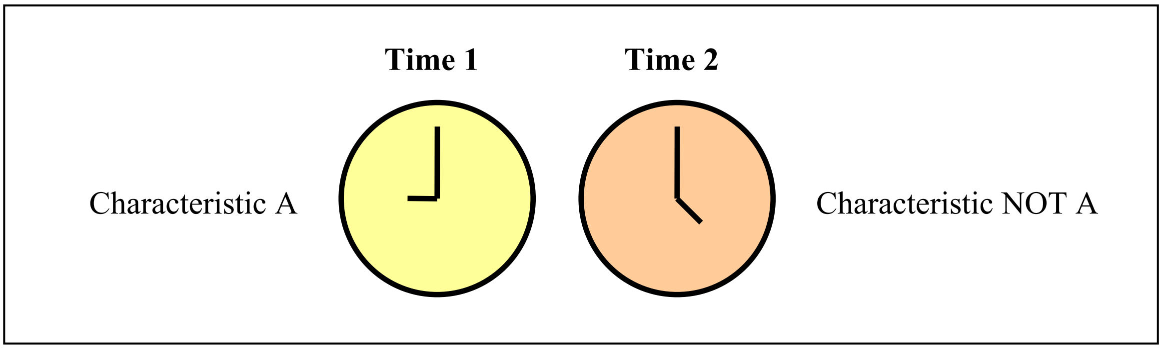
5.3.1. – The 4 Separation Principles

Definition

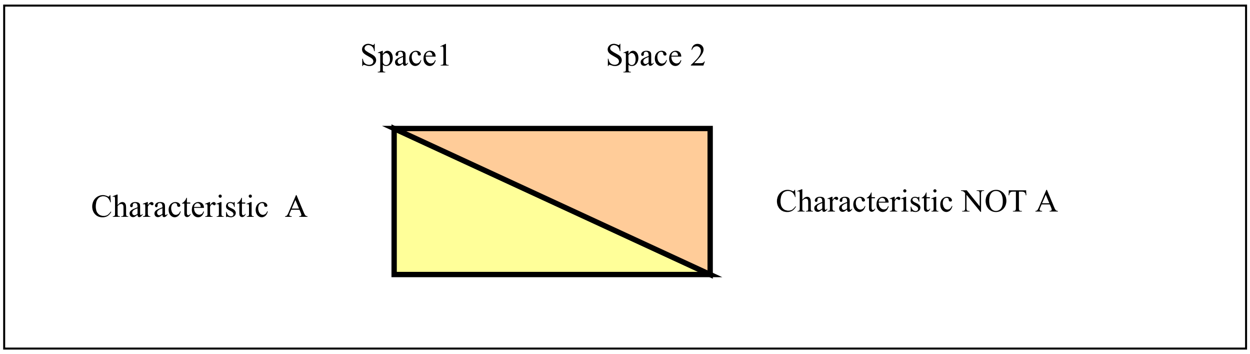
When dealing with a known Physical Contradiction – and the concepts of satisfaction and by-pass are not working - one can use one of the 4 Separation Principles for overcoming this type of contradiction:

- Separation in Time
- Separation in Space
- Separation on Condition / in Relation
- Separation in System Level

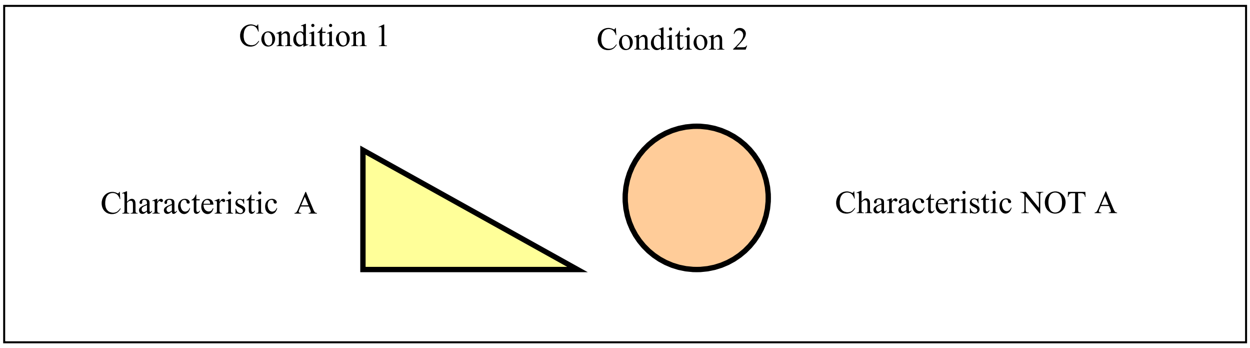
Model



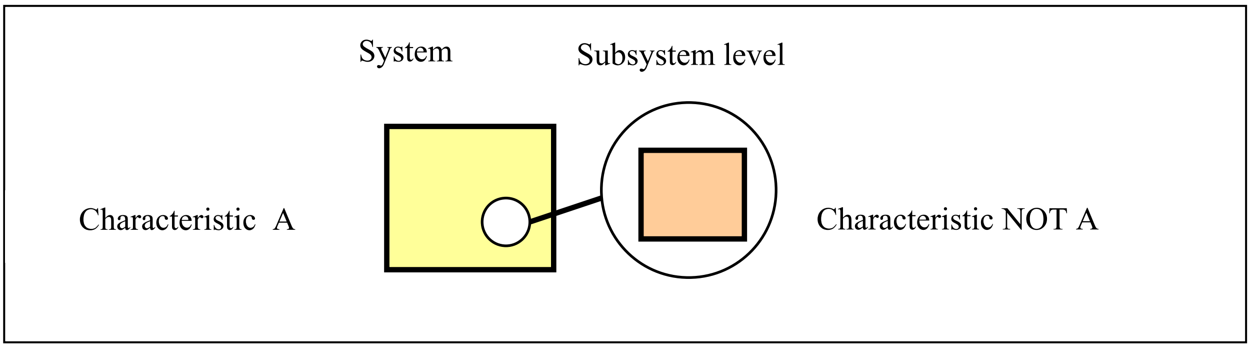
Separation in Time



Separation in Space



Separation on Condition / in Relation

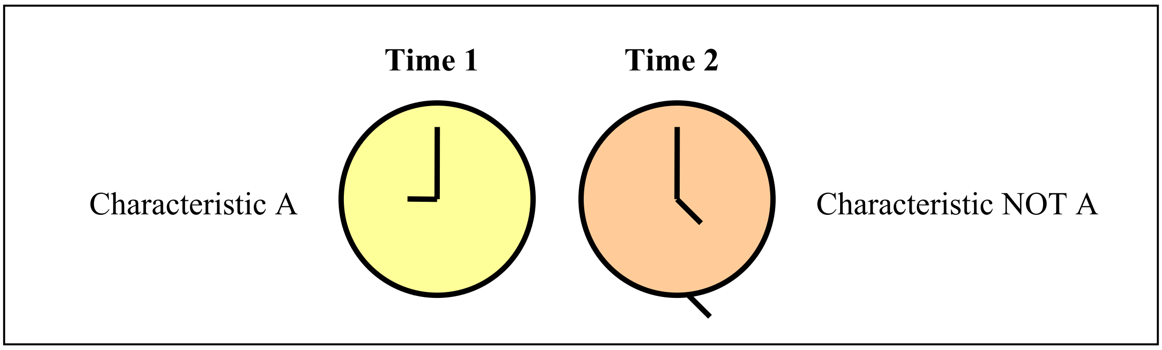


Separation in System Level

5.3.1.1 – Separation in Time

Definition

The concept is to separate the opposite requirements in time.
If a system or process must satisfy contradictory requirements, perform contradictory functions or operate contradictory conditions, try to schedule the system operation in such a way that requirements, functions or operations that conflict take effect at different times.
The concept of the "separation in time" is based on the definition on the so called "operational time":
That means when – at which time - exactly to we need the opposite requirements.



The question we have to ask is:
Do we need characteristic A anytime or is it only needed at a certain time?
If the characteristic A is not needed always, we can try to separate it in time.

Instruments

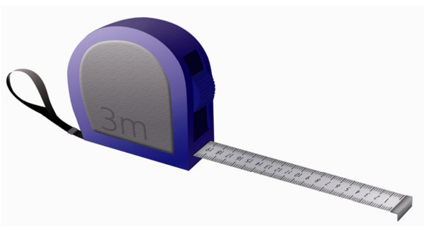
Inventive Principles supporting Separation in Time (This list is not exhaustive.)

- IP 15 – Dynamics
- IP 34 – Rejecting and Regenerating Parts
- IP 10 – Prior Action
- IP 9 – Prior Counteraction

IP 11 – Cushion in advance

Example – Product

A ruler should be long to have a wide range for measuring distances and a ruler should also be small in order to easily be taken away.
Inventive Principle 15 recommends to “dynamize”, i.e. to increase the internal degees of freedom of the ruler.
One product using this principle is the "roll ruler".



Example

Problem formulation:

During a battle, cannons have to be loaded always very quickly. When rapid introducing the blackpowder into the cannon barrel, the powder can still glowing in particles or by radio shock ignite. Therefore a fast reloading of the gun is very dangerous.
The task was to develop of a fast firing gun.

(Photo: R. Adunka)

That can be translated in a physical contradiction:

- The loading time of the gun should short to have a fast firing gun

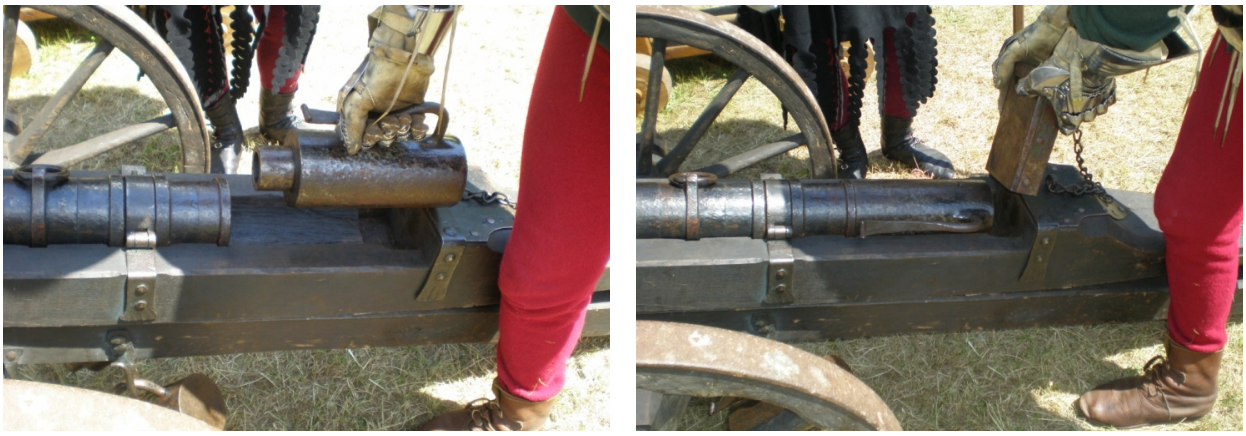
AND

- The loading time of the gun should long to be more safety when loading the gun.

The operational time of the function "fast firing" can clearly separated from the operational time of the function "loading the gun".
We can use the concept of Separation in Time to find ideas.
One of the recommended Inventive Principles supporting Separation in Space is IP 10 – Prior Action.

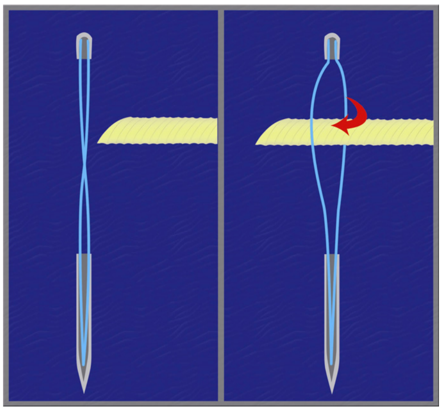
Principle 10 – Prior Action (Preliminary action)

A. Perform required changes to an object completely or partially in advance.
Place objects in advance so that they can go into action immediately from the most convenient location.
Solution:
"Cans chamber" have the blackpowder and the propellant in separated chambers. These chambers were set in for each shot extra. A number of these chambers can be prepared for a battle with blackpowder load and can be used during the battle. The bullet was introduced continually from the front. The risk of ignition of the blackpowder when introducing into the gun was reduced.



(Photo R. Adunka)

Example: Needle with dynamic eye



It is difficult to pass a thick thread through the small eye of a needle. We can formulate the following physical contradiction to represent this situation: A needle must have a large eye to facilitate insertion of the thread, and must have a small eye for convenient sewing.

By separating the contradiction in time this problem can be formulated as follows: **the eye must be large while the thread is inserted, and must be small during sewing, as follows:**

R. Pace of Britain designed a needle made of two thin, spring-like wires of identical length. The wires are welded together at one end, twisted three quarters of a turn, then welded at the opposite end. The resulting needle looks like an ordinary needle, but when slightly unwound, a large slot appears through which a thread can easily pass. When released, the needle returns to its initial shape and grips the thread.

(Source: Ideation, TRIZ Tutorial)

5.3.1.2 – Separation in Space

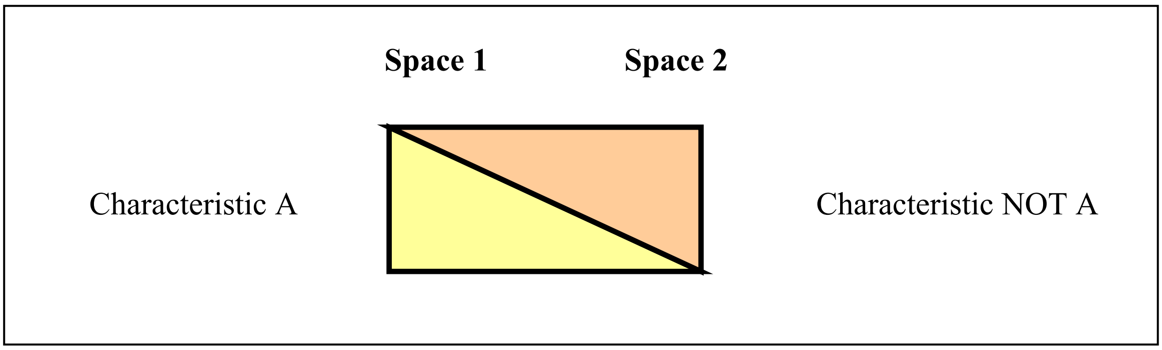
Definition

The concept is to separate the opposite requirements in space.

If a system must perform contradictory functions or operate under contradictory conditions, try to partition the system into subsystems. Then assign each contradictory function or condition to a different subsystem.

The concept of the "separation in space" is based on the definition on the so called "operational space": That means when – on which place - exactly to we need the opposite requirements.

Model



The question we have to ask is:

Do we need characteristic A everywhere or is it only needed in certain places?

If the characteristic A is not needed everywhere, we can try to separate it in space.

Instruments

Inventive Principles supporting Separation in Space (This list is not exhaustive.)

- IP 1 – Segmentation
- IP 2 – Extraction
- IP 3 – Local Quality
- IP 7 – Nesting
- IP 4 – Asymmetry
- IP 17 – Transition into an other Dimension
- IP 13 – The other way round

Example – Product

A coffee cup should be hot to hold the coffee warm for a certain time and the cup should be not hot in order to not burn once fingers.

Inventive Principle 7 recommends to use the idea of nesting.

Starbucks is using this principle:

www.jeremyadamdavis.com

Example

Problem formulation:

At tournaments in the Middle Ages knight´s armor has to protect the knight against body injuries. In order to please the audience the clothing (armor) should also look nice.

So the task was to develop a "charming armor"

(Photo R. Adunka)

That can be translated in a physical contradiction:

- The armor should be out of metal to protect the knight AND
- The armor should NOT be out of metal (fabric, ..) to look charming.

The operational space of the function “protect the knight” (inside) is clearly separable from the operational space of the function “provide a charming look”

We can use the concept of Separation in Space to find ideas.

One of the recommended Inventive Principles supporting Separation in Space is IP 3 – Local Quality.

Principle 03 - Local Quality

A.Transition from homogenous to heterogeneous structure of an object or outside environment (action).

B.Different parts of an object should carry out different functions.

Each part of an object should be placed under conditions that are most favourable for its operation.

Solution:

The so called "Brigandine" is an armor that consists on the inner side out of metal plates and on the outside out of fibre or leather. It was a kind of "bulletproof vest" of the 15th century.

(Photo R. Adunka)

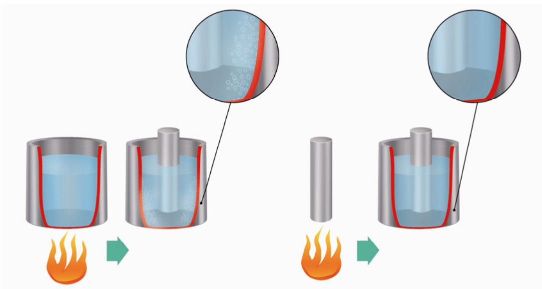
Example: Coating metal workpieces

Metal surfaces are chemically coated as follows: the metal workpiece is placed in a bath filled with a metal salt solution (e.g. nickel, cobalt, etc.). During the ensuing reduction reaction, metal from the solution precipitates onto the surface of the workpiece. The higher the temperature, the faster the process takes place; however, at high temperatures the solution decomposes, and up to 75% of the chemicals are lost by settling on the bottom and sides of the bath. Adding stabilizers is not effective, and conducting the process at a low temperature sharply decreases production.

To apply the principle of separation in space, for example, we should ask ourselves the following question: Do we need this parameter -- temperature, in this case -- to be high (and low) everywhere, or is it necessary in certain places only? If the temperature need not be both high and low everywhere, we can try to separate these opposite requirements in space.

In this case, we need the temperature to be high only near the parts rather than everywhere in the bath. How can this be achieved?

The answer is as follows: The workpiece is heated to a high temperature before it is immersed in the solution, and the process itself is conducted at a low temperature. The solution is therefore hot near the workpiece but cold everywhere else. (One way to accomplish this is to apply an electric current to the workpiece during the coating process.)



