TRIZ and Innovation Management

Dr.-Ing. Pavel Livotov

Innovative Product Development and Theory of Inventive Problem Solving

Pavel Livotov, Ph.D.,
author of more than 70 patented inventions and 30 publications,
TRIZ experience since 1981,
co-founder and member of the Executive Board of the European TRIZ Association ETRIA.
Founder and General Manager of TriSolver Consulting and TriS Europe GmbH
E-mail: p.livotov@tris-europe.com

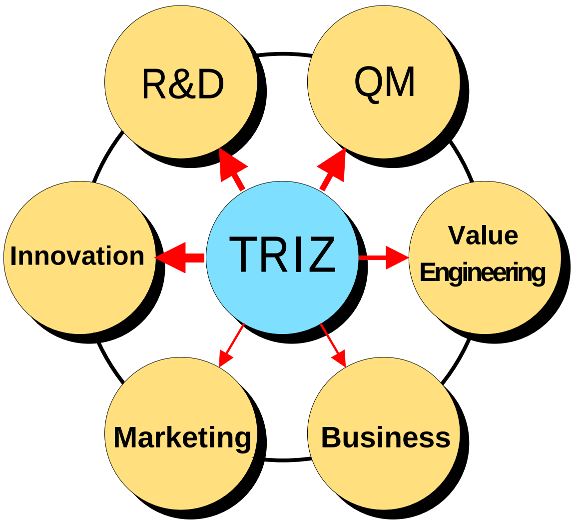
Content

Preface

TRIZ innovation technology is regarded today as the most comprehensive, systematically organized invention knowledge and creative thinking methodology known to man.

TRIZ has the following advantages over traditional innovation supporting methods:

- Marked increase in creative productivity.
- Rapid acceleration in the search for inventive and innovative solutions.
- Scientifically founded approach to the forecasting of the evolution of technological systems, products and processes.



[Fig.1] Application fields of TRIZ

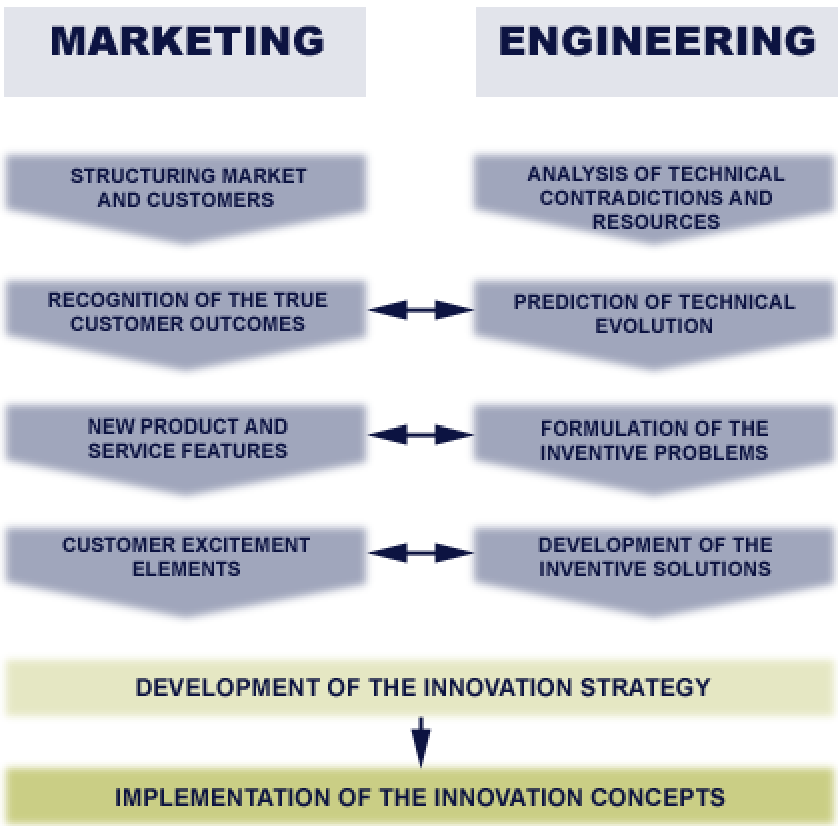
The right integration of TRIZ into Innovation Management enables companies to utilise the full potential of TRIZ for following tasks and application fields:

- Conceptual development of new products, processes und business strategies.
- Forecasting of the evolution of technological systems, products, processes.
- Inventive and technical problem solving.
- Comprehensive search for solutions and protection of company expertise with patent 'fences'.
- Evaluation of the hidden wants and needs of the customer; customer-driven market segmentation.
- Anticipatory failure identification and troubleshooting of new and existing products.
- Advanced solutions for idea and knowledge management.

Nowadays, companies have to deal with many things simultaneously. They constantly have to develop new products and services to strengthen their market position and win new markets with innovative ideas. Today it is not enough to satisfy the customer. Customers want to be 'excited'. Only those companies that meet these high demands will be able to keep their customers in the long run.

The so-called 'excitement elements' and new product features can be accurately and quickly predicted with the help of the evolution patterns of technical systems as the most important TRIZ component. The conventional and modern methods of market research are effectively assisted by TRIZ in the analysis of future market requirements.

As a further development of the QFD method (Quality Function Deployment), the real but often hidden expectations of the customers can be determined and the most effective product features defined. Having completed this phase, the TRIZ tools can now considerably help to implement the required features into the new technical solutions and the innovative product. Such a systematic linking of marketing and TRIZ know-how can lead to a unique market position.



[Fig.2] Linking Marketing and Engineering

Origin and Components of TRIZ

Origin of TRIZ

TRIZ is the internationally acknowledged Russian abbreviation for Teorija Resenija Isobretatelskih Zadac, which can be translated as the Theory of Inventive Problem Solving, also shortened to TIPS.

TRIZ was developed between 1960 and 1980 by the Russian scientist Genrich Altshuller (1926-1998) and his staff (first publication in 1956). In contrast to the common “trial and error” problem solving methods such as brainstorming, synectics, morphological analysis etc., TRIZ only relies on the unbiased laws of evolution of technical systems and therefore enables a focussed search for possible solutions. The discovery and structuring of these laws, as well as other TRIZ components, has been the result of the study and analysis of globally available patents over a period of several decades.

In the 1990’s, TRIZ technology became very popular, particularly in the USA, and was used by a large number of renowned companies such as General Motors, Johnson & Johnson, Ford Motors, Lockheed, Motorola, Procter & Gamble, Rockwell Int., and Xerox etc. It also gained favour amongst German companies including DaimlerChrysler, Siemens, Mannesmann, Hilti, BMW, Bosch and many others.

Technical Contradictions

What TRIZ essentially does is identify, exaggerate and eliminate technical and physical contradictions in technical systems and processes instead of trying to find a “half-hearted” compromise.

