APPLICATION TRIZ IN VALUE MANAGEMENT AND QUALITY IMPROVEMENT

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Zinovy Royzen is the President of TRIZ Consulting established recently after his coming to the United States. He focuses on the development and application the Theory of Inventive Problem Solving (TRIZ) created in the former Soviet Union. He has a wealth of experience in application TRIZ tools and methods in cost reduction, improvement in quality and in reliability, predicting the development of products and technologies, and complex problem solving in the Soviet Union and Bulgaria. As a project manager of The Scientific and Technological Center, Kishinev, he conducted many TRIZ seminars and workshops and has applied TRIZ to many projects in different industries. The largest companies of the former Soviet Union were among his clients. He is an active inventor with many patents.

ABSTRACT

This paper describes some of TRIZ tools and methods based on the Laws of Engineering System Evolution (LESE): Method for Predicting the Development of a System, Principles for Eliminating Engineering Contradiction, Substance-Field Analysis, Standard Solutions for Inventive Problems, and Algorithm for Inventive Problem Solving.

APPLICATION TRIZ IN VALUE MANAGEMENT AND QUALITY IMPROVEMENT

To keep the competitive edge companies have to improve and renew their products and tech-nologies continuously. Engineering creativity is the most important part of any method and technique for this goal including improvement in quality and reliability of products and technologies and cost reduction. Effectiveness of creative thinking is the basis for successful approaching desired goals.

TRIZ has been proven by practice in the Soviet Union to be the most reliable methods for predicting the development of products, defining the most valuable problems to solve, and for complex problem solving quickly and effectively. Applications TRIZ in Value Management and Quality Improvement dramatically increased effectiveness of work and results.

It is common to try to solve a problem in one step and to come up with the solution immediately after definition of a problem. If an idea does not work one has to generate a new idea, and so on, until a workable idea is obtained. This problem solving technique is known as the trial-and-error method. It is good for simple problems where the amount of possible alternatives to generate is not more than 10-15. If the amount is more, it takes a lot of time (days, weeks, months, or sometimes even years) of effort to come to a workable solution.

<u>Creativity in many problem solving methods and techniques based on brainstorming.</u>

Its root is in psychology. Brainstorming breaks problem solving into two steps: free idea generation and then judgment. Alex F. Osborn specified four ground rules for developing creative ideas and solutions through the use of brainstorming[1] :

1. Criticism is ruled out.
2. Freewheeling is desired.
3. Quantity is wanted.
4. Combination and improvement are sought.

These rules help overcome preconceived notions and psychological inertia in generating new ideas. There is no a rule how one should generatenew idea.

TRIZ (TRIZ from the Russian for "the Theory of Inventive Problem Solving") is the next evolutionary step in creating an organized and systematic approach to problem solving. The dev-elopment and improvement of products and technologies, according to TRIZ, are guided by the objective Laws of Engineering System Evolution. TRIZ Problem Solving Tools and Methods are based on them.

TRIZ was created in the former Soviet Union. Genrich S. Altshuller, the creator of TRIZ, began in 1946 an in-depth study of the best inventions and history of the development of numerous products and technologies in different fields and industries. It was one of his greatest ideas to focus on studying inventions instead of studying psychology of creat-ive thinking. He considered an invention's disclosure as a description of inventive problems and ways of their solutions. He discovered the Laws of Engineering System Evolution and created problem-solving tools based on these laws.

LAWS OF ENGINEERING SYSTEM EVOLUTION

The Laws of Engineering System Evolution are the theoretical basis of TRIZ. TRIZ considers every significant improvement of any design or engin-eering system to be a step in its evolution. The most important steps in the development of design and engineering systems in different fields and industries are common. These steps were called the Laws of Engineering System Evolution. They are derived by analysis of thousands of patents and improvement of thousands of products and technologies.

Laws of Engineering System Evolution include:

Increasing the degree of approaching the imaginary Ideal System.

Eliminating contradictions.

Reducing and increasing the number of subsystems.

Increasing the degree of dynamism.

Increasing the degree of control.

Transition from macro to micro level.