(Source: Ideation, TRIZ Tutorial)

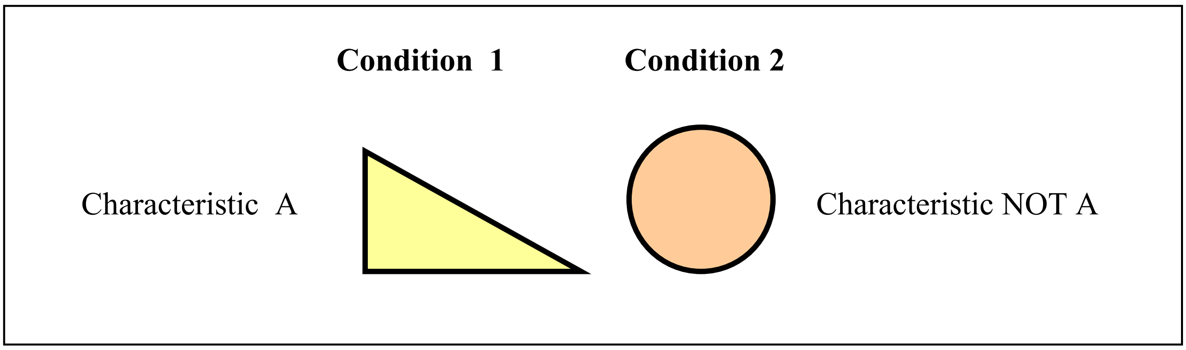
5.3.1.3 – Separation on Conditions // in Relation

Definition

The concept of separating opposing requirements of a condition can resolve contradictions in which a helpful process takes place when special conditions exist. Consider changing the system or the environment so that only the helpful process can take place.

Example: In the kitchen – A sieve will stop the pasta but not the water.

Model



The question we have to ask is:
Can we change or modify the conditions of the system or its surrounding so that both characteristic A and NOT A are fulfilled.

Instruments
Inventive Principles supporting Separation on Condition (This list is not exhaustive.)

- IP 40 – Composite Materials
- IP 31 – Porous Material
- IP 32 – Changimg the Color
- IP 3 – Local Quality
- IP 19 – Periodic Action
- IP 17 – Transition into an other Dimension

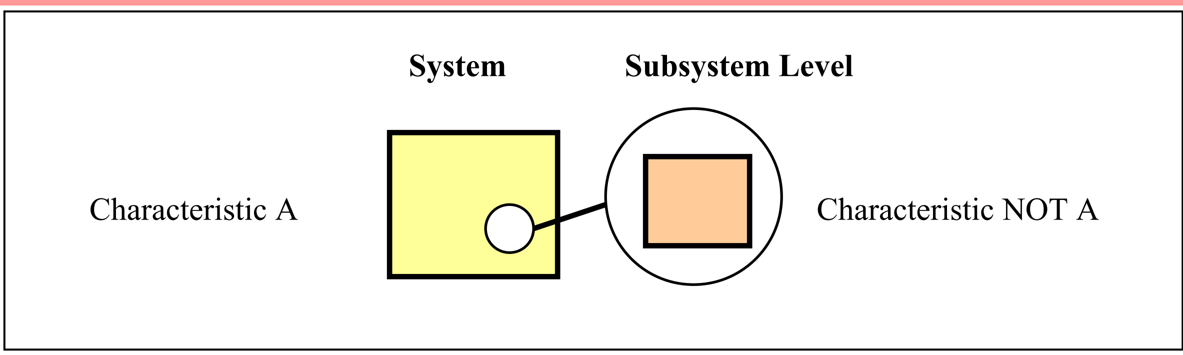
Note: In this case the relationship between the separation concept and the inventive principle is not so evident

Example
Problem formulation:
One customer of a sawmill wants to buy pure saw dust. Vacuum is used to suck the surrounding area of the saw blade. The saw dust is then directed through a metal suction pipe to the collecting tank. Unfortunately also small wooden staffs are sucked by the vacuum and so the content of the tank is contaminated.

The contradiction can be formulated:
The suction (vacuum) should be strong to collect all the saw dust (but also the wooden staffs) and the suction should be rather weak in order not to collect the wooden staffs.

Solution:
By increasing the cross section diameter of the suction pipe within a certain length (convexity) the flow conditions can be changed in a way that larger parts – the wooden staffs – will accumulate there and will not be flow into the collection pipe.

5.3.1.4 – Separation in System Level // by Transition to Sub- or Supersystem
Definition
The concept is to separate the opposite requirements within a whole object or its parts.
If a system must perform contradictory functions or operate under contradictory conditions, try to partition the system and assign one of the contradictory functions or conditions to a subsystem (or several subsystems). Let the system as a whole retain the remaining functions and conditions.



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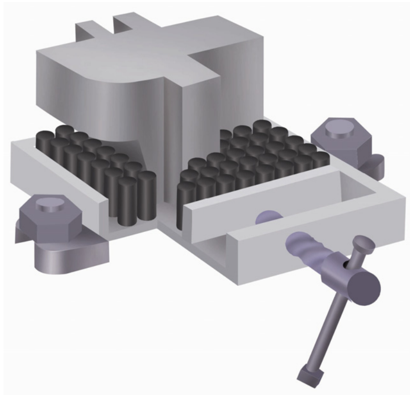
Model
The question we have to ask is:
Can we satisfy characteristic A and NOT-A by s assign one of them to the whole system and the other to its parts?

Example: Gripping workpieces of complex shape



To grip workpieces of complex shape, vice jaws must have a corresponding shape. It is expensive to produce a unique tool for every workpiece, however. Besides, a deformable gripper would be able to adjust its shape to the workpiece to be held, but the supporting capability would be worsened (the gripper would result not stiff enough).
The physical contradiction is thus the following: the gripper should be stiff in order to support the workpiece properly, and the stiffness should be soft in order to modify its geometry to match the complex shape of the workpiece itself.
The answer is as follows: Use a vise with ordinary jaws, but add multiple hard bushings around the workpiece that move horizontally to conform to the workpiece shape (high deformability at system level and low deformability at subsystem level).

(Source: Ideation, TRIZ Tutorial)

5.3.2. – Satisfaction (Effects) & Bypass (Redesign)

Satisfaction:
If the physical contradiction can not be solved by one of the separation principles it might be possible to meet both requirements simultaneously by using a new effect. In most cases this is a radical change of the system structure.
TRIZ Laws of evolution help identifying the direction to overcome the contradiction with such a paradigm shift:

Transition to Supersystem: including
    the Trend mono-bi-poly
    the Trend towards Increased Difference between the integrated systems
    → Reference to Laws of Evolution 6 and 7

Transition to Microlevel or Subsystem: i.e. transition to alternative systems
    → Reference to physical, chemical and geometrical effects

Inventive Principles supporting Separation by Transition to Sub- or Supersystem (This list is not exhaustive.)
- IP 1 – Segmentation
- IP 5 – Merging
- IP 33 – Homogeneity
- IP 12 – Equipotentiality

Note: In this case the relationship between the separation concept and the inventive principle is not so evident

Bypass:
If the physical contradiction can not be solved by one of the separation principles, it might be possible to bypass both requirements. This new solution could cause the contradiction gets irrelevant.
This can be done by looking at different screens of the system operator. The screens can help to find alternative bypass problems still related to the same overall goal.

	PAST	PRESENT	FUTURE
SUPERSYSTEM	What should <any resource of the supersystem> do to prevent the appearance of problem in order achieve the Most Desirable Result?	What should <any resource of the supersystem> do in order to make the <system> deliver the useful function properly without undesirable harmful side effects in order achieve the Most Desirable Result?	If the problem has not been solved, what should <any resource of the supersystem > do in order to make the <system> achieve the Most Desirable Result as well?
SYSTEM	What should the <system> do to prevent the appearance of problem in order achieve the Most Desirable Result?	What should the <system> do to deliver the useful function properly without undesirable harmful side effects in order achieve the Most Desirable Result?	If the problem has not been solved, what should the <system> do to achieve the Most Desirable Result as well?
SUBSYSTEM	What should <any of the subsystems> do to prevent the appearance of problem in order achieve the Most Desirable Result?	What should <any of the subsystems> do in order to make the <system> deliver the useful function properly without undesirable harmful side effects in order achieve the Most Desirable Result?	If the problem has not been solved, what should <any of the subsystems> do in order to make the <system> achieve the Most Desirable Result as well?

→ Reference to Systems Operator and
→ Reference to Transition to Supersystem & Microlevel

5.4. – Effects

Definition

Utilization of scientific effects and phenomena helps an inventor to develop solutions of the highest innovation level, since formulated problem contradiction is being resolved on its physical level.
In order to find the right effects Altshuller started to collect physical phenomena and structured them regarding the required effect or property. So a special knowledge database was born. Out of these several software tools and online services developed over the years.
The traditional classification of effects in TRIZ is the differentiation of physical, chemical and gemoetrical effects.

✦ Physical Effects: enable to transform one form of energy into another

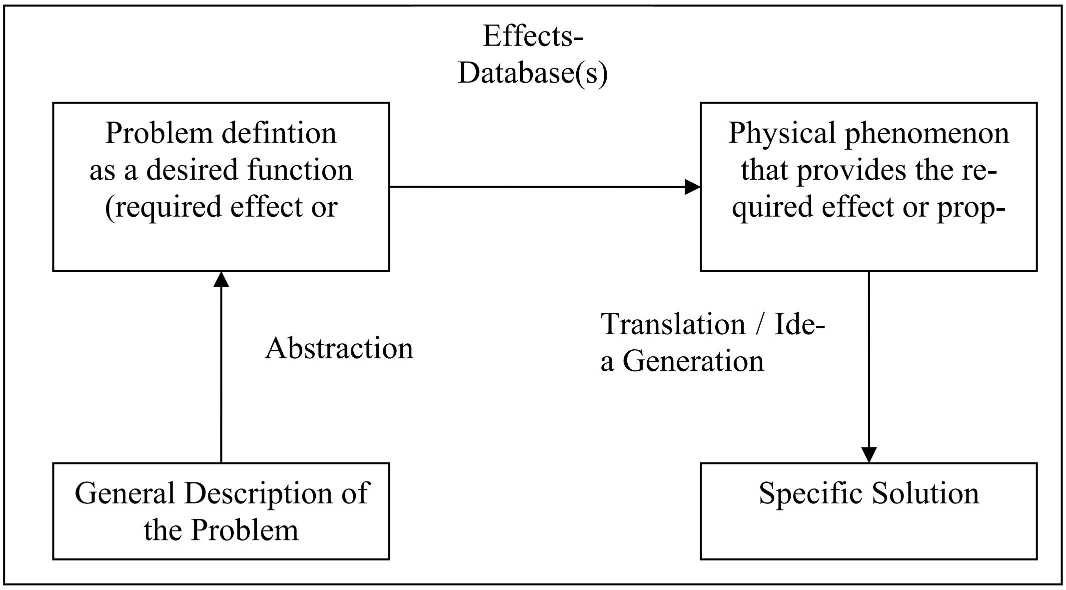
✦ Chemical Effects: enable to obtain some substances from others by the absorption or the emission of energy

Geometrical Effects: organize and redistribute flows of energy and substances that are already available in the system

Geometrical Effects start where Physical and Chemical Effects end.

Note: Within the TRIZ literature the most comprehensive and acknowledged studies about Geometrical Effects (GE) have been published by Vikentiev.

Model



Instruments

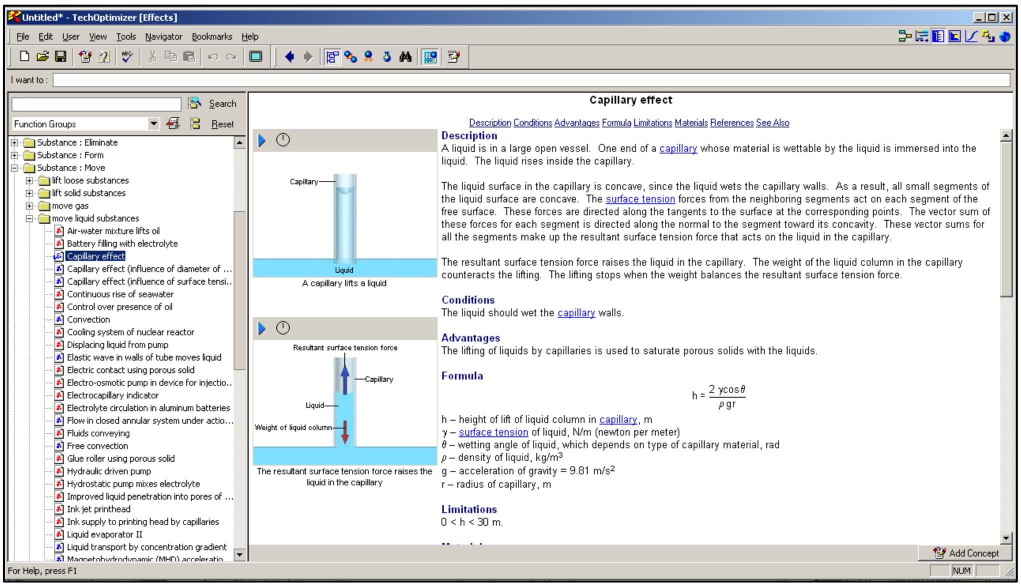
Physical phenomenon that provide the following "required effect or property" have been collected:

1. Measure temperature
2. Reducing temperature
3. Increasing temperature
4. Temperature stabilization
5. Object location
6. Moving an object
7. Moving a liquid or gas
8. Moving an aerosol (dust particles, smoke, mist, etc.)
9. Formation of mixtures
10. Separating mixtures
11. Stabilizating object position
12. Generating and/or manipulating force
13. Changing friction
14. Crashing objects
15. Accumulating mechanical and thermal energy
16. Transferring energy through mechanical, thermal, radiation, or electric deformation
17. Influencing moving object
18. Measuring dimensions
19. Varying dimensions

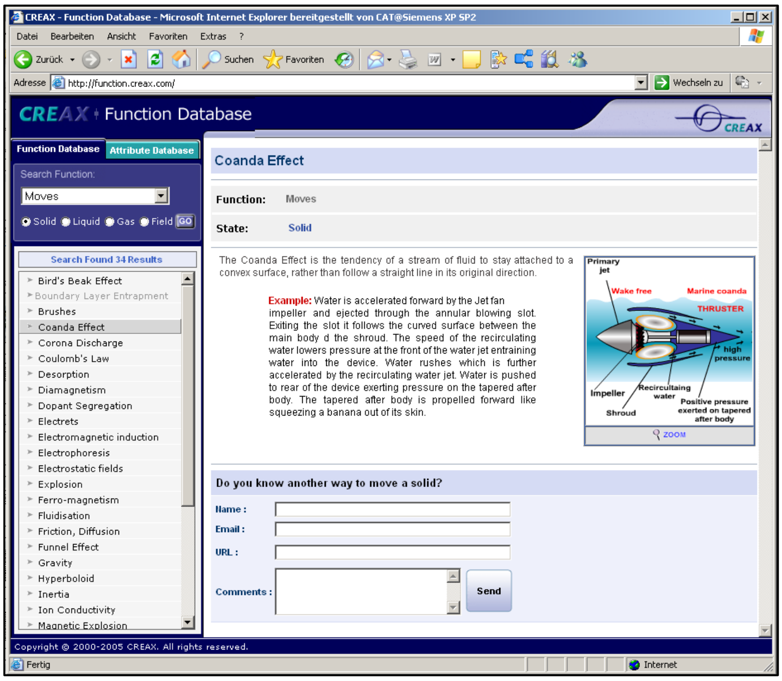
20. Detecting surface properties and/or conditions
21. Varying surface properties
22. Detecting volume properties and/or conditions
23. Varying volume properties
24. Developing certain structures, structure stabilization
25. Detecting electric and magnetic fields
26. Detecting radiation
27. Generating electromagnetic radiation
28. Controlling electromagnetic fields
29. Controlling light, light modulation
30. Initiating and intensification of chemical reactions

Several Software and Online tools have been developed in this field:

Software Invention Machince Inc.: TechOptimizer / Goldfire Innovator



Function Database CREAX : http://fuction.creax.com



5.5. – Substance and-Field- Resources

Definition

TRIZ recommends using the internal, external, by-product and complex substance-field resources of the existing system during problem solving. This meets the requirements of an ideal system and leads to strong solutions with minimal reconstructions as the best result.
Once you have identified your technical system and defined your contradiction, you should evaluate what resources are available to overcome the contradiction. To solve the contradiction, TRIZ recommends using the substance-field resources of the existing system. This meets the requirements of an ideal system.
In TRIZ a resource is everything that can be applied for a solving problem and improving the system without any big expenses. Resources should be easily attainable, free or low cost. Resources can be internal or external to the system or supersystem. Resources can be substances or fields. Other resources include space and time or even other nearby systems.
The identification of these resources provides abundant opportunities for solution concepts to be readily developed. Each resource is a potential solution to your problem. The more resources that are available for use, the greater the solution space to generate more solution concepts.
Resources of an existing system and its elements are the base of the strongest and most efficient solutions. The identification of these resources provides abundant opportunities for solution concepts to be developed. Each resource is a potential solution to the problem. The more resources that are available for use, the greater the solution space is to generate more solution concepts. By using resources we don't need to add "something" from outside the system and can reach very good results.
Resources are also playing an important part in two more concepts of TRIZ:

- the use of the System Operator to guide/improve the search for resources
- the search for resources as a means to reformulate a physical contradiction (see ARIZ part 3)

Model

What kinds of resources are being used in problem solving? The resources can be classified as substances, energy, space, time, functions, information, and combined resources.

The substance resources are all substances and properties of substances (e.g. phase transitions, curie points, thermal/electrical/optical…conductivity etc) used in the analyzed system and in an external environment.

The energy resources are all known kinds of energies and fields (electrical, electromagnetic, thermal fields and etc.). These resources are already present in the improved system or in the external environment where the system resides.

The space resources, we shall perceive an unoccupied space or "hollow", which can be used for changing of the initial system for increasing its efficiency and functionality.

The time resources are, at first, the time prior to the beginning of some main production process, and, secondly, it could be the time between separate stages of the production process. Both of those intervals can be used for improving the basic operation of the system.

The information resources are usually used in solving problems on measuring, detection and separation. Therefore, information resources are data on parameters of substance, fields, change of properties or of object. Thus, the more we shall detect of differences of one substance from other, the more efficiently there can be their measuring or detection.

The functional resources are an opportunity to use known functions of the object on a diverse purpose, or the detection of a new function in the system. A possibility to carry out any additional functions after some changes is also a functional resource. It is a very valuable point of resource utilization because the knowledge and application of the different features or a characteristic property with a new function of the same substance can give a very strong invention.
Note: The search for "functional resources" sometimes causes confusion, because mostly they are already listed.

The **combined resources** are the combination of the above prime resources. Sometimes, there is no resource in the system with required property for solving the problem. We can easily fix this by changing existing substances in the system. We know that a liquid can become a solid substance and vice versa under temperature (water-ice, ice-water), iron can become a magnet, and solid substance can change size under heating or cooling.