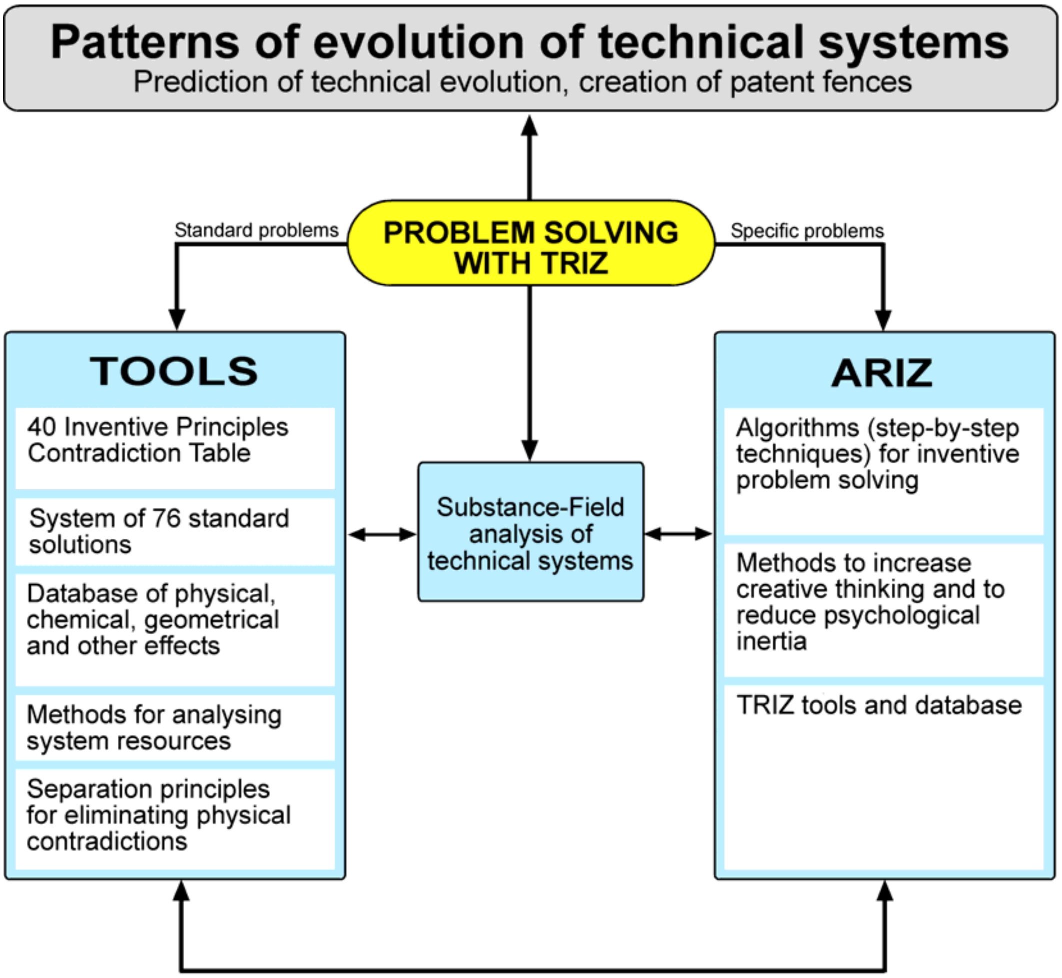
The term “technical contradiction“ (TC) – is the key to the TRIZ concept. A TC represents two contradictory properties of a technical system: improving one part or property of a machine (e.g. engine power) automatically changes another property for the worse (e.g. weight or fuel consumption). According to TRIZ, a problem is solved only if a TC is recognized and eliminated. So-called ‘habitual blindness’, psychological inertia and the all too common tendency to make compromises are all overcome in a logical way. Not only is the scope of the search considerably reduced in size even in the most difficult of cases, TRIZ also opens up completely new ways of thinking.

TRIZ Components

The most important components in TRIZ innovation technology can be summarised in the illustration below. The simpler methods, for example, the 40 inventive principles, can be integrated more easily to be used as active tools but have some restrictions as to their efficiency in solving complex problems. The following Table and Fig. 2 show the TRIZ structure and the paths between the individual methods with regard to the different ways of solving technical problems.

[Table 1] The most important components of TRIZ

No.	TRIZ – tools, methods	Fields of application
1	40 Inventive Principles for eliminating technical contradictions; system of their application in form o the Contradictions Table.	Simple to moderately difficult tasks, recommended for newcomers to TRIZ.
2	System of 76 Standards for solving technical problems: 5 classes / 76 Standards.	Simple to difficult tasks.
3	Step-by-step techniques or algorithms for inventive problem solving (abbr.: ARIZ). Universal tool for solving all kinds of problems.	Extremely difficult problems, comprehensive search for solutions.
4	Substance-Field analysis of technical systems.	Tools for methods nos. 2 and 3.
5	Separation principles for eliminating physical contradictions.	ARIZ tool (no.3).
6	Methods for analysing of system resources.	Tool for nos.2 and 3.
7	Database of physical, chemical, geometrical and other effects and their technical applications.	TRIZ knowledge base; tools for components nos. 1 to 5.
8	Methods to increase creative thinking, to reduce psychological inertia and to “leave beaten tracks”: operator DTC (dimensions-time-cost), simulation with “Little People” etc.	Psychological aids for all TRIZ components.
9	Method of Anticipatory Failure Identification (AFI) i technical systems.	Analysis and prediction of possib sources of failures.
10	Patterns of evolution of technical systems (TS).	Prediction for the development o technical systems, creation of patent fences.



[Fig. 2] TRIZ structure for solving technical problems

Patterns of Evolution of Technical Systems

Patterns of evolution of technical system (TS) are at the heart of TRIZ innovation technology. Some of the most important ones are:

- Evolution or life cycle of a TS.
- Completeness and minimal functionality of all parts of the TS.
- Flow capability of energy and information inside the TS.
- Increase in Ideality (e.g. cost-to-performance ratio).
- Co-ordination and synchronisation of the system dynamics in a TS.
- Transition of a TS to the super-system and from the macro level to the micro level.
- Increase in controllability and flexibility of TS.

Practical applications of these laws are to be found in the various TRIZ tools, in the comprehensive search of solutions and creation of protecting patent fences or in the revealing of the market niches for new products. They are also strategic tools for the analysis of stages in a development and the prediction of the evolution of technical systems.

Principles for the Resolving of Technical Contradictions

40 Inventive Principles

The analysis of several thousand patents led to the conclusion that inventive tasks and technical contradictions from all kinds of industrial branches could be solved by a limited number of basic principles (techniques). Modern TRIZ contains 40 basic Inventive Principles. Here are some examples:

11. Principle of the “safety cushion in advance” (preventative measure).
18. Principle of the utilization of mechanical vibration.
22. Principle of the conversion of harmful influences into beneficial ones.
27. Principle of disposability (using of cheap short-livings objects).
28. Replacement of the mechanical system.
35. Transformation of the physical and chemical properties.

Contradiction Table

The application of these principles takes place in a matrix called a Contradiction Table with 39 lines and 39 columns (see Fig. 3). The 39 engineering input parameters are the most important characteristics of technical systems:

- Mass, length, volume.
- Reliability.
- Speed.
- Temperature.
- Waste (loss) of material.
- Accuracy of measurement.
- Accuracy of manufacturing.
- Convenience of use; etc.

These parameters appear in the table as the properties of a technical contradiction and help to formulate a technical contradiction in a system in standardized terms, for example:

- Speed vs. Reliability
- Mass vs. Strength
- Temperature vs. Accuracy of measurement etc.

As a result of the analysis of the many hundred thousand patents the table shows the inventive principles which are most likely to resolve the formulated technical contradiction. Even though not all of the cells of the Contradiction Table are filled in, it still gives solution principles for more than 1200 types of technical contradictions, substantially reducing the scope of the search to only the most appropriate solution concepts.

Which properties of the system change for the worse? / Properties of the system to be modified or improved		1	...	27	28	...	39
		Mass of the moving object	...	Reliability	Accuracy of measurement	...	Produktivity
1	Mass of the moving object			3, 11 1, 27	28,27 35,26		35, 3 24,37
...	...						
9	Speed	2, 28 13,38		**11,35 27,28**	28,32 1, 24		
10	Force	8, 1 37,18		3, 35 13,21	35,10 23,24		3, 28 35,37
...	...						
39	Productivity	35,26 24,37		1, 35 10,38	1, 10 34,28		

[Fig.3] Search for Solution Principles using the Contradiction Table (detail)

Examples

At speeds of over 60mph, the risk of serious car accidents due to a tyre damage is greatly increased. This already formulates a technical contradiction and can directly be put into the table: increasing the speed of the vehicle (row 9) has a negative influence on the reliability of its running gear (column 27). Looking up the intersection of row 9 and column 27 (table cell 9/27), we find the following solutions in the following order of priority: 11, 35, 27, 28 (see illustration). According to principle 11, the insufficient reliability is to be compensated for by the pre-installation of damage prevention equipment. A possible solution would be to fix a steel disk behind each rim, which in the case of a tyre damage, keeps the car in a level position, thus reducing the risk of a serious accident (US Pat. 2879821).

Another example of the principle no. 11 “safety cushion in advance” is to be found in the pharmaceutical industry. Sleeping pills are covered with a thin film of an emetic substance. If more than the prescribed number of pills is swallowed at one time, the concentration of the emetic substance reaches a threshold value in the stomach, which then provokes vomiting.