<u>How do use resources for problem solving?</u>
This is a short workflow that can be recommended for utilization of the resources and example:

- Formulation of the problem
- Composition of a list of resources in the next order: internal, external, of by-product and complex
- Definition what kind of resources are needed for solving this problem
- Estimation of each of the existing resources and effect from its utilization
- Proposition how to use founded resource

Instruments
See Annex Substance-Field-Resources
The System Operator is a useful tool to search for resources through a systematic scan of the system, its parts and its environment within its whole lifecycle.

5.6 Annexes

5.6.1 The 40 Inventive Principles

Source:

G. Altshuller – Lev Shulyak, Steven Rodman, The Innovation Algorithm, TRIZ, Systematic Innovation and Technical Creativity, Technical Innovation Center, 2000)

Principle 01 - Segmentation

A. Divide an object into independent parts.
B. Make an object easy to disassemble.
C. Increase the degree of fragmentation or segmentation.

Principle 02 - Extraction (Extracting, Retrieving, Removing, Taking out)

A. Extract the "disturbing" part or property from the object.
B. Extract only the necessary part or property from an object.

Principle 03 - Local Quality

A. Transition from homogenous to heterogeneous structure of an object or outside environment (action).
B. Different parts of an object should carry out different functions.
C. Each part of an object should be placed under conditions that are most favourable for its operation.

Principle 04 - Asymmetry

A. Replace symmetrical form(s) with asymmetrical form(s).
B. If an object is already asymmetrical, increase its degree of asymmetry.

Principle 05 – Consolidation (Merging)

A. Consolidate in space homogeneous objects, or objects destined for contiguous operations.
B. Consolidate in time homogeneous or contiguous operations.

Principle 06 - Universality

A. An object can perform several functions; therefore, other elements can be removed.

Principle 07 - Nesting (Matrioshka, "Nested doll")

A. One object is placed inside another. That object is placed inside a third one. And so on …
B. An object passes through a cavity in another object.

Principle 08 – Counterweight (Anti-weight)

A. Compensate for the weight of an object by combining it with another object that provides a lifting force.
B. Compensate for the weight of an object with aerodynamic or hydrodynamic forces influenced by the outside environment.

Principle 09 – Prior Counteraction (Preliminary anti-action)

A. Preload countertension to an object to compensate excessive and undesirable stress.

Principle 10 – Prior Action (Preliminary action)

Perform required changes to an object completely or partially in advance.
Place objects in advance so that they can go into action immediately from the most convenient location.

Principle 11 – Cushion in Advance (Beforehand cushioning)
A. Compensate for the relatively low reliability of an object with emergency measures prepared in advance.

Principle 12 - Equipotentiality
A. Change the condition of the work in such a way that it will not require lifting or lowering an object.

Principle 13 – Do it in Reverse ("The other way round")
A. Instead of the direct action dictated by a problem, implement an opposite action (i.e., cooling instead of heating).
B. Make the movable part of an object, or outside environment, stationary – and the stationary part moveable.
C. Turn the object "upside down".

Principle 14 - Spheroidality (Curvature)
A. Replace linear parts with curved parts, flat surfaces with spherical surfaces, and cube shapes with ball shapes.
B. Use rollers, balls, spirals.
C. Replace linear motion with rotational motion; utilize centrifugal force.

Principle 15 - Dynamics
A. Characteristics of an object or outside environment, must be altered to provide optimal performance at each stage of an operation.
B. If an object is immobile, make it mobile. Make it interchangeable.
C. Divide an object into elements capable of changing their position relative to each other.

Principle 16 - Partial or Excessive Action
A. If it is difficult to obtain 100% of a desired effect, achieve more or less of the desired effect.

Principle 17 – Transition into a New Dimension (Another Dimension)
A. Transition one-dimensional movement or placement of objects into two-dimensional or three-dimensional, etc.
B. Utilize multi-level composition of objects.
C. Incline an object, or place it on its side.
D. Utilize the opposite side of a given surface.
E. Project optical lines onto neighboring areas or onto the reverse side of an object.

Principle 18 - Mechanical Vibration
A. Utilize oscillation.
B. If oscillation exists, increase its frequency to the ultrasonic.
C. Use the frequency of resonance.
D. Replace mechanical vibrations with piezo-vibrations.
E. Use ultrasonic vibrations in conjunction with electromagnetic field.

Principle 19 - Periodic Action
A. Replace a continuous action with a periodic one (impulse).
B. If an action is already periodic, change its frequency.
C. Use pauses between impulses to provide additional action.

Principle 20 - Continuity of Useful Action

A. Carry out an action without a break. All parts of the object should constantly operate at full capacity.

B. Remove idle and intermediate motion.

C. Replace "back-and-forth" motion with rotating one.

Principle 21 – Rushing Through (Skipping)

A. Perform harmful and hazardous operations at a high speed.

Principle 22 – Convert Harm into Benefit ("Blessing in disguise" or "Turn Lemons into Lemonade")

A. Utilize harmful factors – especially environment – to obtain a positive effect.

B. Remove one harmful factor by combining it with another harmful factor.

C. Increase the degree of harmful action to such an extent that it ceases to be harmful.

Principle 23 - Feedback

A. Introduce feedback.

B. If feedback already exists change it.

Principle 24 – Mediator („Intermediary")

A. Use an intermediary object to transfer or carry out an action.

B. Temporarily connect the original object to one that is easily removed.

Principle 25 - Self-service

A. An object must service itself and carry out supplementary and repair operations.

B. Make use of waste material and energy.

Principle 26. Copying

A. A simplified and inexpensive copy should be used in place of a fragile original or an object that is inconvenient to operate.

B. If visible optical copy is used, replace it with infrared or ultraviolet copies.

C. Replace an object (or system of objects) with their optical image. The image can then be reduced or enlarged.

Principle 27 – Dispose (Cheap Short-living Objects)

A. Replace an expensive object with a cheap one, compromising other properties (i.e. longevity).

Principle 28 – Replacement of Mechanical System (Mechanics Substitution)

A. Replace a mechanical system with an optical, acoustical, thermal or olfactory system.

B. Use an electric, magnetic and electromagnetic field to interact with an object.

C. Replace fields that are:

o Stationary with mobile

o Fixed with changing in time

o Random with structured

o Use fields in conjunction with ferromagnetic particles.

Principle 29 – Pneumatic or Hydraulic Constructions (Pneumatics and Hydraulics)

A. Replace solid parts of an object with gas or liquid. These parts can now use air or water for inflation, or use pneumatic or hydrostatic cushions.

Principle 30 – Flexible Membranes or Thin Films (Flexible Shells and Thin Films)
A. Replace customary constructions with flexibe membranes or thin films.
B. Isolate an object from its outside environment with flexible membranes or thin films..

Principle 31 - Porous Material
A. Make an object porous, or use supplementary porous elements (inserts, covers, etc.).
B. If an object is already porous, fill pores in advance with some substance.

Principle 32 – Changing the Color (Color Changes)
A. Change the color of an object or its environment.
B. Change the degree of translucency of an object or its environment.
C. Use color additives to observe an object or process which is difficult to see.
D. If such additives are already used, employ luminescent traces or trace atoms.

Principle 33 - Homogeneity
A. Objects interacting with the main object should be made out of the same material (or material with similar properties) as the main object.

Principle 34 – Rejecting and Regenerating Parts (Discarding and Recovering)
A. After completing its function, or becoming useless, an element of an object is rejected (discarded, dissolved, evaporated, etc.) or modified during its work process.
B. Used-up parts of an object should be restored during its work.

Principle 35 – Transformation of Properties (Parameter Changes)
A. Change the physical state of the system.
B. Change the concentration or density.
C. Change the degree of flexibility.
D. Change the temperature or volume.

Principle 36 - Phase Transition
A. Using the phenomena of phase change (i.e. a change in volume, the liberation or absorption of heat, etc.).

Principle 37 - Thermal Expansion
A. Use expansion or contraction of material by changing its temperature.
B. Use various materials with different coefficients of thermal expansion.

Principle 38 – Accelerated Oxidation (Strong Oxidants)
A. Make transition from one level of oxidation to the next higher level:
- Ambient air to oxygenated
- Oxygenated to oxygen
- Oxygen to ionized oxygen
- Ionized oxygen to ozoned oxygen
- Ozoned oxygen to ozone
- Ozone to singlet oxygen

Principle 39 - Inert Environment (Inert Atmosphere)
A. Replace a normal environment with an inert one.
B. Introduce a neutral substance or additives into an object.
C. Carry out the process in a vacuum.

Principle 40 - Composite Materials
Replace homogeneous materials with composite ones.

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5.6.2. – The 39 Technical Parameters

The 39 Technical Parameters / Characteristics
Source:
G. Altshuller – Lev Shulyak, Steven Rodman, The Innovation Algorithm, TRIZ, Systematic Innovation and Technical Creativity, Technical Innovation Center, 2000)

TP 01 - Weight of moving object
The measurable force, resulting from gravity, that a moving body exerts on the surface which prevents it from falling. A moving object is one which changes position on its own or as a result of some external force.

TP 02 - Weight of non-moving object
The measurable force, resulting from gravity, that a stationary object exerts on the surface on which it rests. A stationary is one which cannot change position on its own or as a result of some external force
Length of moving object

TP 03 - Length of moving object
The linear measure of an object's length, height or width in the direction of observed movement of that object. Movement may be caused by inernal or external forces.

TP 04 - Length of non-moving object
The linear measure of an object`s length, height or width in the direction for which no observed movement occurs.

TP 05 - Area of moving object
the square measure of any plane or portion of a plane of an object which, when acted on by internal or external forces, cannot change its position in space

TP 06-Area of non-moving object
The square measure of any plane or portion of a plane of an object which, when acted on by internal or external forces, cannot change its position in space.

TP07-Volume of moving object
the cubic measure of an object which can change its position in space when acted on by internal or external forces.

TP08-Volume of non-moving object
the cubic measure of an object which cannot change its position in space when acted on by internal or external forces.

TP09-Speed
the rate at which an action or process is completed over time.

TP10-Force
the capacity to cause physical change in an object or system. The change may be full or partial, and permanent or temporary.

TP11-Tension/ Pressure
The intensity of forces acting on an object or system, measured as the force of compression or tension per unit of area.

TP12-Shape
The outward appearance or contour of an object or system. Shape may full or partial and permanent or temporary changes due to forces acting on the object or system.

TP13-Stability of object
The resistance of a whole object or system to change caused by the interactions of its associated objects or systems.

TP 14-Strength
Under definable conditions and limits, the ability of an object or system to absorb the effects of force, speed, stress etc. without breaking.

TP 15-Durability of moving object
The length of time over which an object that changes position in space is able to successfully fulfil its function.

TP 16-Durability of non-moving object
The length of time over which an object that does not change position in space is able to successfully fulfil its function.

TP 17 -Temperature
The loss or addition of heat to an object or system during required functions, which may cause potentially undesirable changes to objects, system or productions.

TP 18-Brightness
The ratio of light energy to heat the area which is being lit by or in a system. Brightness includes the quality of light, degree of illumination, and other characteristics of light.

TP 19-Energy spent by moving object
The energy requirements of an object or system which changes position in space by its own means or by external forces.

TP 20-Energy spent by non-moving object
The energy requirements of an object or system which does not change position in space in the presence of external forces.

TP 21-Power
The ratio of work to the time required to perform that work. Used to measure the time required but potentially undesirable changes in power evident in an objector system under given conditions.

TP 22-Waste of energy
Increased inability of an object or system to exert force, especially when no work or product is produced.

TP 23-Waste of substance
Decrease or elimination of material from an object or system, especially when no work or product is produced.

TP 24-Loss of information
Decrease or elimination of data or input from a system.

T25-Waste of time
Increase in the amount of time needed to complete a given action.

TP26-Amount of substance
The number of elements or the quantity of an element used to create an object or system.

TP27-Reliability
The ability of an object or system to adequately perform its required function during some period of time or cycles.

TP28-Accuracy of measurement
The degree to which a measurement is close to the actual value of the quantity being measured.

TP29-Accuracy of manufacturing
The degree of correspondence between elements of an object or system to its design specification.

TP30-Harmful factors acting on object
Externally produced influences acting on an object or system which reduce efficiency or quality.

TP31-Harmful side effects
Internally produced influences acting on an object or system which reduce efficiency or quality.

TP32-Manufacturability
The convenience and facility with which an object or system is produced.

TP33-Convenience of use
Convenience and facility with which an object or system is operated.

TP34-Repairability
Convenience and facility with which an object or system is restored to operating condition after damage or extensive use.

TP35-Adaptability
The ability of an object or system to reshape or reorder itself as external conditions (environment, function, etc.) change.

TP36-Complexity of device
The quantity and diversity of elements forming the object or system, including the relationship between elements. Complexity may also describe the difficulty of mastering the use of an object or system.

TP37-Complexity of control
The quantity and diversity of elements used in measuring and monitoring an object or system, as well as the cost of measuring to an acceptable error.

TP38-Level of automation
The ability of an object or system to perform operations without human interaction.

TP39-Productivity
The relationship between the number of times an operation is completed and the amount of time it takes to do it.

5.6..3. – The Altshuller Matrix

Part 1/2

↓ Useful Parameter / Feature to improve / Characteristics to be improved

→ Harmful Parameter / Undesired Result / Characteristic that is getting worse

	harmful parameter → / useful parameter ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		weight of mobile object	weight of stationary object	length of mobile object	length of stationary object	area of mobile object	area of stationary object	volume of mobile object	volume of stationary object	velocity	force	tension/ pressure	shape	stability of composition	strength	durability of mobile object	durability of stationary object	temperature	lumination	energy consumption of mobile object	energy consumption of stationary object
1	weight of mobile object	+	-	15, 8, 29,34	-	29, 17, 38, 34	-	29, 2, 40, 28	-	2, 8, 15, 38	8, 10, 18, 37	10, 36, 37, 40	10, 14, 35, 40	1, 35, 19, 39	28, 27, 18, 40	5, 34, 31, 35	-	6, 29, 4, 38	19, 1, 32	35, 12, 34, 31	-
2	weight of stationary object	-	+	-	10, 1, 29,35	-	35, 30, 13, 2	-	5, 35, 14, 2	-	8, 10, 19, 35	13, 29, 10, 18	13, 10, 29, 14	26, 39, 1, 40	28, 2, 10, 27	-	2, 27, 19, 6	28, 19, 32, 22	19, 32, 35	-	18, 19, 28, 1
3	length of mobile object	8, 15, 29, 34	-	+	-	15, 17, 4	-	7, 17, 4, 35	-	13, 4, 8	17, 10, 4	1, 8, 35	1, 8, 10, 29	1, 8, 15, 34	8, 35, 29, 34	19	-	10, 15, 19	32	8, 35, 24	-
4	length of stationary object		35, 28, 40, 29	-	+	-	17, 7, 10, 40	-	35, 8, 2,14	-	28, 10	1, 14, 35	13, 14, 15, 7	39, 37, 35	15, 14, 28, 26	-	1, 10, 35	3, 35, 38, 18	3, 25	-	
5	area of mobile object	2, 17, 29, 4	-	14, 15, 18, 4	-	+	-	7, 14, 17, 4		29, 30, 4, 34	19, 30, 35, 2	10, 15, 36, 28	5, 34, 29, 4	11, 2, 13, 39	3, 15, 40, 14	6, 3	-	2, 15, 16	15, 32, 19, 13	19, 32	-
6	area of stationary object	-	30, 2, 14, 18	-	26, 7, 9, 39	-	+	-		-	1, 18, 35, 36	10, 15, 36, 37		2, 38	40	-	2, 10, 19, 30	35, 39, 38		-	
7	volume of mobile object	2, 26, 29, 40	-	1, 7, 4, 35	-	1, 7, 4, 17	-	+	-	29, 4, 38, 34	15, 35, 36, 37	6, 35, 36, 37	1, 15, 29, 4	28, 10, 1, 39	9, 14, 15, 7	6, 35, 4	-	34, 39, 10, 18	2, 13, 10	35	-
8	volume of stationary object	-	35, 10, 19, 14	19, 14	35, 8, 2, 14	-		-	+	-	2, 18, 37	24, 35	7, 2, 35	34, 28, 35, 40	9, 14, 17, 15	-	35, 34, 38	35, 6, 4		-	
9	velocity	2, 28, 13, 38	-	13, 14, 8	-	29, 30, 34	-	7, 29, 34	-	+	13, 28, 15, 19	6, 18, 38, 40	35, 15, 18, 34	28, 33, 1, 18	8, 3, 26, 14	3, 19, 35, 5	-	28, 30, 36, 2	10, 13, 19	8, 15, 35, 38	-
10	force	8, 1, 37, 18	18, 13, 1, 28	17, 19, 9, 36	28, 10	19, 10, 15	1, 18, 36, 37	15, 9, 12, 37	2, 36, 18, 37	13, 28, 15, 12	+	18, 21, 11	10, 35, 40, 34	35, 10, 21	35, 10, 14, 27	19, 2		35, 10, 21	-	19, 17, 10	1, 16, 36, 37
11	tension/ pressure	10, 36, 37, 40	13, 29, 10, 18	35, 10, 36	35, 1, 14, 16	10, 15, 36, 28	10, 15, 36, 37	6, 35, 10	35, 24	6, 35, 36	36, 35, 21	+	35, 4, 15, 10	35, 33, 2, 40	9, 18, 3, 40	19, 3, 27		35, 39, 19, 2	-	14, 24, 10, 37	
12	shape	8, 10, 29, 40	15, 10, 26, 3	29, 34, 5, 4	13, 14, 10, 7	5, 34, 4, 10		14, 4, 15, 22	7, 2, 35	35, 15, 34, 18	35, 10, 37, 40	34, 15, 10, 14	+	33, 1, 18, 4	30, 14, 10, 40	14, 26, 9, 25		22, 14, 19, 32	13, 15, 32	2, 6, 34, 14	
13	stability of composition	21, 35, 2, 39	26, 39, 1, 40	13, 15, 1, 28	37	2, 11, 13	39	28, 10, 19, 39	34, 28, 35, 40	33, 15, 28, 18	10, 35, 21, 16	2, 35, 40	22, 1, 18, 4	+	17, 9, 15	13, 27, 10, 35	39, 3, 35, 23	35, 1, 32	32, 3, 27, 16	13, 19	27, 4, 29, 18
14	strength	1, 8, 40, 15	40, 26, 27, 1	1, 15, 8, 35	15, 14, 28, 26	3, 34, 40, 29	9, 40, 28	10, 15, 14, 7	9, 14, 17, 15	8, 13, 26, 14	10, 18, 3, 14	10, 3, 18, 40	10, 30, 35, 40	13, 17, 35	+	27, 3, 26		30, 10, 40	35, 19	19, 35, 10	35
15	durabilty of mobile object	19, 5, 34, 31	-	2, 19, 9	-	3, 17, 19	-	10, 2, 19, 30	-	3, 35, 5	19, 2, 16	19, 3, 27	14, 26, 28, 25	13, 3, 35	27, 3, 10	+	-	19, 35, 39	2, 19, 4, 35	28, 6, 35, 18	
16	durability of stationary object	-	6, 27, 19, 16	-	1, 40, 35	-		-	35, 34, 38	-				39, 3, 35, 23		-	+	19, 18, 36, 40		-	
17	temperature	36,22, 6, 38	22, 35, 32	15, 19, 9	15, 19, 9	3, 35, 39, 18	35, 38	34, 39, 40, 18	35, 6, 4	2, 28, 36, 30	35, 10, 3, 21	35, 39, 19, 2	14, 22, 19, 32	1, 35, 32	10, 30, 22, 40	19, 13, 39	19, 18, 36, 40	+	32, 30, 21, 16	19, 15, 3, 17	
18	lumination	19, 1, 32	2, 35, 32	19, 32, 16		19, 32, 26		2, 13, 10		10, 13, 19	26, 19, 6		32, 30	32, 3, 27	35, 19	2, 19, 6		32, 35, 19	+	32, 1, 19	32, 35, 1, 15
19	energy consumption of mobile object	12,18,2 8,31	-	12, 28	-	15, 19, 25	-	35, 13, 18	-	8, 35, 35	16, 26, 21, 2	23, 14, 25	12, 2, 29	19, 13, 17, 24	5, 19, 9, 35	28, 35, 6, 18	-	19, 24, 3, 14	2, 15, 19	+	-
20	energy consumption of stationary object	-	19, 9, 6, 27	-		-		-		-	36, 37			27, 4, 29, 18	35				19, 2, 35, 32	-	+
21	power	8, 36, 38, 31	19, 26, 17, 27	1, 10, 35, 37		19, 38	17, 32, 13, 38	35, 6, 38	30, 6, 25	15, 35, 2	26, 2, 36, 35	22, 10, 35	29, 14, 2, 40	35, 32, 15, 31	26, 10, 28	19, 35, 10, 38	16	2, 14, 17, 25	16, 6, 19	16, 6, 19, 37	
22	waste of energy	15, 6, 19, 28	19, 6, 18, 9	7, 2, 6, 13	6, 38, 7	15, 26, 17, 30	17, 7, 30, 18	7, 18, 23	7	16, 35, 38	36, 38			14, 2, 39, 6	26			19, 38, 7	1, 13, 32, 15		
23	waste of substance	35, 6, 23, 40	35, 6, 22, 32	14, 29, 10, 39	10, 28,24	35, 2, 10, 31	10, 18, 39, 31	1, 29, 30, 36	3, 39, 18, 31	10, 13, 28, 38	14, 15, 18, 40	3, 36, 37, 10	29, 35, 3, 5	2, 14, 30, 40	35, 28, 31, 40	28, 27, 3, 18	27, 16, 18, 38	21, 36, 39, 31	1, 6, 13	35, 18, 24, 5	28, 27, 12, 31
24	loss of information	10, 24, 35	10, 35, 5	1, 26	26	30, 26	30, 16		2, 22	26, 32						10	10		19		
25	waste of time	10, 20, 37, 35	10, 20, 26, 5	15, 2, 29	30, 24, 14, 5	26, 4, 5, 16	10, 35, 17, 4	2, 5, 34, 10	35, 16, 32, 18		10, 37, 36,5	37, 36,4	4, 10, 34, 17	35, 3, 22, 5	29, 3, 28, 18	20, 10, 28, 18	28, 20, 10, 16	35, 29, 21, 18	1, 19, 26, 17	35, 38, 19, 18	1
26	amount of substance	35, 6, 18, 31	27, 26, 18, 35	29, 14, 35, 18		15, 14, 29	2, 18, 40, 4	15, 20, 29		35, 29, 34, 28	35, 14, 3	10, 36, 14, 3	35, 14	15, 2, 17, 40	14, 35, 34, 10	3, 35, 10, 40	3, 35, 31	3, 17, 39		34, 29, 16, 18	3, 35, 31
27	reliability	3, 8, 10, 40	3, 10, 8, 28	15, 9, 14, 4	15, 29, 28, 11	17, 10, 14, 16	32, 35, 40, 4	3, 10, 14, 24	2, 35, 24	21, 35, 11, 28	8, 28, 10, 3	10, 24, 35, 19	35, 1, 16, 11		11, 28	2, 35, 3, 25	34, 27, 6, 40	3, 35, 10	11, 32, 13	21, 11, 27, 19	36, 23
28	accuracy of measurement	32, 35, 26, 28	28, 35, 25, 26	28, 26, 5, 16	32, 28, 3, 16	26, 28, 32, 3	26, 28, 32, 3	32, 13, 6		28, 13, 32, 24	32, 2	6, 28, 32	6, 28, 32	32, 35, 13	28, 6, 32	28, 6, 32	10, 26, 24	6, 19, 28, 24	6, 1, 32	3, 6, 32	
29	manufacturing precision	28, 32, 13, 18	28, 35, 27, 9	10, 28, 29, 37	2, 32, 10	28, 33, 29, 32	2, 29, 18, 36	32, 23, 2	25, 10, 35	10, 28, 32	28, 19, 34, 36	3, 35	32, 30, 40	30, 18	3, 27	3, 27, 40		19, 26	3, 32	32, 2	
30	harmful factors acting on object	22, 21, 27, 39	2, 22, 13, 24	17, 1, 39, 4	1, 18	22, 1, 33, 28	27, 2, 39, 35	22, 23, 37, 35	34, 39, 19, 27	21, 22, 35, 28	13, 35, 39, 18	22, 2, 37	22, 1, 3, 35	35, 24, 30, 18	18, 35, 37, 1	22, 15, 33, 28	17, 1, 40, 33	22, 33, 35, 2	1, 19, 32, 13	1, 24, 6, 27	10, 2, 22, 37
31	harmful side effects of the object	19, 22, 15, 39	35, 22, 1, 39	17, 15, 16, 22		17, 2, 18, 39	22, 1, 40	17, 2, 40	30, 18, 35, 4	35, 28, 3, 23	35, 28, 1, 40	2, 33, 27, 18	35, 1	35, 40, 27, 39	15, 35, 22, 2	15, 22, 33, 31	21, 39, 16, 22	22, 35, 2, 24	19, 24, 39, 32	2, 35, 6	19, 22, 18
32	manufacturability	28, 29, 15, 16	1, 27, 36, 13	1, 29, 13, 17	15, 17, 27	13, 1, 26, 12	16, 40	13, 29, 1, 40	35	35, 13, 8, 1	35, 12	35, 19, 1, 37	1, 28, 13, 27	11, 13, 1	1, 3, 10, 32	27, 1, 4	35, 16	27, 26, 18	28, 24, 27, 1	28, 26, 27, 1	1, 4
33	operation convenience	25, 2, 13, 15	6, 13, 1, 25	1, 17, 13, 12		1, 17, 13, 16	18, 16, 15, 39	1, 16, 35, 15	4, 18, 39, 31	18, 13, 34	28, 13 35	2, 32, 12	15, 34, 29, 28	32, 35, 30	32, 40, 3, 28	29, 3, 8, 25	1, 16, 25	26, 27, 13	13, 17, 1, 24	1, 13, 24	
34	repairability	2, 27 35, 11	2, 27, 35, 11	1, 28, 10, 25	3, 18, 31	15, 13, 32	16, 25	25, 2, 35, 11	1	34, 9	1, 11, 10	13	1, 13, 2, 4	2, 35	11, 1, 2, 9	11, 29, 28, 27	1	4, 10	15, 1, 13	15, 1, 28, 16	
35	adaptabilty	1, 6, 15, 8	19, 15, 29, 16	35, 1, 29, 2	1, 35, 16	35, 30, 29, 7	15, 16	15, 35, 29		35, 10, 14	15, 17, 20	35, 16	15, 37, 1, 8	35, 30, 14	35, 3, 32, 6	13, 1, 35	2, 16	27, 2, 3, 35	6, 22, 26, 1	19, 35, 29, 13	
36	complexity of device	26, 30, 34, 36	2, 26, 35, 39	1, 19, 26, 24	26	14, 1, 13, 16	6, 36	34, 26, 6	1, 16	34, 10, 28	26, 16	19, 1, 35	29, 13, 28, 15	2, 22, 17, 19	2, 13, 28	10, 4, 28, 15		2, 17, 13	24, 17, 13	27, 2, 29, 28	
37	complexity of control	27, 26, 28, 13	6, 13, 28, 1	16, 17, 26, 24	26	2, 13, 18, 17	2, 39, 30, 16	29, 1, 4, 16	2, 18, 26, 31	3, 4, 16, 35	30, 28, 40, 19	35, 36, 37, 32	27, 13, 1, 39	11, 22, 39, 30	27, 3, 15, 28	19, 29, 39, 25	25, 34, 6, 35	3, 27, 35, 16	2, 24, 26	35, 38	19, 35, 16
38	level of automation	28, 26, 18, 35	28, 26, 35, 10	14, 13, 17, 28	23	17, 14, 13		35, 13, 16		28, 10	2, 35	13, 35	15, 32, 1, 13	18, 1	25, 13	6, 9		26, 2, 19	8, 32, 19	2, 32, 13	
39	productivity	35, 26, 24, 37	28, 27, 15, 3	18, 4, 28, 38	30, 7, 14, 26	10, 26, 34, 31	10, 35, 17, 7	2, 6, 34, 10	35, 37, 10, 2		28, 15, 10, 36	10, 37, 14	14, 10, 34, 40	35, 3, 22, 39	29, 28, 10, 18	35, 10, 2, 18	20, 10, 16, 38	35, 21, 28, 10	26, 17, 19, 1	35, 10, 38, 19	1

Part 2/2 (Altshuller Matrix)

↓ Useful Parameter / Feature to improve / Characteristics to be improved
→ Harmful Parameter / Undesired Result / Characteristic that is getting worse

	harmful parameter → useful parameter ↓	21 power	22 waste of energy	23 waste of substance	24 loss of information	25 waste of time	26 amount of substance	27 reliability	28 accuracy of measurement	29 manufacturing precision	30 harmful factors acting on object	31 harmful side effects of the object	32 manufacturability	33 operation convenience	34 repairability	35 adaptabilty	36 complexity of device	37 complexity of control	38 level of automation	39 productivity
1	weight of mobile object	12, 36, 18, 31	6, 2, 34, 19	5, 35, 3, 31	10, 24, 35	10, 35, 20, 28	3, 26, 18, 31	1, 3, 11, 27	28, 27, 35, 26	28, 35, 26, 18	22, 21, 18, 27	22, 35, 31, 39	27, 28, 1, 36	35, 3, 2, 24	2, 27, 28, 11	29, 5, 15, 8	26, 30, 36, 34	28, 29, 26, 32	26, 35 18, 19	35, 3, 24, 37
2	weight of stationary object	15, 19, 18, 15	18, 19, 28, 15	5, 8, 13, 30	10, 15, 35	10, 20, 35, 26	19, 6, 18, 26	10, 28, 8, 3	18, 26, 28	10, 1, 35, 17	2, 19, 22, 37	35, 22, 1, 39	28, 1, 9	6, 13, 1, 32	2, 27, 28, 11	19, 15, 29	1, 10, 26, 39	25, 28, 17, 15	2, 26, 35	1, 28, 15, 35
3	length of mobile object	1, 35	7, 2, 35, 39	4, 29, 23, 10	1, 24	15, 2, 29	29, 35	10, 14, 29, 40	28, 32, 4	10, 28, 29, 37	1, 15, 17, 24	17, 15	1, 29, 17	15, 29, 35, 4	1, 28, 10	14, 15, 1, 16	1, 19, 26, 24	35, 1, 26, 24	17, 24, 26, 16	14, 4, 28, 29
4	length of stationary object	12, 8	6, 28	10, 28, 24, 35	24, 26,	30, 29, 14		15, 29, 28	32, 28, 3	2, 32, 10	1, 18		15, 17, 27	2, 25	3	1, 35	1, 26	26		30, 14, 7, 26
5	area of mobile object	19, 10, 32, 18	15, 17, 30, 26	10, 35, 2, 39	30, 26	26, 4	29, 30, 6, 13	29, 9	26, 28, 32, 3	2, 32	22, 33, 28, 1	17, 2, 18, 39	13, 1, 26, 24	15, 17, 13, 16	15, 13, 10, 1	15, 30	14, 1, 13	2, 36, 26, 18	14, 30, 28, 23	10, 26, 34, 2
6	area of stationary object	17, 32	17, 7, 30	10, 14, 18, 39	30, 16	10, 35, 4, 18	2, 18, 40, 4	32, 35, 40, 4	26, 28, 32, 3	2, 29, 18, 36	27, 2, 39, 35	22, 1, 40	40, 16	16, 4	16	15, 16	1, 18, 36	2, 35, 30, 18	23	10, 15, 17, 7
7	volume of mobile object	35, 6, 13, 18	7, 15, 13, 16	36, 39, 34, 10	2, 22	2, 6, 34, 10	29, 30, 7	14, 1, 40, 11	26, 26, 28	25, 28, 2, 16	22, 21, 27, 35	17, 2, 40, 1	29, 1, 40	15, 13, 30, 12	10	15, 29	26, 1	29, 26, 4	35, 34, 16, 24	10, 6, 2, 34
8	volume of stationary object	30, 6		10, 39, 35, 34		35, 16, 32 18	35, 3	2, 35, 16		35, 10, 25	34, 39, 19, 27	30, 18, 35, 4	35		1		1, 31	2, 17, 26		35, 37, 10, 2
9	velocity	19, 35, 38, 2	14, 20, 19, 35	10, 13, 28, 38	13, 26		10, 19, 29, 38	11, 35, 27, 28	28, 32, 1, 24	10, 28, 32, 25	1, 28, 35, 23	2, 24, 35, 21	35, 13, 8, 1	32, 28, 13, 12	34, 2, 28, 27	15, 10, 26	10, 28, 4, 34	3, 34, 27, 16	10, 18	
10	force	19, 35, 18, 37	14, 15	8, 35, 40, 5		10, 37, 36	14, 29, 18, 36	3, 35, 13, 21	35, 10, 23, 24	28, 29, 37, 36	1, 35, 40, 18	13, 3, 36, 24	15, 37, 18, 1	1, 28, 3, 25	15, 1, 11	15, 17, 18, 20	26, 35, 10, 18	36, 37, 10, 19	2, 35	3, 28, 35, 37
11	tension/ pressure	10, 35, 14	2, 36, 25	10, 36, 3, 37		37, 36, 4	10, 14, 36	10, 13, 19, 35	6, 28, 25	3, 35	22, 2, 37	2, 33, 27, 18	1, 35, 16	11	2	35	19, 1, 35	2, 36, 37	35, 24	10, 14, 35, 37
12	shape	4, 6, 2	14	35, 29, 3, 5		14, 10, 34, 17	36, 22	10, 40, 16	28, 32, 1	32, 30, 40	22, 1, 2, 35	35, 1	1, 32, 17, 28	32, 15, 26	2, 13, 1	1, 15, 29	16, 29, 1, 28	15, 13, 39	15, 1, 32	17, 26, 34, 10
13	stability of composition	32, 35, 27, 31	14, 2, 39, 6	2, 14, 30, 40		35, 27	15, 32, 35		13	18	35, 24, 30, 18	35, 40, 27, 39	35, 19	32, 35, 30	2, 35, 10, 16	35, 30, 34, 2	2, 35, 22, 26	35, 22, 39, 23	1, 8, 35	23, 35, 40, 3
14	strength	10, 26, 35, 28	35	35, 28, 31, 40		29, 3, 28, 10	29, 10, 27	11, 3	3, 27, 16	3, 27	18, 35, 37, 1	15, 35, 22, 2	11, 3, 10, 32	32, 40, 25, 2	27, 11, 3	15, 3, 32	2, 13, 25, 28	27, 3, 15, 40	15	29, 35, 10, 14
15	durabilty of mobile object	19, 10, 35, 38		28, 27, 3, 18	10	20, 10, 28, 18	3, 35, 10, 40	11, 2, 13	3	3, 27, 16, 40	22, 15, 33, 28	21, 39, 16, 22	27, 1, 4	12, 27	29, 10, 27	1, 35, 13	10, 4, 29, 15	19, 29, 39, 35	6, 10	35, 17, 14, 19
16	durability of stationary object	16		27, 16, 18, 38	10	28, 20, 10, 16	3, 35, 31	34, 27, 6, 40	10, 26, 24		17, 1, 40, 33	22	35, 10	1	1	2		25, 34, 6, 35	1	20, 10, 16, 38
17	temperature	2, 14, 17, 25	21, 17, 35, 38	21, 36, 29, 31		35, 28, 21, 18	3, 17, 30, 39	19, 35, 3, 10	32, 19, 24	24	22, 33, 35, 2	22, 35, 2, 24	26, 27	26, 27	4, 10, 16	2, 18, 27	2, 17, 16	3, 27, 35, 31	26, 2, 19, 16	15, 28, 35
18	lumination	32	13, 16, 1, 6	13, 1	1, 6	19, 1, 26, 17	1, 19		11, 15, 32	3, 32	15, 19	35, 19, 32, 39	19, 35, 28, 26	28, 26, 19	15, 17, 13, 16	15, 1, 1, 19	6, 32, 13	32, 15	2, 26, 10	2, 25, 16
19	energy consumption of mobile object	6, 19, 37, 18	12, 22, 15, 24	35, 24, 18, 5		35, 38, 19, 18	34, 23, 16, 18	19, 21, 11, 27	3, 1, 32		1, 35, 6, 27	2, 35, 6	28, 26, 30	19, 35	1, 15, 17, 28	15, 17, 13, 16	2, 29, 27, 28	35, 38	32, 2	12, 28, 35
20	energy consumption of stationary object			28, 27, 18, 31			3, 35, 31	10, 36, 23			10, 2, 22, 37	19, 22, 18	1, 4					19, 35, 16, 25		1, 6
21	power	+	10, 35, 38	28, 27, 18, 38	10, 19	35, 20, 10, 6	4, 34, 19	19, 24, 26, 31	32, 15, 2	32, 2	19, 22, 31, 2	2, 35, 18	26, 10, 34	26, 35, 10	35, 2, 10, 34	19, 17, 34	20, 19, 30, 34	19, 35, 16	28, 2, 17	28, 35, 34
22	waste of energy	3, 38	+	35, 27, 2, 37	19, 10	10, 18, 32, 7	7, 18, 25	11, 10, 35	32		21, 22, 35, 2	21, 35, 2, 22		35, 32, 1	2, 19		7, 23	35, 3, 15, 23	2	28, 10, 29, 35
23	waste of substance	28, 27, 18, 38	35, 27, 2, 31	+		15, 18, 35, 10	6, 3, 10, 24	10, 29, 39, 35	16, 34, 31, 28	35, 10, 24, 31	33, 22, 30, 40	10, 1, 34, 29	15, 34, 33	32, 28, 2, 24	2, 35, 34, 27	15, 10, 2	35, 10, 28, 24	35, 18, 10, 13	35, 10, 18	28, 35, 10, 23
24	loss of information	10, 19	19, 10		+	24, 26, 28, 32	24, 28, 35	10, 28, 23			22, 10, 1	10, 21, 22	32	27, 22				35, 33	35	13, 23, 15
25	waste of time	35, 20, 10, 6	10, 5, 18, 32	35, 18, 10, 39	24, 26, 28, 32	+	35, 38, 18, 16	10, 30, 4	24, 34, 28, 32	24, 26, 28, 18	35, 18, 34	35, 22, 18, 39	35, 28, 34, 4	4, 28, 10, 34	32, 1, 10	35, 28	6, 29	18, 28, 32, 10	24, 28, 35, 30	
26	amount of substance	35	7, 18, 25	6, 3, 10, 24	24, 28, 35	35, 38, 18, 16	+	18, 3, 28, 40	13, 2, 28	33, 30	35, 33, 29, 31	3, 35, 40, 39	29, 1, 35, 27	35, 29, 25, 10	2, 32, 10, 25	15, 3, 29	3, 13, 27, 10	3, 27, 29, 18	8, 35	13, 29, 3, 27
27	reliability	21, 11, 26, 31	10, 11, 35	10, 35, 29, 39	10, 28	10, 30, 4	21, 28, 40, 3	+	32, 3, 11, 23	11, 32, 1	27, 35, 2, 40	35, 2, 40, 26		27, 17, 40	1, 11	13, 35, 8, 24	13, 35, 1	27, 40, 28	11, 13, 27	1, 35, 29, 38
28	accuracy of measurement	3, 6, 32	26, 32, 27	10, 16, 31, 28		24, 34, 28, 32	2, 6, 32	5, 11, 1, 23	+		28, 24, 22, 26	3, 33, 39, 10	6, 35, 25, 18	1, 13, 17, 34	1, 32, 13, 11	13, 35, 2	27, 35, 10, 34	26, 24, 32, 28	28, 2, 10, 34	10, 34, 28, 32
29	manufacturing precision	32, 2	13, 32, 2	35, 31, 10, 24		32, 26, 28, 18	32, 30	11, 32, 1		+	26, 28, 10, 36	4, 17, 34, 26		1, 32, 35, 23	25, 10		26, 2, 18		26, 28, 18, 23	10, 18, 32, 39
30	harmful factors acting on object	19, 22, 31, 2	21, 22, 35, 2	33, 22, 19, 40	22, 10, 2	35, 18, 34	35, 33, 29, 31	27, 24, 2, 40	28, 33, 23, 26	26, 28, 10, 18	+		24, 35, 2	2, 25, 28, 39	35, 10, 2	35, 11, 22, 31	22, 19, 29, 40	22, 19, 29, 40	33, 3, 34	22, 35, 13, 24
31	harmful side effects of the object	2, 35, 18	21, 35, 2, 22	10, 1, 34	10, 21, 29	1, 22	3, 24, 39, 1	24, 2, 40, 39	3, 33, 26	4, 17, 34, 26		+					19, 1, 31	2, 21, 27, 1	2	22, 35, 18, 39
32	manufacturability	27, 1, 12, 24	19, 35	15, 34, 33	32, 24, 18, 16	35, 28, 34, 4	35, 23, 1, 24		1, 35, 12, 18		24, 2		+	2, 5, 13, 16	35, 1, 11, 9	2, 13, 15	27, 26, 1	6, 28, 11, 1	8, 28, 1	35, 1, 10, 28
33	operation convenience	35, 34, 2, 10	2, 19, 13	28, 32, 2, 24	4, 10, 27, 22	4, 28, 10, 34	12, 35	17, 27, 8, 40	25, 13, 2, 34	1, 32, 35, 23	2, 25, 28, 39		2, 5, 12	+	12, 26, 1, 32	15, 34, 1, 16	32, 26, 12, 17		1, 34, 12, 3	15, 1, 28
34	repairability	15, 10, 32, 2	15, 1, 32, 19	2, 35, 34, 27		32, 1, 10, 25	2, 28, 10, 25	11, 10, 1, 16	10, 2, 13	25, 10	35, 10, 2, 16		1, 35, 11, 10	1, 12, 26, 15	+	7, 1, 4, 16	35, 1, 13, 11		34, 35, 7, 13	1, 32, 10
35	adaptabilty	19, 1, 29	18, 15, 1	15, 10, 2, 13		35, 28	3, 35, 15	35, 13, 8, 24	35, 5, 1, 10		35, 11, 32, 31		1, 13, 31	15, 34, 1, 16	1, 16, 7, 4	+	15, 29, 37, 28	1	27, 34, 35	35, 28, 6, 37
36	complexity of device	20, 19, 30, 34	10, 35, 13, 2	35, 10, 28, 29		6, 29	13, 3, 27, 10	13, 35, 1	2, 26, 10, 34	26, 24, 32	22, 19, 29, 40	19, 1	27, 26, 1, 13	27, 9, 26, 24	1, 13	29, 15, 28, 37	+	15, 10, 37, 28	15, 1, 24	12, 17, 28
37	complexity of control	18, 1, 16, 10	35, 3, 15, 19	1, 18, 10, 24	35, 33, 27, 22	18, 28, 32, 9	3, 27, 29, 18	27, 40, 28, 8	26, 24, 32, 28		22, 19, 29, 28	2, 21	5, 28, 11, 29	2, 5	12, 26	1, 15	15, 10, 37, 28	+	34, 21	35, 18
38	level of automation	28, 2, 27	23, 28	35, 10, 18, 5	35, 33	24, 28, 35, 30	35, 13	11, 27, 32	28, 26, 10, 34	28, 26, 18, 23	2, 33	2	1, 26, 13	1, 12, 34, 3	1, 35, 13	27, 4, 1, 35	15, 24, 10	34, 27, 25	+	5, 12, 35, 26
39	productivity	35, 20, 10	28, 10, 29, 35	28, 10, 35, 23	13, 15, 23		35, 38	1, 35, 10, 38	1, 10, 34, 28	18, 10, 32, 1	22, 35, 13, 24	35, 22, 18, 39	35, 28, 2, 24	1, 28, 7, 10	1, 32, 10, 25	1, 35, 28, 37	12, 17, 28, 24	35, 18, 27, 2	5, 12, 35, 26	+