Magic of Contradiction Matrix

Holding no less power of attraction is the Contradiction Matrix, as a method of using the 40 principles. As known, the Matrix - as a result of about 7 years of investigation work – delivers an approach on how to select the best principles to resolve one specific technical contradiction, in order to reduce the trial-and-error work involved in applying all 40 principles.

In spite of the fact that in TRIZ cradle - Russia even in the 1980's the Matrix was no longer the most recommended of strong TRIZ tools, a lot of attempts to improve this empirical and early TRIZ method are still known nowadays:

- Adding/reducing the number of lines or columns,
- Changing the titles of 39 technical parameters,
- Up-dating the matrix cells or filling the «empty» matrix cells,
- «Customising» matrix:
  The user can re-invent the matrix according their experience,
- Other mathematical experiments, up to random choice of matrix cells etc.

Although such attempts are being undertaken with the best intentions, they do not contribute to TRIZ significantly, neither practically nor theoretically. Also, the best and fullest matrix would not guarantee the solution of difficult problem. Not the Matrix but the Principles are crucial for problem solving. They are good to enhance technical creativity but only scratch the surface of the problem in complicated situations.

In practice one should warn all newcomers to TRIZ about «blind trust» to the Matrix. One can remember the earlier experience of using the matrix in Russia, still in printed form: the pointer often unintentionally hit the false matrix cell, but nevertheless it did work.

For the matrix-fans we recommend hence formulating several contradictions for one problem situation, forming a set of recommended principles and as the next step using those principles which were recommended more than once. The correct application of the matrix in this case gives a small number of principles, which were recommended 3…8 times (e.g. principles N.35 - 8 times; N.5 - 5 times, N.19 - 3 times etc.), and a longer «tail» of principles which were recommended only once. In any case this approach helps to understand and to document the bundle of underlying technical contradictions in the system that may be of high importance for problem analysis.

Longevity of 40 Principles

Although formulated about 30 years ago, the 40 Altshuller's Innovation Principles have remained till now the most popular and usable TRIZ tool. How could it happen that the Principles, suitable only for simple to moderately difficult tasks [Altshuller, Creativity as an exact science, 1979] and good for newcomers to TRIZ, are still playing such important role in industrial TRIZ practice? As a seemingly «inevitable» piece of TRIZ classics, one can find them - sometimes slightly modified - almost in every modern TRIZ book or software. A lot of researchers and practitioners since the 1970's till now have been inspired to re-invent, improve or up-date the Altshuller's work, for example:

- To modify principles for management and organisational tasks (Voronkov , 1973)
- To create double «direct-reverse» principles (Flikstein, 1973)
- To add new principles or sub-principles (Polovinkin, 1976)
- To adapt the principles for radio-electronics (Gutkin, 1976)
- To simplify principles or to reduce their number,
- To adapt principles for food, science, architecture, software, advertising etc.

The reason for such «affection» for the principles is obvious: principles are simple to use or modify and can be easily integrated in brainstorming or daily engineer's work. One established part of industrial practice is the composition of the specific groups of principles for solving different kinds of problems, for example:

- Statistically most often usable principles for general problems (Principles 35, 10, 1, 28…)
- Most suitable principles for solving product design problems
- Principle sets for cost reduction or system evolution
- Customized principle sets etc.

We gained some more objective reasons for the longevity and attractiveness of the 40 principles through a scientific analysis of innovation and invention process in about 100 German companies in 2000-2002 [see Proceedings of the ETRIA Conference TRIZ Future 2003, Strasbourg, Nov. 2002]. This investigation confirmed the fact that although the importance of systematic and directed problem-solving and innovation in the industry is high, the level of satisfaction with the existing methods and processes is also relatively high. Hence there is no broad natural impulse to use more effective and comprehensive TRIZ methods in general, at least in daily work.

We have found that about 52% of all technical problems in the industry are being solved through corporate technical know-how and common sense. The next 37% of problems can be cracked with simple creativity methods such as brainstorming and morphological analysis or with the help of direct feature or technology transfer from other technology fields. For both these segments the engineers' work and creativity can be enhanced effectively by relatively simple TRIZ-methods, i.e. 40 principles. For the mighty TRIZ methodology there remains only 11% of all problems.

System of 76 Standards for Technical Problem Solving

76 Standards Solutions

The 40 inventive principles and the Contradiction Table are the simplest TRIZ tools. The analysis of more complex tasks revealed that they could only be solved by the simultaneous use of several such principles, together with various physical effects. Such a particularly effective combination of principles and effects forms the system of Standard solutions of inventive tasks.

TRIZ Standards are general laws for the synthesis and transformation of technical systems (TS). They are based on the patterns of evolution of TS. Some of the Standards directly represent the practical application of these laws. The modern system of Standards leads to structured and highly systematic working methods and can further be used to analyse the technical evolution of the systems and products. It consists of 76 Standards, which are classified into 5 classes and 18 groups:

- Class 1: Synthesis and transformation of the technical systems.
- Class 2: Enhancement of efficiency of the technical systems.
- Class 3: Stages of evolution of the technical systems.
- Class 4: Measurement and detection in technical systems.
- Class 5: Assistance in the application of the Standards.

Substance-Field Analysis

The Standards operate with abstract models of technical systems, which are easy to build using so-called substance-field analysis. Each technical system can be described in terms of available substances, fields and their interaction. “Substances” are objects or parts of the system regardless of their degree of complexity. The term “field” not only covers the four classical physical fields such as electromagnetic field, gravitational field and the fields of strong and weak nuclear interaction. In TRIZ, the term “field” also includes all other forms of “technical” fields such as the field of temperature, field of centrifugal force, pressure field, the acoustic field, field of smell, etc.

Example 1

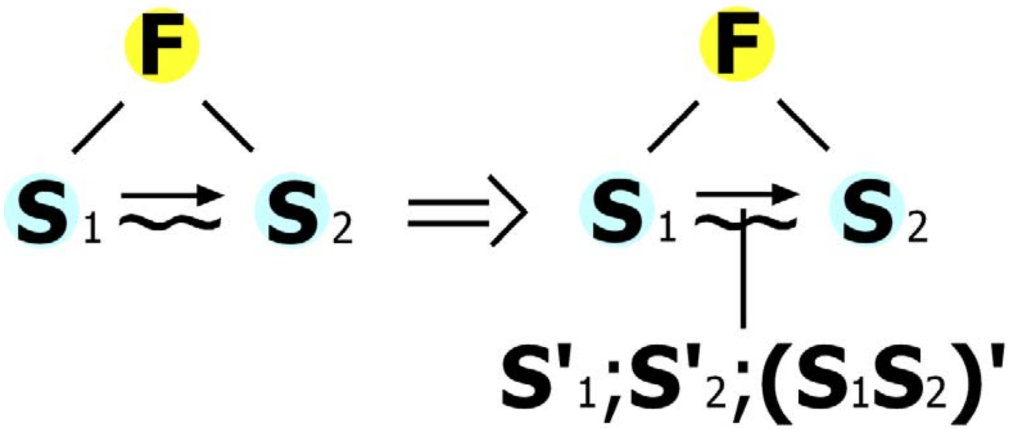
The minimal number of components for a complete substance-field model of a technical system is two substances and one field, which form a triangle through their interaction. Once a substance-field model has been formulated, a suitable standard solution can be suggested as illustrated in the following example.

Metal balls are transported by compressed air through a system of pipes, which has many bends. As a result of the continuous impacting of the balls, the bends of the pipe ware quickly. Additional coatings (a typical compromise solution) have a higher resistance to the balls but still wear. This means that

between two substances of a technical system (balls and pipe), there is an harmful interaction, which has to be eliminated.