5.6.4 Effects

Source:

G. Altshuller – Lev Shulyak, Steven Rodman, The Innovation Algorithm, TRIZ, Systematic Innovation and Technical Creativity, Technical Innovation Center, 2000)

Required effect or property	Physical phenomenon that provides the required effect or property
Measure temperature	Thermal expansion and its influence on the natural frequency of oscillations Thermoelectric phenomena Radiation spectrum Changes in optical. electrical and magnetic properties of substances Transition over the Curie point Hopkins, Barkhausen and Seebeck effects
Reducing temperature	Phase transitions Joule-Thomson effect Rank effect Magnetic calorie effect Thermoelectric phenomena
Increasing temperature	Electromagnetic induction Eddy current Surface effect Dielectric heating Electronic heating Electrical discharge Absorption of radiation by substances Thermoelectric phenomena
Temperature stabilization	Phase transitions, including transition over the Curie point
Object location	Introduction of makers; that is, substances that are able to transform existing fields (like luminophores) or generate their own fields (like ferromagnetic materials) and therefore are easy to detect Reflection and emission of light Photo effect Deformation Radioactive and X-ray radiation Luminescence Changes in electric or magnetic field Electrical discharge Doppler effect
Moving an object	Magnetic field applied to influence an object or magnet attached to the object Magnetic field applied to influence a conductor with direct current passing through it Electric field applied to influence an electrically charged object Pressure transfer in a liquid or gas Mechanical oscillations Centrifugal force Thermal expansion Pressure of light

Moving a liquid or gas	Capillary force Osmosis Toms effect Waves Bernoulli effect Weissenberg effect
Moving an aerosol (dust particles, smoke, mist, etc.)	Electrization Applied electric or magnetic field Pressure of light
Formation of mixtures	Ultrasonics Cavitation Diffusion Applied electric field Magnetic field applied in combination with magnetic material Electrophoresis Solubilization
Separating mixtures	Electric and magnetic separation Electric and magnetic field applied to change the pseudo viscosity of a liquid Centrifugal force Sorption Diffusion Osmosis
Stabilizating object position	Applied electric or magnetic field Holding a liquid by hardening through the influence of an electric or magnetic field Gyroscope effect Reactive force
Generating and/or manipulating force	Generating high pressure Applying a magnetic field through magnetic material Phase transition Thermal expansion Centrifugal force Changing hydrostatic forces by influencing the pseudoviscosity of an electroconductive or magnetic liquid in a magnetic field Use of explosives Electrohydraulic effect Optical hydraulic effect Osmosis
Changing friction	Johnson-Rabeck effect Radiation effect Abnormally low friction effect No-wear friction effect
Crashing objects	Electrical discharge Electrohydraulic effect Resonance Ultrasonics Cavitation Use of lasers

Accumulating mechanical and thermal energy	Elastic deformation Gyroscope Phase transitions
Transferring energy through mechanical, thermal, radiation, or electric deformation	Oscillations Alexandrov effect Waves, including shock waves Radiation Thermal conductivity Convection Light reflection Fiber optics Lasers Electromagnetic induction Superconductivity
Influencing moving object	Applied electric or magnetic fields, with no influence through physical contact
Measuring dimensions	Measuring the natural frequency of oscillations Applying and detecting magnetic or electric makers
Varying dimensions	Thermal expansion Deformation Magnetostriction Piezoelectric
Detecting surface properties and/or conditions	Electrical discharge Reflection of light Electronic emission Moiré effect Radiation
Varying surface properties	Friction Absorption Diffusion Bauschinger effect Electrical discharge Mechanical or acoustic oscillation Ultraviolet radiation
Detecting volume properties and/or conditions	Introduction of markers; that is, substances that are able to transform existing fields (like luminophores) or generate their own fields (like ferromagnetic materials), depending on the properties of a material Changing electric resistance, which depend on structure and/or propertie variations Interaction with light Electro- and/or magneto-optic phenomena Polarized light Radioactive and x-ray radiation Electronic paramagnetic or nuclear magnetic resonance Magneto-elastic effect Transition over the Curie point Hopkins and Barkhausen effect Ultrasonics Moessbauer effect Hall effect

Varying volume properties	Electric or magnetic applied to vary the properties of a liquid (pseudoviscosity, fluidity) Influencing by magnetic field via introduced magnetic material Heating Phase transition Ionization by electric field Ultraviolet, X-ray or radioactive radiation Deformation Diffusion Electric or magnetic field Bauschinger effect Thermoelectric, thermomagnetic or magneto-optic effect Cavitation Photochromatic effect Internal photo effect
Developing certain structures, structure stabilization	Interference Standing waves Moiré effect Magnetic waves Phase transitions Mechanical and acoustic oscillation Cavitation
Detecting electric and magnetic fields	Osmosis Electrization Electrical discharge Piezo-and segneto-electrical effects Electrets Electronic emission Electro-optical phenomena Hopkins and Barkhausen effect Hall effect Nuclear magnetic resonance Gyromagnetic and magneto-optical phenomena
Detecting radiation	Optical acoustic effect Thermal expansion Photo effect Luminescence Photoplastic effect
Generating electromagnetic radiation	Josephson effect Induction of radiation Tunnel effect Luminescence Hann effect Cherenkov effect
Controlling electromagnetic fields	Use of screens Changing properties (for example, varying electrical conductivity) Changing objects shapes

Controlling light, light modulation	Refraction and reflection of light Electro- and magneto-optical phenomena Photo elasticity Kerr and faraday effects Hann effect Franz-Keldysh effect
Initiating and intensification of chemical reactions	Ultrasonics Cavitation Ultraviolet, X-ray and radioactive radiation Electric discharge Shock waves

5.6.5 Substance-and-Field Resources

Source:
G. Altshuller – Lev Shulyak, Steven Rodman, The Innovation Algorithm, TRIZ, Systematic Innovation and Technical Creativity, Technical Innovation Center, 2000)

Substance Resources

Waste
Raw materials and products
System elements
Inexpensive substance
Substance flow
Substance properties

Field Fesources

Energy in the system
Energy from the environment
Build upon possible energy platforms
System waste becomes system energy

Space Resources

Empty space
Another dimension
Vertical arrangement
Nesting

Time Resources

Pre-work
Scheduling
Parallel operations
Post work

Informational Resources

Sent by substance
Inherent properties
Moving information
Transient information
Change of state information

Functional Resources

Resources space within primary function
Using harmful effects
Using secondary generated functions

5.6.6 Glossary: Contradictions / Effects / Resources

Contradiction
One of the main TRIZ postulates and a decisive factor of an inventive task.
In general, opposed requirements to one and the same object.
Contradictions are divided into Administrative, Technical and Physical Contradictions.

Administrative Contradiction:
We speak about administrative contradiction when it is necessary to do something, but we do not know how to do it.
(contradiction between the needs and abilities)

Technical Contradiction:
We speak about a technical contradiction when we improve one part (or one parameter) of the technical system with the help of known methods, but that entails the worsening of other part (or the other parameter) of the technical system.
This contradiction is a conflict between characteristics within a system: improvement of one parameter of the system leads to worsening of another parameter
(an inverse dependence between parameters/characteristics of a machine or technology)

Physical Contradiction:
We speak about a physical contradiction when we impose mutually opposed requirements to the same parameter on one and the same part of the system.
(opposite/contradictory physical requirements to an object)

Inventive Principles / 40 Principles:
Altshuller identified 40 Principles that could be used to eliminate technical contradictions.

Separation Principles:
For overcoming a physical contradiction, there are four “physical” principles and a database of physical phenomenon and effects.

Contradiction Matrix / Altshuller Matrix
Developed by G. Altshuller.
The matrix suggests Inventive Principles to solve contradictions arising while trying to improve a feature or a characteristic of any product, process or system.

Technical Parameters / Characteristics
Altshuller also identified 39 parameters or characteristics of technical systems that can be used to develop and describe a technical contradiction. With these parameters we can use the Contradiction Matrix.

5.6.7 References - Contradictions / Effects / Resources

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TASKS FOR TETRIS MATERIALS. (IGOR KAIKOV)

Introduction

All of the following tasks are given in a simplified, adapted form. We have chosen as examples the simple technical systems which are familiar to all. We have solved real problems of mechanical engineering that may be used as the educational materials to many of the principles and rules of TRIZ. However, for the purposes of this course, these examples should be subjected to such a significant adaptation and simplification that they may give the students the wrong idea about the substance and the level of complexity of real problems.

We believe that this simplified form, without corresponding descriptions of the problem situation, its transformation from a fuzzy situation into the correctly set problem, is inappropriate and even harmful for the purposes of this course.

In later versions of the given educational textbook we will give real customized production problems with corresponding explanations of the methods of transition from the diffuse situation to the formulation of the problem.

In the present course we limit the description to educational examples. They are analyzed in detail, with comments and tips (help) and possible (test) answers. However, students have freedom to analyze the problem independently and find solutions in accordance with the rules of TRIZ.

Note that as a rule you can come up with the same solution in different ways, using various tools of TRIZ. The tool, which would seem to you personally as most effective, depends on the type of problem, and the level of your knowledge and skills. Ability to use various tools of TRIZ is one of the conditions of success in solving real problems. It is worth to remind, that one of the goal of TRIZ is a theory, is to provide thinking skills such that the problem solver becomes able to create his/her own solving tools.

Inventive problems are nonlinear problems in many senses. Therefore, during solving them, sometimes it is worth a look in the encyclopaedia, reference books, learning more about the history of the development of a technical system...

When you have solved the problem, do not stop there. Think - what are your shortcomings or the disadvantages of solutions suggested by the authors in the textbook? The famous 18-th century French naturalist Georges Buffon (Buffon, Georges-Louis Leclerc, (1707-1788) finished each his article or book with a list of unsolved problems. It gave a fresh and broad perspective on the problem, attracting new researchers, made it easier to take the next step.

Good Luck!

1 Problem (a crash-proof key)

1 Problem Situation

The locks with flat keys that are represented on Fig. 1, 2, 3, are often used in locks of drawers, wardrobes and doors (Fig. 3). The top part of a key, that we hold to turn into a keyhole, is called «a head». The low part of the key that is put into a keyhole in order to open or close a lock, is called «a barb».

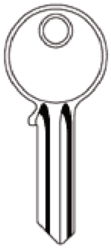

Fig. 1. http://www.ps.com.ua/file.php?id=14u5.gif

Fig. 2. http://keyservice.tomsk.ru/upload/avtorussia.JPG

Fig. 3. http://www.keyservice.ru/pics/keys/

A key is thin, light and takes up little space in a pocket or a bag. However it has a significant disadvantage. If we accidentally hit a key left in a lock, it could break. Then it is difficult to draw a broken part from the keyhole. And besides, it is difficult to unlock a door or a drawer of a table. In this case we have to break a lock, and sometimes things in which it was inserted: a door, a drawer. In order to escape this unpleasant situation, it would be good to have «a crash-proof key ».
Come up with a design of a key that will not brake even at strong pushes. Let the other things as a table or a door, a lock remain unchangeable… It is necessary to modify only a key. And more precise it is necessary to modify «a head» of the key.

* Typical Mistakes (made before the problem solving)

There are some typical mistakes that trainees make when they solve this problem. The most significant mistake is to iterate through the options: and what, if we do so… and if we do otherwise? Do not try to «guess» a solution. Following the rules during the training is more important than to find an answer. The analysis of a problem that is conducted correctly under the rules is more useful and effective than an accidentally found answer. Besides, think over what solutions would be offered by trainees that do not know the rules of TRIZ. Some typical incorrect steps are listed below.

1. Usually it is proposed to make a key with harder materials, as a special steel.
2. To change a key profile, replacing a flat key on a key with a round or another profile that has greater durability/strength. Of course, then it would be necessary to modify a lock.
3. Warning signs to be careful and not to touch accidentally a key, inserted into the keyhole. each time remove the key after the unlocking and locking and not leave it sticking in the lock.

We leave you to find weaknesses of each as a training job. Afterwards, please apply TRIZ rules for your better solution.

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2 Prompt-1

IFR:
The key protects itself from a breakdown in a moment when we accidentally push or touch it with force. However, the key preserves the ability to perform its function – to unlock and close a lock.

3 Prompt-2

Contradiction 1:
The key must be broken, since force is applied to it; and the key must not be broken in order not to change a lock or a door.