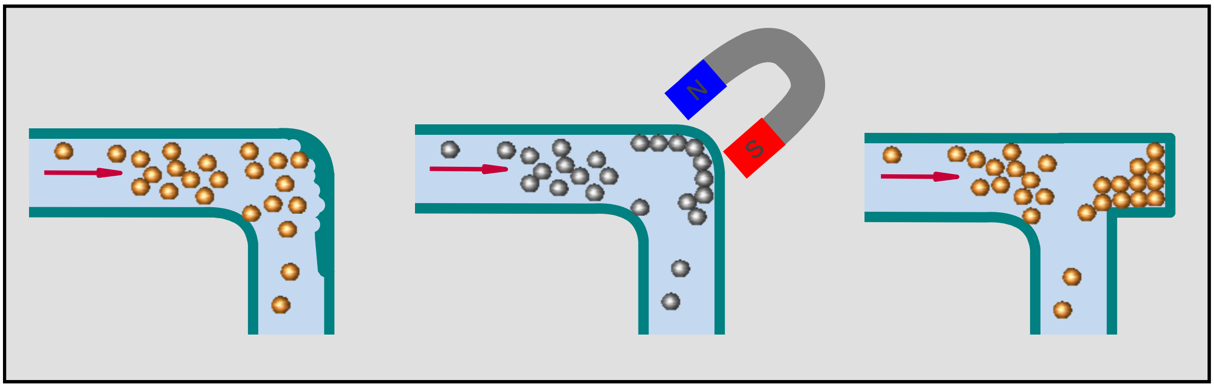
To eliminate such harmful effects in technical systems, Class 1 standards are used. A possible solution is detailed in Standard 1.2.2 "Eliminating harmful effects by system resources" (see illustration):

"If the contact of two substances S_1 and S_2 leads to harmful effects, a third substance S_3 is to be introduced as a modification of one or both of the existing substances".



[Fig. 4] Substance-field transformation of the standard solution 1.2.2

The result is shown below. The inside of the pipe bend is lined with a layer of the same type of balls. They are either positioned in a pocket or, alternatively, are held in place by a permanent magnet. The stream of balls no longer hits the walls of the pipe but rather the other balls instead. If one of the balls is knocked out of place, another replaces it. The technical contradiction is resolved: there is no more wear of the pipe bends.



[Fig. 5] Illustration of a Standard application

Example 2

Using the same principle, a problem from another field of industry can be solved. The wings of hydrofoils are often subject to cavitation erosion when passing through water at high speeds. Small imploding air bubbles gradually destroy the hydrofoil's wings, even if they are made of highly resistant material. There is obviously a harmful interaction between two substances: water and metal, which can be eliminated using the Standard mentioned above by modifying one of the substances present in the process. If we think of ice and vapour as a kind of "modified water", one of the possible solutions could be found: the part of the hydrofoil wing in question is cooled to a degree where a thin protective, constantly renewable layer of ice is formed.

These examples clearly demonstrate the advantages of modifying one of the existing substances in the process rather than introducing a third substance, which in most cases, leads to further complications.

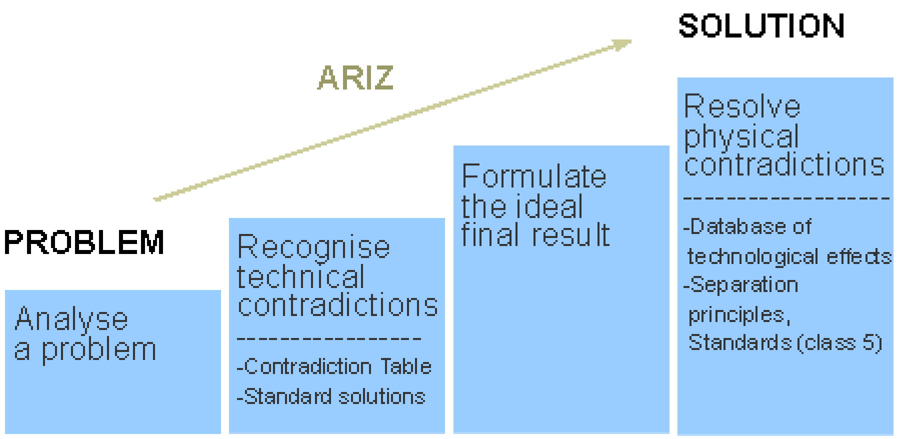
Algorithm for Inventive Problem Solving ARIZ

ARIZ Procedures

The algorithm for inventive problems solving (abbr.: ARIZ) is the most universal and powerful step-by-step TRIZ method for the solving of all kinds of problems, starting with the analysis of the problem and the system resources and concluding with the evaluation of all possible solutions. It is normally used if the 40 Inventive Principles or Standards don't provide a satisfactory result. ARIZ helps the user to:

- analyse a problem,
- recognise technical contradictions,
- formulate the ideal final result,
- identify the physical contradictions on which the problem is based and then to resolve them.

These main procedures in ARIZ will be further demonstrated by an example. The full ARIZ process (TriS Version) comprises 9 stages with around 70 steps.

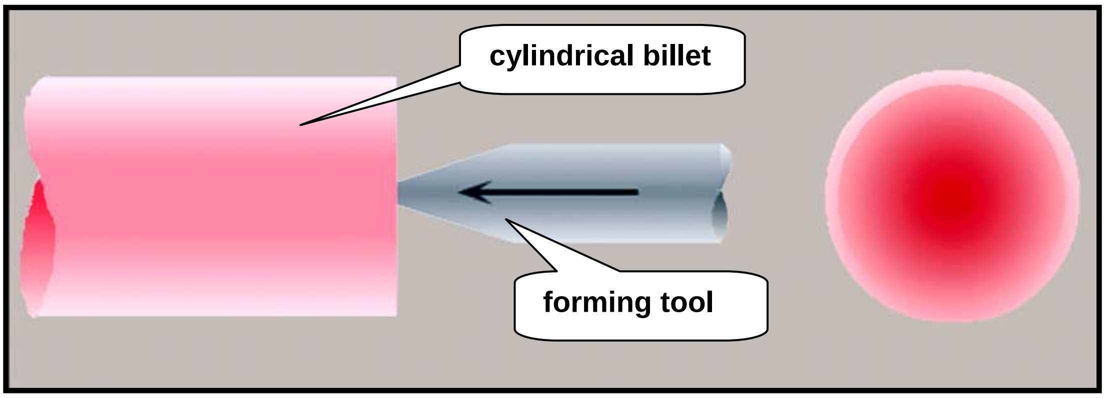


[Fig. 6] Main stages of the Inventive Algorithm ARIZ

Example

Initial Situation

The first stage when using ARIZ is to analyse the initial situation and to formulate the problem. In the manufacture of seamless tubes, a hot cylindrical billet (tube) is pierced by a pointed forming tool (piercing plug). The tube is supported and rotated by rollers. After the insertion of the piercing plug into the hot tube, it often starts to wander inside the tube. The problem is aggravated as the length of the tubes is increased, up to a value of 6 m or more. How can the wandering of the plug be eliminated?



[Fig. 7] Using ARIZ to solve a problem

Formulation of the Technical Contradiction
The technical contradiction is as follows: with the increasing length of the tube (desired result), the support for the piercing plug decreases. As a result, the accuracy in the manufacture and dimensioning of the tube decreases (undesired effect). At this stage, an effort to resolve the technical contradiction with the help of the Contradiction Table or the system of Standards could be made.

Formulation of the Ideal Final Result
The Ideal Final Result (IFR) for the problem solution would be like this: an infinitely long tube supports and guides the piercing plug precisely into its centre. The technical contradiction is amplified by such a formulation. The IFR is targeting now the perfect solution. Every technical contradiction has definite physical reasons, which are described in the following stage.

Formulation of the Physical Contradiction
To accomplish the IFR, the tube has to have two mutually exclusive physical properties: on the one hand it has to be ***hard*** to support itself and the piercing plug, and on the other hand it has to be ***soft*** to allow the piercing plug to penetrate into its centre.

This represents a physical contradiction. To resolve it, ARIZ uses the Separation Principles for resolving physical contradictions, the Class 5 Standards as well as a database of more than 1000 physical, chemical and geometrical effects.

Separation Principles
One of the simplest methods for resolving physical contradictions is to separate the controversial properties either in time or space, using the Separation Principles. The tube has to be hard, particularly on the outside, but soft on the inside. All that now has to be done is to search the database for a physical effect that can influence the hardness of the steel.

Utilisation of System Resources
Before "external" means are applied, it is always favourable to first thoroughly analyse the system's "internal" resources (substance, fields, time, space, information, function) and use them wherever possible to solve the problem. Such an analysis is one of the most important stages in ARIZ.

Resolving of the Physical Contradiction
The hardness of the material is a function of the temperature. As the tube is heated anyway to allow the piercing plug to penetrate it, all the system requires is a suitable distribution of the heat: cold on the outside and hot towards the centre. This can easily be achieved by spraying the tube with cold water. The piercing plug now automatically takes the easiest route – towards the warmest and therefore softest point in the tube, i.e. exactly in the middle.

Comprehensive Search for Solutions with ARIZ

The case illustrated above represents a very simplified example for the application of ARIZ. In reality, practically every problem consists of several technical and physical contradictions. One of the significant advantages of ARIZ application for the industry is the possibility of systematically defining the complete search field for a concrete technical system (TS) or task.

The systematic resolving of these using ARIZ procedures normally leads to a large number of solutions being suggested (generally between 30 to 100). The entire scope of the search can be completely described through this approach, and made transparent to the user as well. The result is a unique opportunity for a comprehensive and systematic search for solutions in accordance with defined priorities.

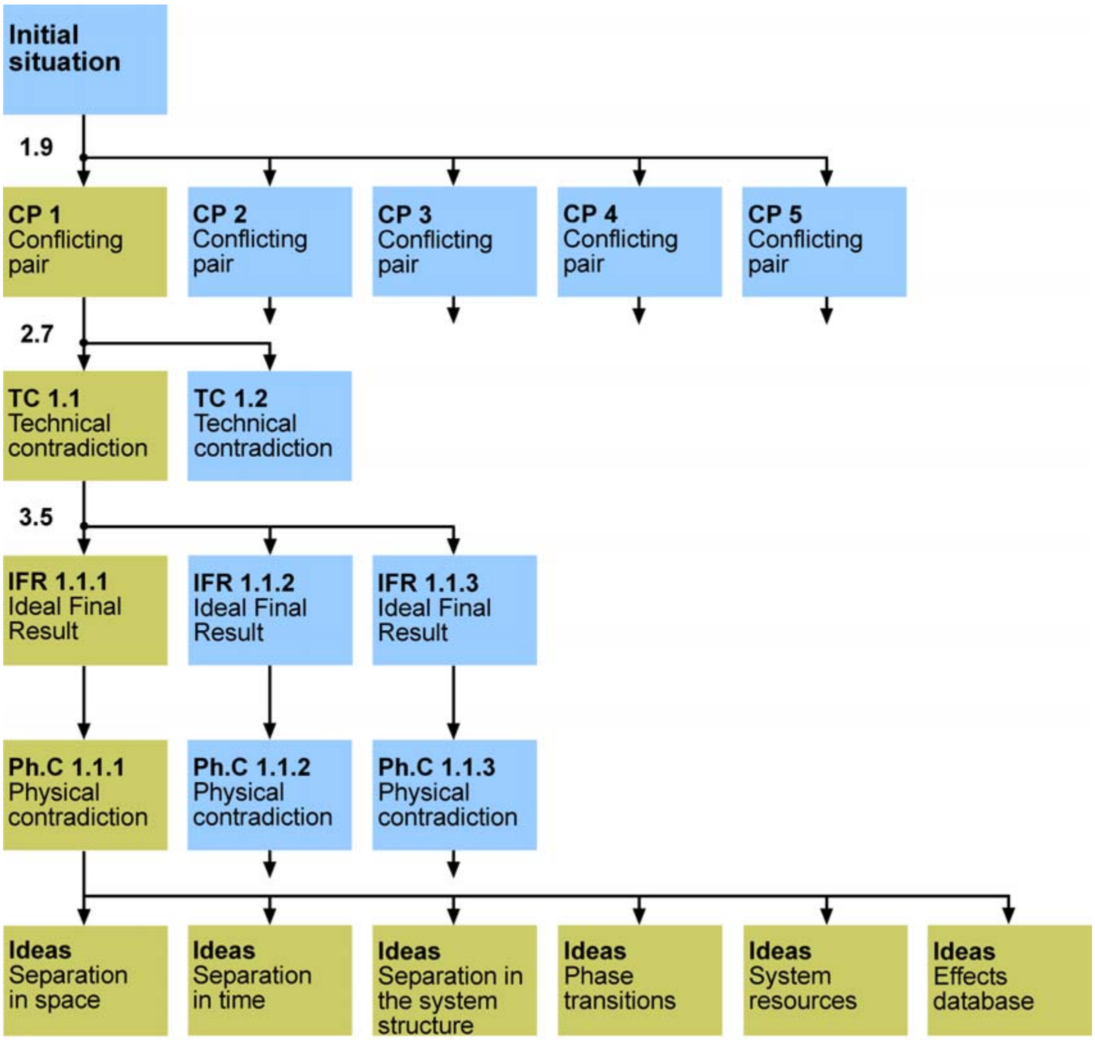
An important role here is played by the first part of the method - Problem Analysis with following elements:
- System components and function analysis
- System resources, existing solution principles and anticipated results
- System levels from the sub- to super-systems and definition of the search field
- Technical conflicts - decomposition of the initial situation to particular problems

As an initial problem situation in a technical systems (TS) usually consists of several particular problems or technical conflicts, the conflicting system components or several conflicting pairs (CP) can be identified (Fig. 8).

A conflicting pair consists of components of the TS, whose interaction is responsible for causing a negative property or undesired effect. The conflicting pairs represent all relevant interactions and problems within the technical system.

The sequence of their analysis, according to their importance and beginning with most important particular problem, should be defined for the further problem solving process. After the analysis of the core CP was initially chosen, all other conflicting pairs are then subsequently analysed for the comprehensive search for solutions.

For each conflicting pair several technical contradictions, ideal final results and physical contradictions on the macro and micro level are to be formulated. Due to this approach, a complete search tree with typically more than 100 formal physical problems could be created and solved with the known tools and separation principles as shown in the Fig. 8. The TriS^{IDEAS} software supports a multi-path computer-aided application of the method and all TRIZ-principles, standards and checklists including contradiction matrix, effects pointer and main 22 lines of evolution as well.



[Fig. 8] Graph of the comprehensive search for solutions

Database of Technological Effects

Many perfect technical solutions are based on the combination of physical, chemical, geometrical and other effects. Many times though, engineers do not have a reliable link between the practical task and physics. This shortcoming is solved with the TRIZ database of effects.

For each desired action or operation, which is demanded by a physical contradiction, there is a list of corresponding effects and practical examples as illustrated in the table below. Almost every effect in the database has an input and output cell, naming the effect and the result that can be achieved by applying it, e.g. thermo-mechanical effect or mechanical-electrical effects. This allows the combination of different effects to solve complex tasks.

[Table 2] Fragment of the database of physical effects

Desired Effect	Physical Effects, Methods
Increasing temperatu	Electromagnetic induction, eddy currents, skin effect, dielectric heating, thermo-electric effects, exothermic reactions, absorption of radiation, etc.
Mixing of materials, forming of solutions	Ultrasound, cavitation, diffusion, electrolysis, electrophoresis, magnetic fields in combination with ferromagnetic substances, electric fields, geometrical effects, etc.
Changing the dimensions of an object	Thermo-mechanical effects (thermal expansion, memory of metals), deformation, magneto-electrical striction, piezoelectric effect, phase change, chemical reactions etc.