4 Tool

IFR
The key protects itself from a breakdown in a moment when we accidentally push or touch it with force. However, the key preserves an ability to perform its function – to unlock and close a lock.

Contradictions:

Contradiction 1:
A key must be broken, since force is applied to it; and the key must not to be broken in order not to change a lock or a door.

Comment 1:
Is a key always broken when we apply force? When we open a door and turn the key into the keyhole, we apply force to it. If force is applied in the correct direction, the key is not broken, and performs its function, i.e. opens a lock. It is necessary to check this Technical System (TS) with the Law of Harmonization (see: LTSE – The Laws of Technical System Evolution).

Contradiction 2:
The key must be broken in order to transform the applied force to the work at an accidental push; and the key must not be broken in order not to change a lock and a door.

Comment 2:
Now, if accidentally applied force does not break the key during a push and turns it into a key-hole, then the key would not be broken, «energy» of the push will not work on a breakage of the key, but on its turn. But it appears a new problem - unwanted closing-opening of the lock under random hits. Sometimes such undesired opening-closing of the lock can be much more dangerous in its consequences than a breakage of the key.
The analysis must be conducted by identifying as many relevant contradictions as possible, in order to have a more detailed profile of the ideal solution.

Contradiction 3:
The key must rotate under random hits to avoid breaks; and the key must not rotate under ran

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dom hits to avoid to open or close the lock.

Contradiction 4:
The key must stick out of the keyhole in order we can use it (to rotate, close and open the lock, remove); and the key must not stick out of the keyhole in order not to be pushed and broken.

Contradiction 5:
The «head» of the key should be long in order to turn the key and open the lock, and the «head» must be short in order not to break the key during a random applied force.

“Tongs” Model

1. IS – Initial Situation description: Undesirable (negative) situation (Negative Effect – NE). What would we like to change?

If you accidentally push a flat key, left in the keyhole, it breaks down. It is essential that a flat key, inserted into the keyhole, does not break at any random push.

2. Imagine that magic wand is in your hand (MDR):
The key itself protects against breakage at a time when we accidentally push, touch it with force. However, the key retains the ability to perform its function - to open and close the lock.

3. Barrier (Contradiction) that prevents us form overcoming the negative effect (NE=IS) and obtain the MDR:
The key is to rotate at a random push in order not to be broken, and the key must not rotate at a random push in order not to open-close a lock in moments of random pushes.

According to the ARIZ logic (chapter 3 of the handbook) it is necessary to identify the operational space and the operational time of the contradiction. Then the separation principles can be applied to overcome the contradiction itself (chapter 5).
Indeed, the conflicting requirements in this case can be separated in space, since different behavioural characteristics of the key are requested, as a function of the direction of the applied force (a torque to open/close the lock, a side force when accidentally hit).
Two inventive principles emerge as relevant to implement the separation:

Inventive Principle № 1: “Segmentation”
A) Divide an object into independent parts.
B) Make an object easy to disassemble.
C) Increase the degree of fragmentation or segmentation of an object.

Inventive Principle № 15: “Dynamics”
A) Characteristics of an object (or outside environment) must be altered to provide optimal performance at each stage of an operation.
B) Divide an object into elements capable of changing their position relative to each other.

5 Possible solution
The «barb» and the «head» of the key are connected by a hinge. When the key is rotated in the lock, the hinge remains unmovable, since the rotation of the «head» and the «barb» fit in this case. They move as a single entity. This result is achieved by means of harmonization, fix cou-

pling of two parts when such force is applied.

However, if we apply force to the «head» of the key, and this force is directed perpendicularly to the axis of the key, the «head» turns over the «barb» on a hinge. The fix coupling of two key parts is absent in this case (Fig. 4).
Compare: the metal bracelet of clocks is bent well in one direction, when the links of the bracelet move relatively to each other on hinges. And it remains hard, if you put your strength so that links are not moved on hinges. (Fig. 5).

Fig. 4. (Photo by Kaikov I.)

Fig. 5. (Photo by Kaikov I.)

2 PROBLEM: AN UMBRELLA. (IGOR KAIKOV)

1 Possible solution

Everyone is familiar with this situation. A big umbrella protects well against rain.
It is also possible that two persons go under one umbrella... But strong gusts of wind turn it inside out. Sometimes they break it. The small umbrella withstands the gusts of wind better,

but protects against rain worse. Certainly, we can make a very big and sturdy umbrella with thick spokes, thick and durable fabric. But it will be difficult and inconvenient to carry the umbrella in this case even for two persons. In such moments it is necessary to keep it firmly in the hands. What can we do? Come up with a new design of an umbrella that will have a big dome and protects well against rain, will not be broken when the strong gusts of wind blow, and is comfortable to carry.

Fig.1

* Typical mistakes (made before problem solving)

- Usually it is offered to «strengthen» an umbrella. Make it more substantial: with thick spokes and a solid fabric. Contrast this solution with the first solution in the previous problem of a crash-proof key (see: Typical Mistakes made before the problem solving). Have you noticed the similarities in the logic? Traditional logic prompts us a bad solution, a solution «in the forehead». The wind could be so strong that the stronger spokes and fabric will not help to escape the problem... The paradox of dialectical logic that is the base of TRIZ is just the opposite. We need to «weaken» the umbrella, make it more pliable, flexible.

- One of the famous solutions is – The SENZ Umbrella – that overcomes partially the problem. «The SENZ Umbrella has been designed to directly fill a need - to prevent a strong wind from turning an umbrella inside out. The SENZ team has redesigned the umbrella to be both stronger and more aerodynamic». (Fig.2)

Fig.2. *http://www.moreinspiration.com/Innovation.aspx?id=1473*

However, this umbrella has a significant disadvantage. The dome of the umbrella has an asymmetric shape. It is necessary to travel with them like a boat, directing its narrow part towards wind. Now according to the inventor, an umbrella is less susceptible to gusts of wind. In addition to the complexity of the use of such umbrella, there are problems with its manufacture. The spokes have different lengths and must be coordinated with an asymmetrical dome during assembly. In addition, the diameter of the manufactured umbrella is of the small size, it's impossible to use it in two persons and the side wind would be undesirable in any case!

- Another kind of ideas for «strengthening» a design of the umbrella is to add additional elements to help the spokes to withstand the pressure of the wind. Of course, use such an umbrella is extremely inconvenient. You have to disclose an umbrella properly (Fig.3).

Fig.3.

- Another famous solution is a flexible dome of the umbrella. During a gust of wind, it is not broken, it turns inside out. But in the inverted position it does not protect against rain. In addition, the owner of an umbrella should return the umbrella dome in the initial state every time after a gust of wind.

- From despair some are ready to «surrender» to a task and say: let's make the umbrella of such size that protects against rain a bit and does not break when the weak wind blows. And in the rain and strong wind, we'll stay at home ... For some, this decision may be good. But not for us!

Prompt-1

IFR:

An umbrella protects itself against the gusts of wind, does not worsen its function to protect against rain without the design complexity.

3 Prompt-2

Contradiction 1:

An umbrella must be large in order to defend from rain well.

But an umbrella must be small in order to prevent that wind breaks it up.

Contradiction 2:
An umbrella must have holes to prevent that wind breaks it up.
But an umbrella must not have holes in order to defend from rain well.

Contradiction 3:
An umbrella must have a special form in order to be protected from wind gusts, and the umbrella must have a normal shape to make it easier to produce.

Contradiction 4:
An umbrella must be specially shaped in order to be protected from wind gusts, and an umbrella must have a normal form, the form of a hemisphere, in order to protect from rain uniformly.

4 Tool

IFR:
An umbrella protects itself against the gusts of wind, does not worsen its function to protect against rain.

"Tongs" Model

1. IS – Initial Situation description: Undesirable (negative) situation (Negative Effect – NE). What would we like to change? :
A big umbrella protects well from rain. But the strong gusts of wind turn it inside out. But sometimes they break it. A small umbrella withstands gusts of wind better but protects against rain much worse.

2. Imagine that magic wand is in your hand (MDR):
The umbrella protects a person from rain well and is not broken by the gusts of wind.
The umbrella protects itself against the gust of wind, does not worsen its function to protect from rain.

3. Barrier (Contradiction) that prevents us form overcoming the negative effect (NE=IS) and obtain the MDR:
A large dome of the umbrella acts as sails in the gusts of wind; i.e. the wind gusts directed inside the dome of the umbrella, are the most dangerous. Indeed, they turn the umbrella inside out and break it. The external wind gusts «slide» along an umbrella.

4. Follow the ARIZ steps, or at least its intrinsic logic, to analyze the contradiction by identifying the operational zone, the operational time, the available resources and search for separation opportunities.
Follow the steps 1-3 of ARIZ as described in section 3 and then apply the separation principles as described in section 5.

Let's examine some inventive principles applied to the present contradiction.

Inventive Principle № 1 "Segmentation"

A) Divide an object into independent parts.
B) Make an object easy to disassemble.
C) Increase the degree of object fragmentation or segmentation.

Comment
We examine the contradiction 1: an umbrella is big – small. The following idea arises: To divide the umbrella into two umbrellas, for example, to use two small umbrellas rather than a big one (Fig.4). The obvious drawback of this solution is the inconvenience in use.
Similarly, we should consider that two knives are not scissors yet.

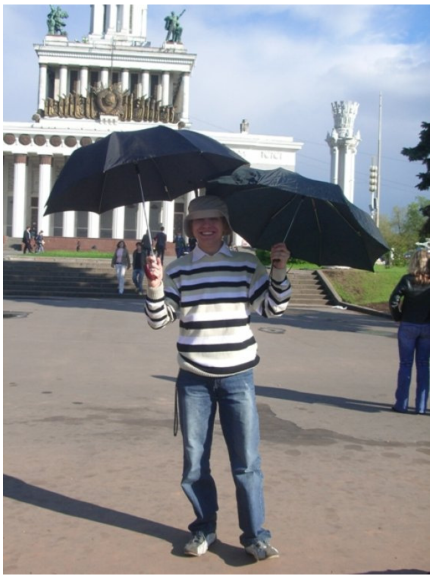

Fig. 4. How to use two small umbrellas instead of one big?
http://www.dvorec.ru/reg/foto/11455_1153293970.jpg

Inventive Principle № 15 "Dynamics"

A) Characteristics of an object (or outside environment) must be altered to provide optimal performance at each stage of an operation.
B) Divide an object into elements capable of changing their position relative to each other.

Comment
We examine the contradiction 1: an umbrella is big – small. The following idea arises:
It rains constantly, so as long as it rains, the umbrella must be open. The gusts of wind blow inside the umbrella periodically. During a gust of wind the umbrella turns into a small, after the wind has passed, it turns into a big umbrella.

Inventive Principle № 21 "Rushing Through" (Skipping)
Perform a harmful and hazardous operation or its stages at high speed.

Comment
We examine the contradiction 1: an umbrella is big – small, and the contradiction 2: an umbrella has a hole to drain off a gust of wind and does not have a hole to protect from the rain. The following idea arises:

The hole occurs only when a gust of wind blows. The wind itself opens a «window». There is a new challenge: how can we protect ourselves from the rain during the opening of the hole? Although the time during which the hole in the umbrella is opened is small, during this time interval there is no good protection from the rain.

Comment
This is a very important point. Some problems are solved in two steps. We have found a way of draining off a gust of wind from the inside of the umbrella dome, but we do not know how to protect ourselves from the rain at this point. This situation is already described in the form of the contradiction, it is important to find a way to resolve the contradiction.

Inventive Principle № 22: Convert Harm into Benefit ("Blessing in disguise" or "Turn lemons into lemonade")

A) Utilize harmful factors – especially environment – to obtain a positive effect.
B) Remove one harmful factor by combining it with another harmful factor.

Comment
We examine the contradiction 2: an umbrella has a hole to drain off a gust of wind and does not have a hole to protect from the rain. The following idea appears:
A gust of wind creates excessive pressure inside the dome of the umbrella. The flow of air does not allow that drops of rain penetrate inside through the hole in the dome of the umbrella.

Inventive Principle № 25 "Self-service"

A) An object must service itself and carry out supplementary and repair operations.
B) Make use of waste materials and energy.

Comment
We examine the contradiction 1: an umbrella is big – small, and the contradiction 2: an umbrella has a hole to drain off a gust of wind and does not have a hole to protect from the rain. The following idea arises:
The umbrella of large diameter has a hole in a form of valve. In a normal position the hole is closed. At the moment of a wind gust the air flow opens the valve in this hole. After passing of the air flow the valve closes automatically, for example, under the weight of the valve cover. The valve can be made in the form of cloth, imposed on the hole.

5 Possible solution

The dome of the umbrella consists of two parts, superimposed on each other with a little overlap. A gust of wind creates an excessive pressure inside the dome of the umbrella. The edge of the upper part of the umbrella dome rises over the lower part, draining off the air. The gust of wind ITSELF opens this kind of valve in the umbrella dome.
At the time when air passes through the umbrella becomes «an umbrella with a hole». The raindrops can not get into the space under the umbrella, because the excessive air pressure prevents it.

After the flow of air gust through the umbrella, the fabric of the upper part of dome falls under its own weight and re-adheres to the bottom of the dome, forming a coherent whole. The drops of rain, falling down the umbrella, can not get into the space inside the umbrella, since the upper part of the dome covers the edge of the lower part of a couple of centimeters. (It is like the tiles on the roof of the house). See Fig. 5 – Fig. 8.

Fig.5. *(Photo by Kaikov I.)*

F ig.6. *(Photo by Kaikov I.)*

Fig.7. *(Photo by Kaikov I.)*

Fig. 8. *(Photo by Kaikov I.)*

INNOVATIVE CONNECTING ROAD FOR HIGH PERFORMANCE ENGINES

Preliminary note

The present exercise has been inspired by a case study related to an activity carried out by Gaetano Cascini and Francesco Saverio Frillici in favour of SCAM srl (Italy) during the summer of 2006. Some details have been therefore omitted.

Introduction

A connecting rod for 4 strokes engines is basically constituted by three subsystems (fig. 1): the stem with a small "eye" at its narrowest end where the piston pin is inserted; the "hat", a semi-circular part that, together with the wider end of the stem, constitutes the "big eye" where the connecting rod is mounted on the engine shaft; 2 screws that fix the hat on the stem.

A connecting rod is subjected to fatigue loads, due to alternating inertia loads and gas pressure in the combustion chamber. As a consequence, the screws must support a highly variable normal stress and in high performance engines (e.g. Formula 1) constitute one of the weakest points of the overall system.

During the last decade relevant improvements have been obtained thanks to special steel and titanium alloys tailored to support fatigue loads with high strength and low fragility. Within this trend, a niche market of special steel screws for extreme loading conditions has grown and 2-3 main producers share the world market. As a consequence these companies can arbitrarily define the price of the screws.

A small competitive firm producing shafts and connecting rods for race engines is clearly not able to sign exclusive supply agreements with the above mentioned screw producers, because of reduced production volumes. Besides, the biggest competitors have higher chances to sign exclusive supply agreements. As a consequence there's the necessity to radically change the structure of a connecting rod.

It is worth to mention that due to external constraints it is not possible to build a one-piece connecting rod, by mounting it on a multi-parts shaft. It is also evident that, due to the special destination of the connecting rod, reducing weight is the most important requirement to be satisfied.

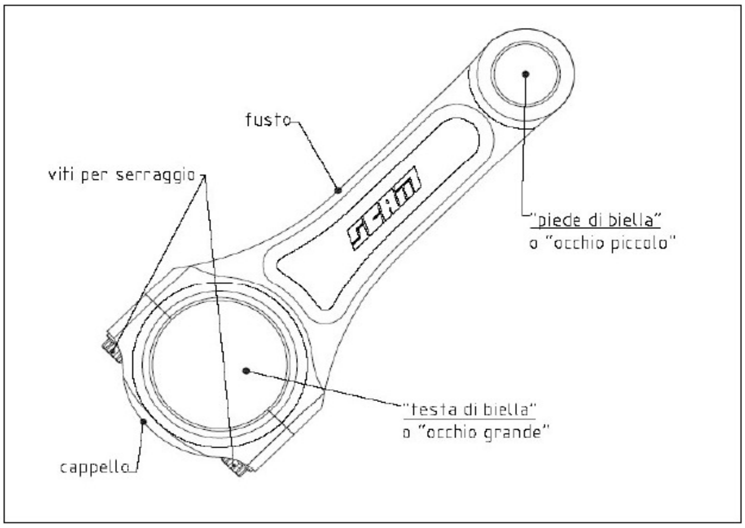

Fig. 1 – Connecting rod for 4 strokes engines.

Since the system is very simple, a functional analysis doesn't provide a clear view of the design choices behind each detail. Nevertheless, by taking into account the design parameters, several contradictions can be identified. Among them, a step by step ARIZ analysis has been performed to the following.

ARIZ-85C, step 1.1

- TC-1: if the connecting rod is equipped with small/light screws that join the stem and the hat of the connecting rod, then the screws are submitted to fatigue stress that overcome their maximal strength.
- TC-2: if the connecting rod is equipped with screws capable of supporting the fatigue loads acting on the connecting rod, then their weight exceeds the maximum acceptable value.

ARIZ-85C, step 1.2

The technical contradiction above involves the following conflicting pair:

- Tool: the screw(s)
- Product: the connecting rod

ARIZ-85C, step 1.3

In Fig. 2 conflicts TC-1 and TC-2 are depicted, by representing the excessive weight of the screws as an own harm, even if it should be better represented as an inertia overload (harm) on the overall system.

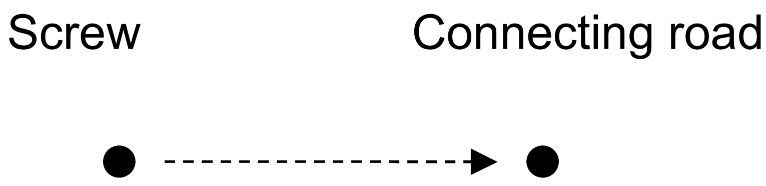

Fig. 2a – ARIZ-85C - Step 1.3: TC1

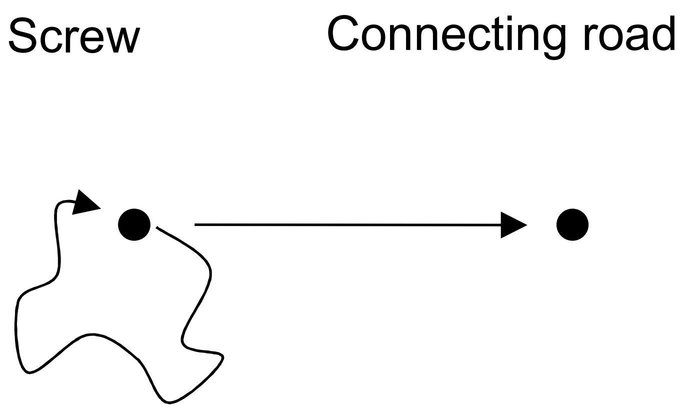

Fig. 2b – ARIZ-85C - Step 1.3: TC2

ARIZ-85C, step 1.4
TC-1 was chosen as the side of the contradiction to act on, since it is closer to ideality (no weight).