Computer Aided Innovation CAI

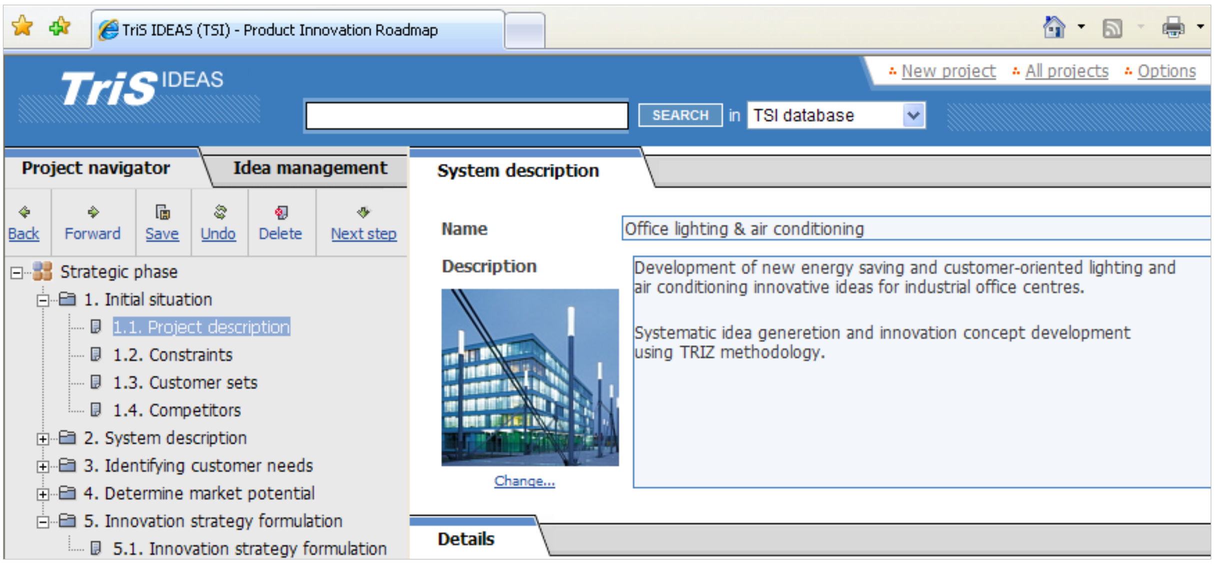
Origin of Computer Aided Innovation

After the introduction of TRIZ into the USA in the early 1990's, its techniques and databases were used as the basis of innovation software, as well as being modified for computer-based applications. This was the birth of a new field of technical engineering - Computer Aided Innovation, CAI.

Advantages of CAI

The different TRIZ components have to be used according to the complexity of the task. In practice, it has been shown that provable results can only be achieved by users who have knowledge of at least 10-15% of the whole potential of TRIZ, without having to consult a handbook or an electronic thesaurus.

In other words, it is not the computer programs that do all the thinking or deliver inventions at the click of a mouse button. They assist the qualified user in solving technical problems and developing ingenious new products by providing contradictive thinking methods, TRIZ tools and the patterns of evolution of technical systems. The CAI software then accelerates the innovation process and ensures the quality of possible solutions.



[Fig.9] Web-based software package TriS^{IDEAS} organizes innovation as a controllable process, making innovation success predictable and repeatable.

Anticipatory Quality Control using TRIZ

Anticipatory Failure Identification AFI

New production methods and systems often only achieve an acceptable standard of reliability after a large number of breakdowns. Therefore, methods of anticipatory failure identification are growing in importance. They help to determine the risk of potential breakdowns even when the experience is lacking.

The TRIZ tool for anticipatory failure identification, AFI for short, is an effective and creative method. Amongst the most important applications for this method are the analysis of previous breakdowns which have happened for no apparent reason, as well as the prediction of hidden sources of potential breakdown scenarios or damage.

AFI Procedures

The general procedures of the AFI method can be performed with or without the aid of software and are made up of the following main stages:

- Inverting the task: "What actions will definitely cause a system to fail?" With this method sources of errors are systematically "generated" using both the whole potential of TRIZ and the checklists of typical faults.
- Functions are not only analysed as to whether they are performed or not, but also whether they might be excessively or incompletely carried out.
- Sources of errors are taken to the theoretical extreme. Resources from the system and the surroundings are utilised with the occurrence of each fault.
- After re-inverting the task, TRIZ tools for the development of fault-avoidance measures are used. This approach helps to overcome the general tendency to accept compromises.

FMEA Supplementation

The anticipatory failure identification can effectively supplement existing quality control methods such as FMEA method (Failure Modes and Effects Analysis), HAZOP/PAAG (Hazard and Operability Analysis) or be integrated into other methods (Fig.10)

The AFI method prevents "mental blockages" and motivates the user to find new, inventive solutions. The method is so effective that the user are sometimes frustrated by the large number of errors identified in technical system (machines, procedures etc.) and it amazes them that the system had worked at all in the first place. This is quite normal, since the sources of errors are only possible sources of errors. The engineers' job then is to prevent these identified errors from happening, as is illustrated in the example below.

Example of the AFI Method

When analysing the probability of faults occurring in waterproof electrical and electronic circuits using the classic FMEA method, hardly any consideration is given to the possibility that the individual system components could be exposed to moisture, and thus fail. Such a risk is generally regarded as highly improbable.

This is not the case however when AFI methods are utilised. Even if a circuit were thought to be completely waterproof, various ways of how moisture could enter the 'protected' area would be found. One of the possible connections to the external surroundings is, in this case, through cables or insulated conductors. Very often there is a thin layer of woven material under the insulation, which can carry the moisture along its fibres through capillary action. The 'subversive' capillary effect can be further aggravated by voltage.

			Methods for Failure Prevention				
Search for hidden faults depending on difficulty		**Application field**	**Check-lists**	**Fault and event trees**	**HAZOP/ PAAG**	**FMEA**	**AFI**
3	Causes of inexplicable failures and accidents	Analysis of random critical faults					●
3	Failure modes by lack of experience	New products and technologies		○	○	○	●
2	Hidden failure modes and chains of failures	Reinforced quality assurance	○	○	○	●	●
1	Typical failure modes	Standard quality assurance	●	●	●	●	●

[Fig. 10] Overview of methods for failure prevention and risk analysis.

TRIZ for Business and Management

TRIZ for Executives

Applying the TRIZ ‘thinking’ tools of inventive problem solving in engineering successfully replaces the unsystematic trial-and-error method in the search for solutions in the everyday life of engineers and developers. The majority of organisational management decisions made by the executives and managing directors however are still based on their intuition and personal experience. Therefore often complex contexts are extremely simplified, alternatives ignored, constraints avoided, risk not evaluated correctly and resources, knowledge and potentials not utilised for the best problem solving at the right time.

This is part of the reason for the growing demand from management people for systematic and powerful thinking tools, which assist the executives processing the information and making the right decisions in time.

The TRIZ Innovation Technology offers such thinking tools. TRIZ knowledge and professional TRIZ application experience together with TRIZ-based thinking for management tasks helped to identify the technology tools which come into play:

- TRIZ tools, such as Innovation Principles for Business and Management as well as Separation Principles for resolving organisational contradictions and conflicts, for example.
- Substance-Field Analysis for visualizing highly complex systems.
- Procedures and checklists of the anticipatory failure identification for prediction and evaluation of risks.
- Operators for revealing and utilising system resources as a basis for effective and cost-saving decisions.
- Patterns of evolution of technical systems to support systematic and multi-dimensional thinking.

Components of the Thinking Structure

If agreement is obtained that management decisions should be based on more methodology, the TRIZ knowledge base along with its analytic methods can effectively be used. TRIZ for business and management basically use these five components:

1. Identification and theoretical exaggeration of conflicts

Non-technical conflicts such as organisational or administrative contradictions and conflicts on different levels (personnel, team, company area, entire company, branch of industry etc.) should be identified, theoretically exaggerated and then solved in the next stages. The desired result is to substantially decrease or even eliminate all negative tendencies and features, while at the same time keeping and intensifying all positive and useful factors.

2. A positive attitude towards complexity

Instead of simplifying complex combinations and interactions when analysing a task, the TRIZ methodology allows even highly complex and multi-dimensional interconnections to be clearly explained. The complexity of a task itself becomes the prerequisite to finding the best solution.

3. Consideration of patterns of evolution

The hierarchic and systematic consideration and evolutionary development of the conflicting entities and factors play an important role in the analysis and evaluation of possible decisions. Further TRIZ evolutionary criteria such as adaptability, controllability and periodic occurrences complete the systematic approach to the problem.

4. Anticipatory evaluation of risks

Decisions and strategies are tested by the method of the Anticipatory Failure Identification. The strength of this method is to find weaknesses within the proposed management solution by systematically trying to “prove them wrong”. All available resources are utilised deliberately to cause the concept failure. Hidden risks of a decision are effectively revealed and can be avoided in further steps.