ARIZ-85C, step 1.5
Intensifying this conflict leads to the elimination of the screw: if the connecting rod is equipped with the lightest/smallest screw, i.e. no screw at all joining the stem with the hat, then the screws are not able to support any load.

ARIZ-85C, step 1.5
Thus, the problem model can be summarized as follows:

- the conflicting pair is constituted by the screw and the connecting rod;
- the absent screw doesn't add any weight to the system, but is not able to support any load;
- It is necessary to find an X-component/field/property, which would support the loads action the connection rod, without adding weight to the assembled connection rod it-self.

ARIZ-85C, step 1.7
The above described problem can be preliminarily approached by means of the Inventive Standards.
Indeed, in the intensified form of the conflict, we have an incomplete S-F model with just a Substance (the connecting rod). Thus, Standard 1-1-1 should be applied.
Due to the nature itself of the system and the impossibility to radically change its structure, a Mechanical Field interaction should be kept.
Indeed, the opportunity to substitute the screws by fixing together hat and stem (e.g. welding, mating with interference) was properly considered, but finally discarded due to other system requirements.

ARIZ-85C, step 2.1
The operational zone where the conflict arises is constituted by the "big eye", i.e. the portion of the connecting rod aimed at being connected with the engine shaft.

ARIZ-85C, step 2.2
The intervals when the connecting rod is subjected to traction loads (T1'), the time when it is subjected to compression loads (T1'') and the time when the connecting rod is mounted on the shaft (T2) constitute the operational time.

ARIZ-85C, step 2.3
The main internal resources can be identified:

- System resources: stem, hat, screws with their shapes, geometrical position/orientation, material etc;
- Subsystem resources: the small eye, head of the screw, thread of the screw;
- Supersystem resources: piston pin, piston, shaft.

ARIZ-85C, step 3.1
IFR-1: An X component, without complicating the system, and without causing harmful side effects (mainly exceed maximum weight) join together stem and hat of a connecting rod under traction (T1') and compression (T1'') loads, by forming a stable closed eye to be connected to the engine shaft and preserves the connecting rod ability to transmit forces.

ARIZ-85C, step 3.2
Then, the Ideal Final Result can be consequently intensified, by avoiding the introduction of any new substance/field and applying as the X-component the resources identified at step 2.3, primarily the resources of the tool itself.

The IFR can be reformulated accordingly:

- the screw size/shape/position, without overcoming its admissible weight, join together stem and hat of a connecting rod under traction (T1') and compression (T1'') loads, by forming a stable closed eye to be connected to the engine shaft and preserves the connecting rod ability to transmit forces;
- the stem/hat is shaped so to allow the adoption of light screw(s) capable of joining together stem and hat of a connecting rod under traction (T1') and compression (T1'') loads, by forming a stable closed eye to be connected to the engine shaft and preserving the connecting rod ability to transmit forces;

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ARIZ-85C, step 3.3
At macro level, the physical contradictions can be expressed by analyzing the preferred state/ value of each physical parameter of the above listed resources.

Among the others, the following physical contradiction was selected:

- the screw during T1' and T1'' should be positioned orthogonal to the axis of the connecting rod in order to avoid to be submitted to fatigue loads and should be positioned parallel to the axis of the connecting rod in order to fix together the stem and the hat of the connecting rod and to transmit its forces properly.

ARIZ-85C, step 3.4
The physical contradiction at micro-level can be formulated as follows:

- during T1' and T1'' there should be force transmitting particles (in this case it is worth to consider the particles of a field, not just of a substance) so that a screw orthogonal to the axis of the connecting rod fix together the stem and the hat of the connecting rod and there should not be force transmitting particles so to avoid fatigue loads on the screw itself.

ARIZ-85C, step 3.5
The big eye of the connecting rod should contain force transmitting particles so that a screw orthogonal to its axis fix together the stem and the hat of the connecting rod itself without applying fatigue loads to the screw.

ARIZ-85C, step 3.6
The last formulation of the physical contradiction triggers a conceptual solution even without applying any inventive principle, just by translating the IFR-2 into a structure. The connecting rod is reshaped so that the mating surface of stem and hat becomes parallel to its axis; consequently, a screw orthogonal to its axis fix them together and due to its placement orthogonal to the force direction is not submitted to fatigue loads. Thus traditional steel alloys can be adopted even reducing the size of the screw itself.

The solution is almost depicted, but still a clearer definition of the way to transmit forces between the big eye and the small eye must be conceived.
With the aim of submitting the screw just to a static normal load, avoiding shear (both static and alternating!!) we have to introduce something new in the system.
A mechanical designer will quickly visualize numerous possible structures fulfilling this task. In our case the introduction of a hinge was proposed as depicted in fig. 3.

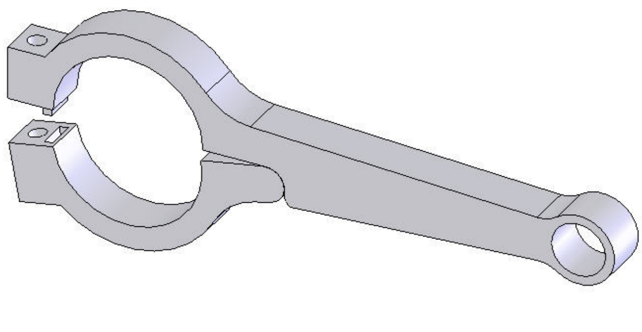

Fig. 3 ***– Initial solution: the screw fix the big eye of the connecting rod, but is not subjected to fatigue loads.***

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Indeed, the introduction of a new substance (the hinge) increases the complexity of the system.
In other words the hinge should be there, in order to assume the role of transmitting forces between the big eye and the rest of the connecting rod, but should not be there in order to reduce the complexity of the system.

With the same logic followed between steps 3.1 and 3.2, instead of introducing new substances, it is suggested to adopt available resources.
Among the available resources identified at step 2.3, the pin of the piston can be used as the

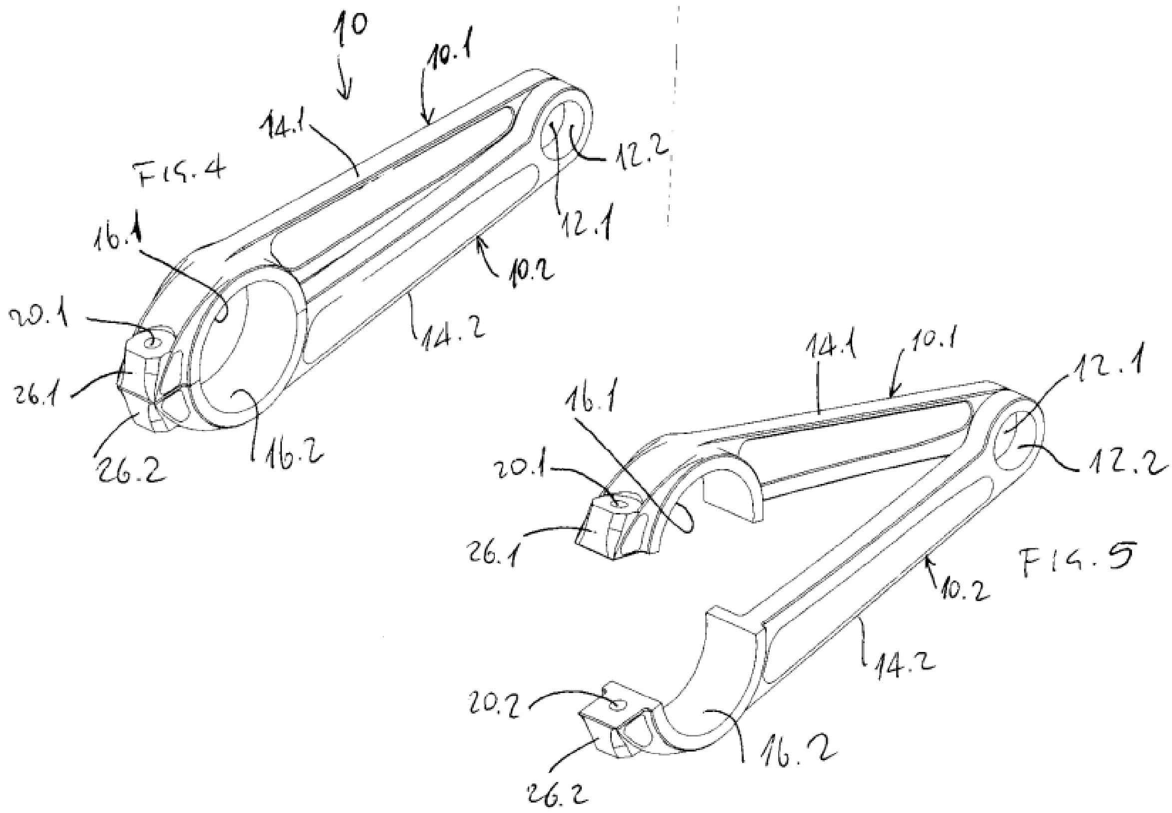

Fig. 4 – Solution evolved according to an increased use of available resources. The final connecting rod is 12% lighter than the original one and its screws are subjected to fundamentally static loads instead of alter-

Conclusions

The final solutions allowed the development of a new generation of connecting rods for race engines: with a lightly more complicated assembly process (indeed a negligible drawback in this specific field), a double relevant advantage was reached: the connecting rod is 12% lighter than the original one thanks to the reduced mass of the stem allocated to screw containment; moreover, traditional steel screw can be adopted instead of special alloys thanks to the absence of fatigue loads.

How many times have you seen ballpoint pens, in a pocket or into a bag, leaking their ink and causing a big stain! The ball of the pen tip lets pass ink even when it is not requested, so producing the harmful effect. Let's try to solve this problem with the instruments offered by TRIZ.

The first step toward the solution is choosing the right problem to solve: for this aim it is helpful to adopt a system thinking approach, i.e. to use the System Operator (paragraph 1.3.3.5). The starting point is the definition of the reference box of the schema, that sets the detail level and the time of the system and of the problem we want to describe, and from which all the others boxes result. The problem is very simple: we have a pen that dirties some cloth or fabric in general; this could be a good choice for the central box of the nine screens. The relative question will be: how can the elements of the system, which are the pen and the cloth or fabric, make that the ink doesn't stain? The others boxes as completed as represented in figure 1.

Elements: Other pens, other cloth, user, environment, ... **Question:** How can other pens, other cloth, user, environment, …, avoid the ink leakage?	**Elements:** Other pens, other cloth, user, environment, ... **Question:** How can other pens, other cloth, user, environment, …, avoid that the ink leaked from the pen tip reaches the cloths?	**Elements:** Other pens, other cloth, user, environment, ... **Question:** How can other pens, other cloth, user, environment, …,avoid that the ink on the cloth doesn't leave any stain?
Elements: Pen, fabric **Question:** How can pen and fabric avoid the ink leakage?	**Elements:** Pen, fabric **Question:** How can pen and fabric avoid that the ink leaked from the pen tip reaches the cloths?	**Elements:** Pen, fabric dirty **Question:** How can pen and fabric dirty avoid that the ink on the cloth doesn't leave any stain?
Elements: Ball, ink, tank, point, stylus, pen tip, fabric fibers, ... **Question:** How can the ball, ink, tank, point, …, avoid the ink leakage?	**Elements:** Ball, ink, tank, point, stylus, pen tip, fabric fibers, ... **Question:** How can the ball, ink, tank, point, …, avoid that the ink leaked from the pen tip reaches the cloths?	**Elements:** Ball, ink out from the pen, tank, point, stylus, pen tip, dirty fabric fibers, ... **Question:** How can the ball, ink out from the pen, tank, point, …, avoid that the ink on the cloth doesn't leave any stain?

Fig. 1: Searching for roundabout problems: System Operator completed

As you can see, the *past* column, that of the prevention opportunities, represents the time before the ink comes out from its tank so the problem becomes how to stop the ink inside; from the *present* column, standard solutions as a pen cap or a retractable pen tip could be suggested; while on the right column (*future*), i.e. of the mitigation of the problem, the question concerns how to transform a problem into a no-problem, thus even if the ink came out from the pen it doesn't produce any undesired effect.
The next step is choosing the right problem to solve: for example we can consider the subsystem past as the starting problem because we have a lot of possible subjects able to solve it, and it is better to prevent some problems than to try to solve them when they are already happened. So it is useful to build a functional model of this initial situation.

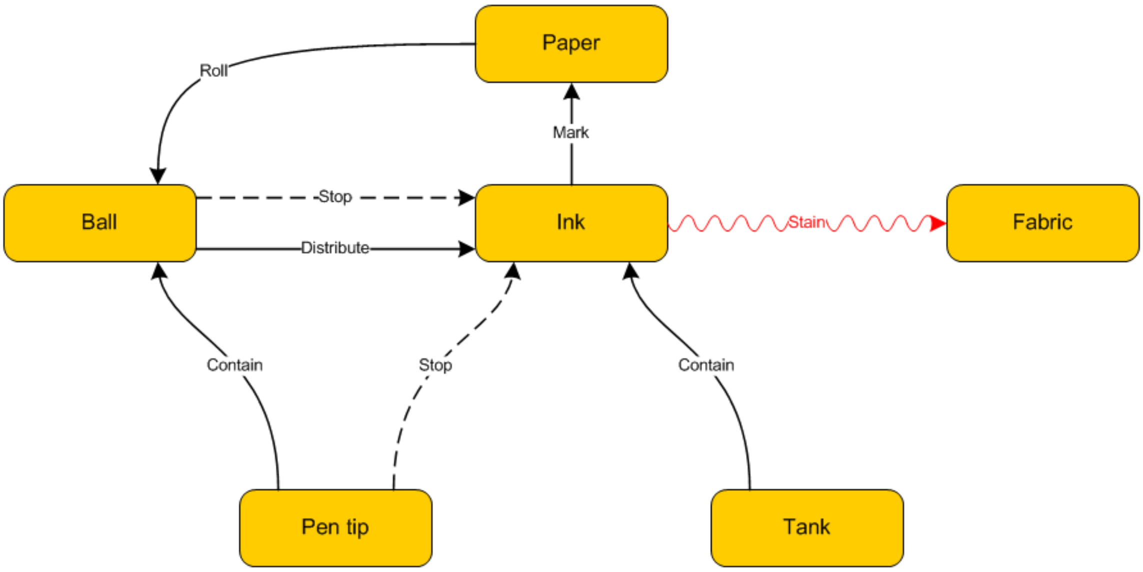

Fig. 2*: Functional model describing the situation in the Sub-System Past box of the System Operator*

As you can see there are three critical functions: two insufficient and one harmful that is the main problem to solve. At this point we can formulate the IFR of the situation, starting from the element that causes the harmful function, the ink. ARIZ (chapter 3) suggests that this element, by itself and without worsening the system, at the time requested, solve the problem generated; in our specific situation this becomes: the ink, by itself without worsening the pen, when writing isn't needed, avoids coming out from the tank. This is our goal, our best result even if it could seem slightly fanciful. Now we have to ask why it is not possible to reach the IFR, taking into consideration all the available resources we have, in order to find one or more contradiction to be solved. Focusing the attention on the ink, one of the cause of its leakage is the ink fluidity: in fact if the ink wasn't liquid, it won't leak from the tank and so it won't cause the stain, but the main useful function won't be developed any more, or not as well as we want. We have a contradiction, as represented in figure 3.

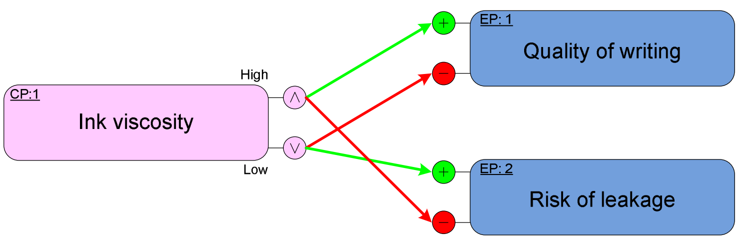

Fig. 3: the OTSM contradiction model (paragraph 5.1.2)

We can represent the two sides of the contradiction also with a functional model, in order to see which element and sub-functions of the system are involved by the modification of the control parameter.

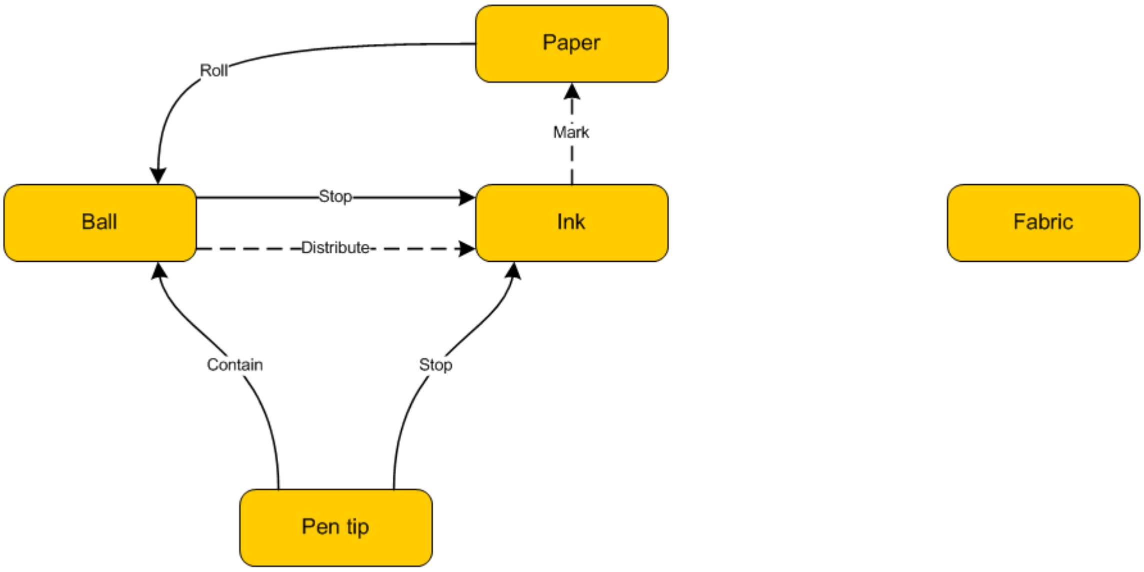

Fig. 4: Functional model with the CP "ink viscosity" at the opposite value than actual

Now we can try to solve this contradiction starting from the definition of Operational Zone and Operational Time. The Operational Zone can be considered as the sum of the external surface of the ball, the internal surface of the point, the amount of ink near the ball, the rest of the ink into the tank and the surface of the paper. While the Operational time is the interval when the ball rolls, i.e. the time when we want to write, and the period when the ball doesn't roll, i.e. when we don't want to write. The next step, following ARIZ suggestions, is the exaggeration of the conflict: to overcome some psychological barriers it is needed to bring the opposite values of the Control Parameter in contradiction at their extreme, thus the ink viscosity must be imagined as infinity or equal to zero. What does it mean an infinity viscosity? We can translate it as the ink wasn't fluid anymore, i.e. the ink is solid. This could suggest to the use of a pencil instead of a pen. On the other side we have to imagine a viscosity very low almost zero, i.e. as a gas. We can imagine a mixture of a transparent alcohol with solid particles: the alcohol evaporates in contact with air and the solid particles create a stopper on the point for the rest if the ink.