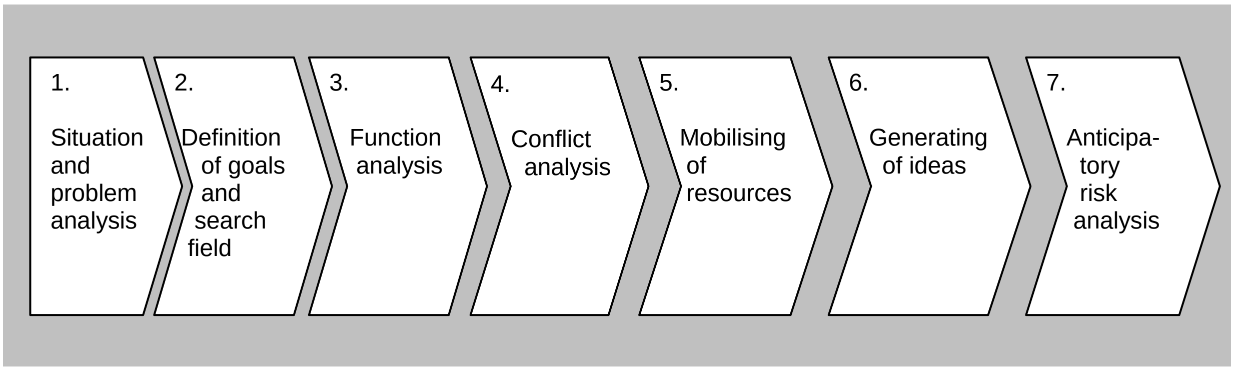
5. Utilisation and expansion of resources and knowledge

The central function of knowledge and idea management is to utilise the personal and collective knowledge in time, to broaden the boundaries of knowledge and to provide timesaving access to knowledge and idea pools. The TRIZ database with its many thousands of effects and examples offers a solid basis for the effective knowledge management.

The process for problem solving in business and management

For the first step a non-technical problem should be formulated in terms of a conflict or contradiction with positive and negative aspects similar to the technical contradiction. This conflict can then be strengthened in terms of deepened physical contradiction. By using the 12 double innovation principles or the separation principles for the deepened conflicts the problem can be overcome.

The amount of generated ideals is considerably faster and higher compared with the solutions managers usually come up with. Especially for critical cases a problem solving process with the following main phases is suggested: Function and Conflict Analysis, Mobilisation of Resources, Generating of Ideas, Evaluating of the Results and Anticipatory Risk Analysis (Fig. 12).



[Fig. 12] The process for problem solving in business and management

12 innovation principles for business and management

The 12 double principles for Business and Management (Table 3) assist the user resolving organisational contradictions and conflicts. They broaden the individual experiences and intuition of the manager and in addition help them to quickly formulate several different approaches to difficult situations.

Each principle represents two contradictory lines of action, which have to be taken into consideration when searching for solutions. There is no recommendation as to which action is the more suitable. The user is thus stimulated to think in a dialectic and creative way.

[Table 3] 12 Principles for solving organizational tasks in business and management

1. Combination – Separation 2. Symmetry – Asymmetry 3. Homogeneity – Diversity 4. Expansion – Reduction 5. Mobility – Immovability 6. Consumption – Regeneration 7. Standardisation – Specialisation	8. Action - Reaction 9. Continuous action – Interrupted action 10. Partial action – Excessive action 11. Direct action – Indirect action 12. Preliminary action – Preliminary counteraction

Example

In companies quite often problems arise due to difficulties in communication. As an example the communication lack between a highly technically competent and thus important individual and the rest of the staff can be used. The resulting personal conflicts then have a negative effect upon the productivity and the working climate. Here are some suggestions using the principles as to how to defuse the problem:

Principle 1. Combination - Separation:

- "Isolate" the person for the staff to avoid direct contact and organize a central counsellor.
- Arrange for the "difficult" person to work at home or to have flexitime.
- Set up a database or an Expert System to make the expertise of the person available to others.

Principle 2. Symmetry - Asymmetry:

- Reduce asymmetry in company expertise; internally train or hire several experts.

Principle 3. Homogeneity – Diversity:

- Encourage psychological homogeneity and raise the tolerance threshold of the colleagues.

Principle 4. Expansion – Reduction

- Reduce the individual's direct involvement with colleagues and in projects.

Principle 5. Mobility – Immovability:

- Reduce the individual's sphere of movement within the company through organizational means.

Principle 7. Standardisation - Specialisation:

- Standardise company knowledge and working methods. Introduce knowledge management.
- Use the unique (or specialist) knowledge of the individual to build up the knowledge management system or have them organise this task.

Principle 8. Action - Reaction:

- Arrange a social and psychological guidance program for the individual.

Principle 9. Continuous action - Interrupted action:

- Only involve the individual in a consultative role and in certain phases of a project.

Principle 10. Partial action – Excessive action:

- Reduce the amount of time that the individual spends in projects.

Principle 11. Direct action – Indirect action:

- Provide a mediator or a social buffer for the individual in the team or in the company.

Success Potential of TRIZ and CAI

The advantages and the success potential of using TRIZ and Anticipatory Failure Identification (AFI) have technical and psychological aspects.

Technical Aspects

- Completely new approaches for solving problems in the most important company divisions: Research and Development, Quality Control, Marketing, optimising of products and processes etc.
- Faster and more effective problem solving and innovation processing by rigorously avoiding trial-and-error methods. Reduced risks and costs during the development stage.
- Forecasting the development of technical systems, creating protecting patent fences, revealing uncovered product niches.
- Enhanced quality control and optimised products through a focussed search for alternative solutions and the application of anticipatory failure identification.
- Generating of ideas in seemingly hopeless situations, where practically all conceivable solutions are covered by competitor’s patents.
- Optimal use of system resources: e.g. eliminating negative effects in a machine or process by only slightly modifying the technical system.
- Integration and supplementation possibilities with DFMA (Design for Manufacture and Assembly), FMEA (Failure Mode and Effects Analysis), QFD (Quality Function Deployment), Value Engineering, Taguchi (Robust Design) and other methods.

Psychological Aspects

- TRIZ increases the creativity and inventiveness of engineers and project teams.
- TRIZ eliminates ‘habitual blindness’.
- TRIZ encourages systematic thinking processes and the will to search for less trivial solutions.
- TRIZ improves teamwork; the invention process becomes a controllable procedure and is no longer an act of pure inspiration.

Implementation of TRIZ and CAI in Companies

Industrial experience

A great number of users confirm that the TRIZ Methodology is much too extensive to be successfully introduced parallel to the usual business and daily work.

Therefore, a systematic support by experts in the field of the TRIZ methods can be very helpful in the starting phase. Firstly, it helps to integrate the TRIZ techniques into the working processes of the company and secondly, it builds up competence within the company through the training of a team of TRIZ experts.

Corporate Training in TRIZ

The desire to give one's own management and development teams the necessary knowledge about the methods of systematic and inventive problem solving often conflicts with busy schedules and the general shortage of time during the working day.

To overcome this conflict, TriS Europe Company has developed a special training programme for business and industry.

The training programme consists of 4 application-specific stages each lasting 2 to 4 days. The following options are then open to the company,

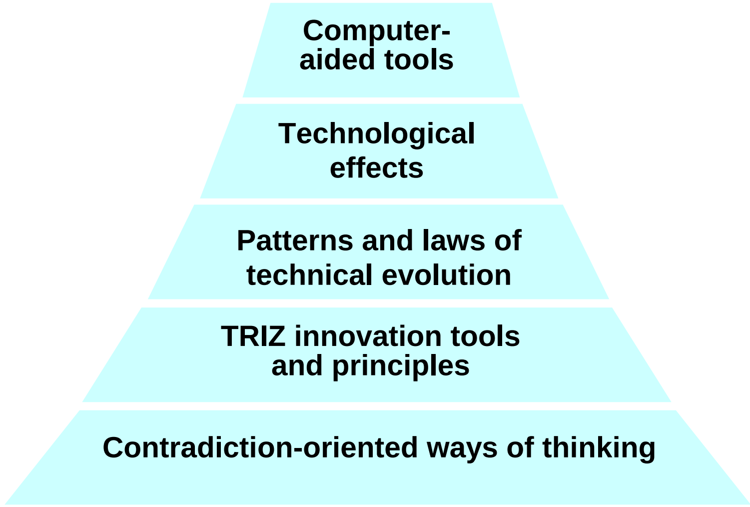
- The training of their own TRIZ experts through the participation in all levels of the programme.
- Having a greater number of employees trained through a rotation-system.