Other solutions could be suggested by the application of the Separation Principles (paragraph 5.3). Start with the separation in time. Is it true that a high value of the viscosity is needed in the whole operational time, and a low value of the viscosity is required during the whole operational time? It is obvious that the answer is "No", so we can apply the separation principle. We would desire a high value of ink viscosity when the ball doesn't roll in order to prevent accidental leakage of ink, and we want a low value of ink viscosity when the ball rolls, so when the pen is writing. Any idea? Let's continue…

To apply the separation in space we have to answer "No" also to this question: is it true that we need a high value of ink viscosity in the whole operative zone, and we want a low value of this viscosity in the whole operative zone? This time the answer is "Yes", so we can't separate in space.

The third principle is that of the separation on condition: in which condition do we want a high ink viscosity, and in which one do we want a low viscosity? If the pen is writing, i.e. if the pen is moving, we need a low ink viscosity, while if the pen is still viscosity has to be high. Is it possible to change viscosity with movement? Taking into consideration the Effect Database, a tool of the TRIZ Knowledge Base, we can find that some fluids could have a property called "tixotropy": if some kinetic energy is provided viscosity of the fluid decreases, and it increases again if the fluid is still. In lifetime we use a lot of substances with this property: toothpaste, honey, ketchup and paint. Even if this could be a strange solution, one of the famous brands of ballpoint pen uses this kind of ink (see figure 5).

Fig. 5: the famous pen with tyxotropic ink

Now if we take into account again the functional model represented in Fig. 2, at the left side there are two insufficient functions: the ball and the point doesn't stop in a sufficient manner the ink. Why? What are the Control Parameters responsible of this failure? Among the others, one CP, that could be the same for both the functions, is the clearance between the pen tip and the ball: if it is too large, the ink could leak also when the pen is not writing. But what happens if the clearance is close? The ink doesn't come out any more, but probably the ball is no more able to distribute in a sufficient way the ink when it is requested and so the writing is no more fluent as before. So we have another contradiction, represented in Fig. 6.

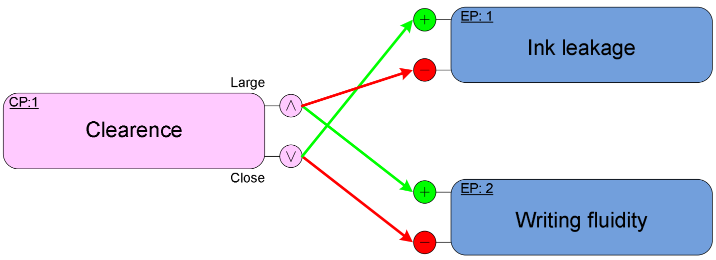

Fig. 6: *the OTSM representation of the contradiction*

As already seen before we have to define the Operational Zone and the Operational Time of the contradiction: the first one is the sum of the internal surface of the pen tip and the external surface of the ball; while the Operational Time could be considered as the sum of the period when the ball is rolling and the period when it is still. The next step is the exaggeration of the conflict: how is it possible to write with the ball stuck to the point (clearance equal to zero)? Or how can we imagine a very large clearance between the ball and the point? For example we can trim directly the ball and to let completely open the channel within the point. Try to think some solution starting from these suggestions.
Now the Separation Principles are the tool to apply to solve the contradiction. The first one is that on time: is it true that the clearance is needed large and close during the whole operational

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time? The answer is “No”, because we need a large clearance when the ball is rolling, i.e. when the pen is writing, and a close one when the ball is still. How can we realize this separation? For example if a spring is put behind the ball, when the user pushes the pen on the paper the ball goes back creating a bigger clearance, and when the pen is not writing the spring pushes the ball against the cone of the point closing the clearance and so the ink cannot come out (see Fig. 7).

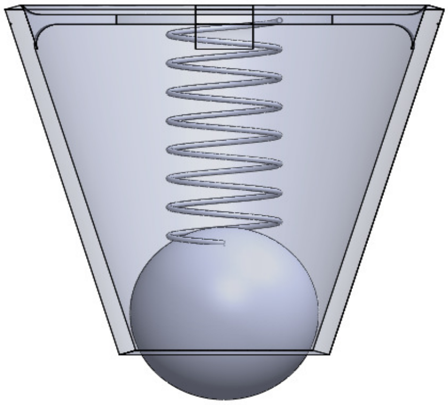

Fig. 7: a schematic model of the proposed solution

Such a preliminary concept can be further evolved by analyzing with a System Operator approach which resources already available within the system can play the role of the spring (e.g. thanks to internal elasticity?).

To apply the second separation principle (i.e. separation in space), the question “is it true that we want a large and close clearance in whole operational space?” must have a negative answer. This time yet, the answer is “yes”, so we can’t apply the separation principle.
We can apply neither the third separation principle, because there aren’t any different conditions in which it is better to have a large clearance than a closer one.
The fourth principle is that in system level, or macro to micro level: how can we have macroscopically a large clearance and microscopically a close one? Or better vice versa: can we have at macro level a closer clearance and at micro level a larger one? A possible way to reach this situation is to have a ball realized as a golf ball, i.e. a ball with some cavities on the surface: the diameter of the ball close any clearance with the pen tip and so the ink couldn’t leak, but if ball is rolling the cavities carry the ink from the tank to the paper so the pen could normally write.

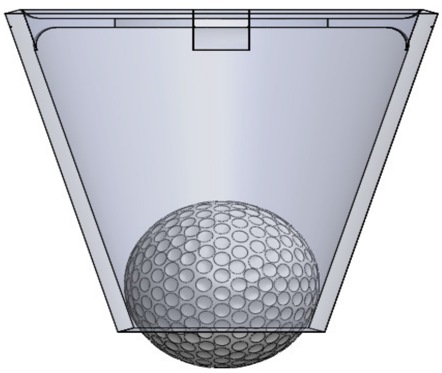

Fig. 8: the suggested solution – a cross-section of the point and the golf like ball

We are in winter, near a small town on the top of a mountain. In night time, air is very chilly and temperature goes below 0° C. Under this conditions the moisture of the air freezes and ice covers everything, including the high voltage cables. Besides, sometimes it snows, and the snow fallen down accumulates on the wires. If the snow is melted by the sun, then it turns on ice during the night. Day by day, the layer of ice grows, and its weight stretches the wires that could be broken. If this happens, people in the village have no power in their houses until the damage is repaired. So a solution is needed for the society providing power.

Fig. 1: *Electric wires covered by ice*

The first proposed solution was to increase the diameter of the copper wires, but it is known that the copper is very expensive and it would be necessary to replace the whole electric line. Another solution would be burying all the cables underground in order protect them, but the investment wouldn't be paid by the small town as well as doubling the number of pylons supporting the wires.
One of the technicians suggests exploiting the heat generated by Joule effect by the wires; nevertheless, it would be necessary to increase the intensity of the current, which would imply an increment of energy consumption.

A non standard solution must be found, let's follow a TRIZ-based problem solving process.

When it is not clear how to solve a problem or which is the problem to solve, the first TRIZ tool to use is the System Operator (paragraph 1.3.3.5), that allows choosing the right problem analyzing the initial situation also from a temporal point of view or in a cause-effect chain. We have to start with the definition of the reference box (*system present)*. It is not significant which is the level of detail or the temporal stage chosen as starting box; besides, it is extremely important to perform a consistent analysis while searching for roundabout problems in the other boxes.
We have the initial problem, that is a lot of ice forms on electric wires and this produce wires broken; so we can choose this scene as central box of our system operator and the elements to

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list will be only wires, ice and current, and we have to consider this question: how can the elements of the “system present” counteract the harmful action of the ice on the wires? Now we can complete the scheme as represented in figure 2.

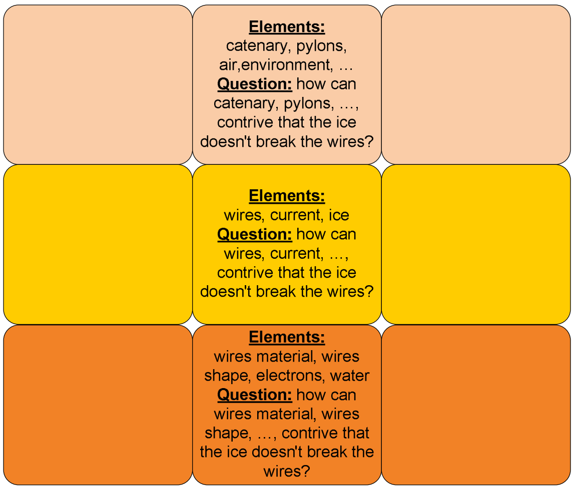


Fig. 2*: search for roundabout problems: present column of the system operator*

Remember that all the boxes on the same column are characterized by the identical “temporal frame”, while the boxes on the same row represent the identical system level; it is worth to remember that each column is characterized by the same problem/question, while subjects, i.e. the resources to solve it, change.
Focusing the attention on a column on the left side of the matrix (past) means looking at prevention opportunities: the time of the left boxes is when the big amount of ice is still not formed, but it is in the form of water, snow or humidity and obviously a thin layer of ice.
Vice versa, moving the attention towards the right side of the matrix (future) means admitting that the problem in the present column has not been solved, and a compensative approach should be searched in the future. In this case, on the right column, it is assumed that ice has broken the wires.
As a consequence, different questions/specific problems are associated to the different cells of the System Operator matrix. The completed schema is reported in figure 3. It is worth to notice that in a general situation the System Operator can be constituted by more than 9 boxes, since each subsystem can be further divided in sub-subsystems, each time frame has a past and a future etc. It is suggested to stop the analysis when the question brings to expected tasks out of the business/role of the problem solver (e.g. how to avoid a change of the weather condition?).

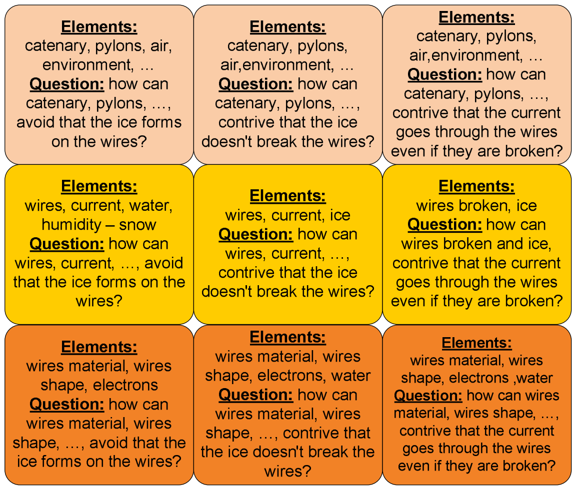


Fig. 2: Searching for roundabout problems: System Operator completed

Now we have to choose among nine (possibly more) different specific problems, all aiming at the achievement of the same final goal: supplying the inhabitants of the small city in the mountain with a regular electric power service.
Let's start from the central box.
To better understand how the system works, and how the problem appears, it is useful to build a functional model of the system under the operating conditions corresponding to the selected box of the System Operator.
In this case, the model will be very simple since we have just a few elements. We have to start with representing the useful function (u.f.) of the system: the wires drive or conduct the current. Then we could add all other elements present which take part to the u.f. or are consequences of it, and eventually those who produce or take part to the harmful function, i.e. ice breaks wires. When we have listed all the elements, we have to consider all the actions performed each other. The result is presented in figure 4 .

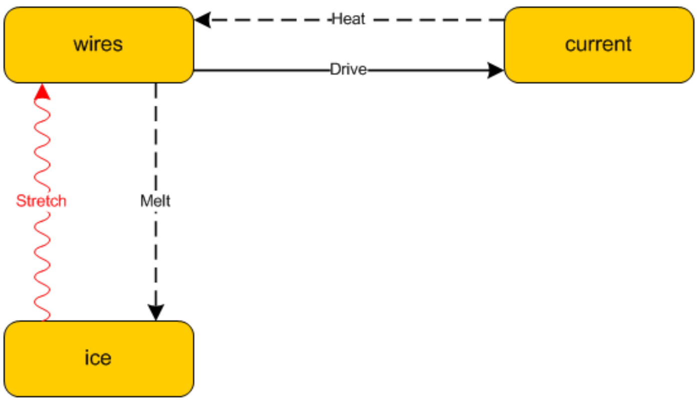


***Fig.4:** Functional model describing the situation in the System Present box of the System Operator.*

To avoid the ice breaking the electric cables, we can use the heat generated by the current, despite it is not sufficient to melt ice. So we can imagine to increase current intensity in order to increase the Joule effect and so the temperature of the wires. Now we have to build a functional model under the assumption of a high current flowing through the wires (figure 5).

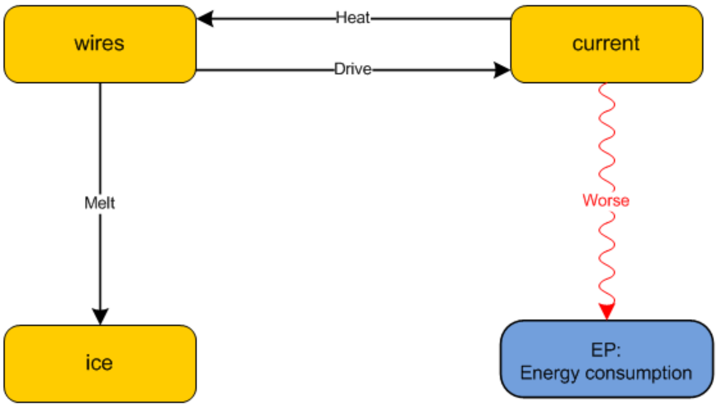


Fig. 5: *Functional model of the system when a high current is applied to the electric line.*

As represented in figure 5, a high current doesn't cause directly a harmful function on some element, but simply the worsening of an evaluation parameter. So we have a contradiction: in fact if the current intensity has a high value the problem with ice is solved, but a harmful function appears towards energy consumption; besides, if the electric current is low, the heat generated by Joule effect is not sufficient to melt the ice. The model of this contradiction is represented in figure 6.

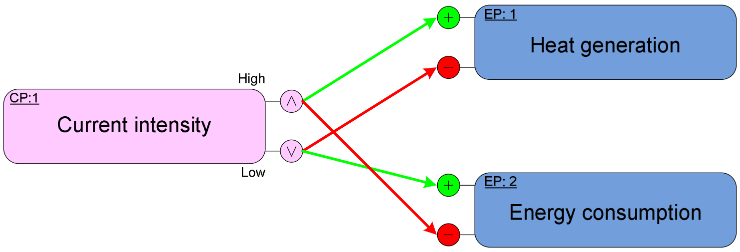
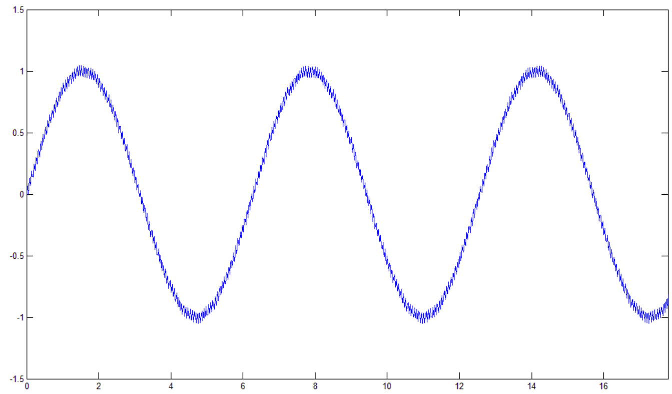


Fig. 6*: the OTSM model of a contradiction (paragraph 5.1.2)*

Following the steps suggested by ARIZ (chapter 3) Operational Zone and Operational Time must be identified.
The Operational Zone can be considered as the sum of the external surface of the wires, the surfaces of ice in contact with them and the section of the wires where current passes through. While the Operational Time is the interval when the ice stretches wires the ice starts forming and during the electric current transmission.
Now, as explicated in paragraph 5.3 of the TETRIS handbook, we can apply the Separation Principles to solve the physical contradiction. The first one is the separation in time: we can apply this principle if the following question has a negative answer: is it true that we want an high value of the current during the whole operational time, and we want a low (normal) value of the current during the whole operational time? It is clear that the answer here is "No!"
In fact, we need extra currents only when the ice stretches wires, and normal current during the rest of time. Which are the resources of super-system or directly available able to change current intensity according to mechanical stress on wires? Moreover a new problem appears: how is it possible to measure the wires mechanical tension or an overload so as to change the current intensity? Possible solutions could be found using the Class 4 of the Standard Solution (chapter 4).
The second principle for overcoming physical contradictions is separation in space. Similarly to the previous one, the principle is relevant in the specific situation if the following question has a negative answer: is it true that we want a high value of the current in the whole operational zone, and we want a low value of the current in the whole operational zone?
Indeed, a high value of the current is needed only on the surface of the wires in order to heat them and to melt ice, while a normal (low) value of the current is required in the rest of the section of the wires to feed the town and avoid energy waste.
What kind of resources do we have within the system, or easily accessible from the super system, to create a different value of the current density on the surface of the wires and in their internal section?
If the personal/team knowledge is not sufficient to answer to this kind of question, we can take into consideration another tool of the TRIZ knowledge base, the Effects Database (paragraph 5.6.4), where we can find the *skin* or *surface effect*, according to which if the alternate current has a high frequency its density near the surface of the wire is greater than at its core.

Therefore we can heat the wires only where we really need without an excessive consumption of energy, by superimposing a high frequency small intensity current on the regular 50-60 Hz power supply.



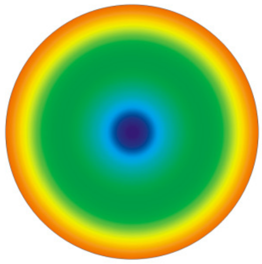


Fig. 7: *left – the main sinusoidal wave of the AC current with the overlap of the high frequency additional current; right – the current density distribution in a cross section of the wire*