The contents, number and duration of the levels are tailored to match the requirements of the company. This way, the complete training cycle can be completed within 2 to 12 months depending upon the time available.

Gaining TRIZ competence

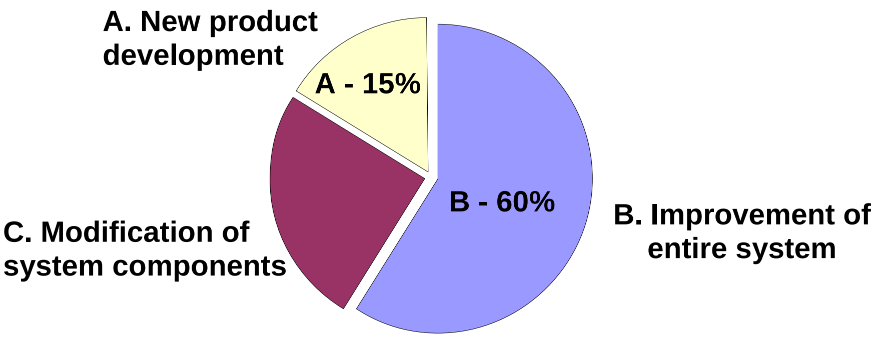
Depending on requirements, TRIZ knowledge can be conveyed through practical training or, even more effectively, by conducting pilot projects for solving actual tasks. The recommended distribution of TRIZ knowledge within a company is illustrated below (Fig.13). The basic knowledge, such as "contradiction-oriented ways of thinking" should be widely spread throughout all company levels.

The use of special TRIZ tools or software applications should be restricted to a limited number of specialists within the company. It is also advisable to carefully choose how you advance from the simple methods to the more complex methods and tools in order to prevent disappointment in applying TRIZ.



[Fig. 13] Recommended distribution of TRIZ knowledge within a company

The figure 14 demonstrates three types of task levels in accordance to problem difficulty, wherein on task level C (partial system improvement) the satisfactory solution could be found in 2 days, and on the levels B (improvement of entire system) and A (development of totally new products) the projects can be completed successfully in 4 and 12 weeks respectively.



[Fig. 14] Three typical levels of TRIZ support of the innovation tasks

Platform for innovation and quality management

In comparison to the well-known methods of quality control and product development such as QFD, FMEA, DFMA, Taguchi and many others, TRIZ, as a complex innovation technology and consisting of various methods and tools, has to be highly rated. It helps to create an expandable internal platform for innovation and quality management in the companies. With dynamically growing global competition, a rapid implementation of TRIZ might not only invigorate and strengthen a company, it might just save it.

Literature

1. Altshuller G.S., Shapiro P.B. (1956): On the psychology of inventiv creativity, Moscow 1956 (rus.) - first publication about TRIZ.
2. G.S. Altschuller: Erfinden – Wege zur Lösung technischer Probleme. VEB Verlag Technik Berlin, 1984. Limitierter Nachdruck 1998, 280 Seiten, ISBN 3-00-002700-9
3. Pavel Livotov, Vladimir Petrov: Innovationstechnologie TRIZ. Produktentwicklung und Problemlösung. Handbuch. 2002, Hannover, 302 Seiten, ISBN 3-935927-02-9
4. Terninko, John, B. Zlotin, A. Zusman: TRIZ - der Weg zum konkurrenzlosen Erfolgsprodukt. Landsberg/Lech: Verlag Moderne Industrie, 1998, 288 Seiten, ISBN 3-478-91920-7
5. H. Teufelsdorfer, A. Conrad: Kreatives Entwickeln und innovatives Problemlösen mit TRIZ / TIPS. Einführung in die Methodik und ihre Verknüpfung mit QFD. Verlag Publicis MCD, 1998, 120 Seiten, ISBN 3-89578-103-7
6. Rolf Herb, Thilo Herb, Veit Kohnhauser: TRIZ - Der systematische Weg zur Innovation. Werkzeuge, Praxisbeispiele, Schritt-für-Schritt-Anleitungen. Landsberg/Lech: Verlag Moderne Industrie, 2000, 260 Seiten, ISBN 3-47891-980-0
7. Bernd Gimpel, Rolf Herb, Thilo Herb: Ideen finden, Produkte entwickeln mit TRIZ. Taschenbuch, Hanser Fachbuch, 2000, 180 Seiten, ISBN 3446211594
8. Tilo Pannenbäcker: Methodisches Erfinden in Unternehmen. Bedarf, Konzept, Perspektiven für TRIZ-basierte Erfolge. Gabler Verlag, 2001, 324 Seiten, ISBN 3409118411
9. Michael A. Orloff: Grundlagen der klassischen TRIZ. Ein praktisches Lehrbuch des erfinderischen Denkens für Ingenieure. Springer-Verlag Berlin Heidelberg, 2002, 270 Seiten, ISBN 3540668691
10. Bernd Klein: TRIZ/TIPS - Methodik des erfinderischen Problemlösens. Taschenbuch, Oldenbourg, Mchn, 230 Seiten, 2002, ISBN 3486259520
11. Manfred von Ardenne, Gerhard Musiol u. Siegfried Reball: Effekte der Physik und ihre Anwendungen, Verl. HARRI DEUTSCH, 1997, 891 Seiten, ISBN 3817111746
12. G.S. Altshuller: Creativity as an Exact Science. The Theory of the Solution of Inventive Problems. Gordon & Breach Science Publishers, 1984, ISSN 0275-5807
13. Genrich Altshuller: And Suddenly the Inventor Appeared. TRIZ, the Theory of Inventive Problem Solving. Technical Innovation Center, 1996, ISBN 0964074028
14. G. Altshuller, U. Fedoseev, S. Rodman, L. Shulyak: 40 Principles: TRIZ Keys to Technical Innovation. Technical Innovation Center, 1997, 141 pages, ISBN 0964074036

15. Victor R. Fey, Eugene I. Rivin: The Science of Innovation - A Managerial Overview of the TRIZ Methodology. The TRIZ Group, 1997, 82 pages, ISBN 0965835901
16. Genrich Altshuller: The Innovation Algorithm - TRIZ, Systematic Innovation and Technical Creativity. Technical Innovation Center, 1999, 312 pages, ISBN 0964074044
17. Yuri Salamatov: TRIZ - The Right Solution at the Right Time. A Guide to Innovative Problem Solving. Insytec, Hattem, The Netherlands, 1999, 256 pages, ISBN 90-804680-1-0
18. John Terninko, Alla Zusman, Boris Zlotin: Systematic Innovation - An Introduction to Triz (Theory of Inventive Problem Solving). Saint Lucie Pr., 1998, 150 pages, ISBN 1574441116
19. TRIZ Research Report: An Approach to Systematic Innovation, 1998, ISBN: 1879364999
20. Vladis Kosse: Solving Problems with TRIZ. Ideation International Inc, 1999, 123 pages, ISBN 1928747019
21. B. Zlotin, A. Zusman G. Altshuller, V. Philatov: Tools of Classical TRIZ. Ideation International Inc., 1999, 266 pages, ISBN: 1928747027
22. Ideation Research Group: TRIZ in Progress. Ideation International Inc., 1999, 248 pages, ISBN: 1928747043
23. Ph.D. Stan Kaplan, S. Visnepolschi, B. Zlotin, A. Zusman: New Tools for Failure & Risk analysis. An Introduction to Anticipatory Failure Determination (AFD) and The Theory of Scenario Structuring. Ideation International Inc., 1999, ISBN 1928747051
24. Semyon D. Savransky: Engineering of Creativity: Introduction to TRIZ Methodology of Inventive Problem Solving. CRC Press, 2000, 394 pages, ISBN 0849322553
25. Boris Zlotin and Alla Zusman: Directed Evolution: Philosophy, Theory and Practice. Ideation International Inc., 2001, 103 pages
26. Kalevi Rantanen: Simplified TRIZ: New Problem Solving Applications for Engineers. St. Lucie Press, 2002, 280 Seiten, ISBN 1574443232