Application different power fields in engineering.

Matching and non-matching characteristics.

Removing a human from taking part in performance and control of an engineering system.

S-curve life-line and three stages of the development of an engineering system.

A number of steps were revealed for every Law of Engineering System Evolution. Analysis shows that the development of any product or technology depend on these Laws of Engineering System Evolution. Survey shows that ignoring or misunderstanding the Laws of Engineering system Evolution is dangerous and very expensive for companies.

METHOD FOR PREDICTING THE DEVELOPMENT OF AN ENGINEERING SYSTEM

The Laws of Engineering System Evolution can be applied consciously to predict the develop-ment of products and technology, improve their quality and reliability and reduce cost. Methods for Predicting the Development of an Engineering

System based on application of the Laws of Engineering System Evolution include two major phases: problem definition by applying the Laws of Engineering System Evolution and problem solving. The sets of Laws of Engineering System Evolution cover all possible ways and directions of the development of a system because they were derived by study of the development of thousands products and technologies and proved by thousands of patents.

Applying this method, one can define the most important and valuable problems for improvement of one's system before these problems arise or before existing conditions are considered a problem. It is not necessary to wait until these problems arise. Very often these problems are very complex and only TRIZ problem solving tools help solve them quickly and effectively. Thus, one can predict the next step in the development of any product or technology.

System approach in TRIZ helps predict the development not only a system but also its subsystems, and super systems. It is possible to predict the influence of their development to each other. TRIZ Method for Predicting the Develop-ment of an Engineering System is unique. The result of the predicting is unique as well. It is a set of new engineering and design ideas and solutions. This set of solutions obtained by solving the problems defined by application Laws of Engineering System Evolution covers all possible directions of the product or technology development. Most solutions are patentable. They can protect the market of the system.

The solutions can be classified into several groups: solutions that can be implemented today, tomorrow, or the day after tomorrow. Classification depends on changes in design or technology required by a solution. The set of the classified new inventions and solutions is the basis of reliable long-term innovation strategy.

INCREASING THE DEGREE OF APPROACHING THE IMAGINARY IDEAL SYSTEM

TRIZ considers the real development of an engineering system only when it increases the degree of approaching the imaginary Ideal System. In TRIZ, an Ideal System is the system that doesn't exist but its function is performed. The Ideal Solution is an approach to the Ideal System. It means one makes necessary improvements without any changes, without any payment for its implementation, and without the deterioration of anything else in the system.

System approach requires definition of the image of the Ideal System not only for a system, but also for all its sub-systems and super systems.

It is common in engineering to pay for any improvement, but in TRIZ the imagination of the Ideal System helps one to define the most valuable problems for cost reduction and improvement of the system. These problems worth solving even though very often they are very complex. Image of the Ideal System and Ideal Solution helps overcome pre-conceived notions and psychological inertia. It shows the direction in problem solving and improvement like a lighthouse and helps avoid wasting a lot of effort. In contrast with brainstorming, there is no need to generate as many ideas as possible. The goal in problem solving is to approach the Ideal Solution.

ELIMINATING CONTRADICTIONS

Analysis of patents shows that good solutions of a complex invention are based on the eliminationof engineering contradictions. An engineering cont-radiction is a situation in problem solving where improving something in the system causes the deterioration of something else. Very often desire to improve something in a system conflicts with something else. Engineering contradiction make a problem very complex. In TRIZ such kinds of problems are called inventive problems. An inventive problem has great many possible alternatives and finding the best workable solution is very difficult by guessing or by generating as many ideas as possible. TRIZ classifies solutions into five levels.

First level solutions do not eliminate engineering contradictions. They are feasible solutions that may be chosen from up to 10- 15 possible alternatives. Very often possible alternatives are well known and available and improvement of a system is not significant.

Second level solutions eliminate engineering contradictions connected with this improvement by employing knowledge of the same discipline as the problems.

Third level solutions eliminate engineering contradictions connected with this improvement by employing knowledge of the same science as the problems.

Fourth level solutions eliminate engineering contradiction connected with this improvement by employing knowledge of a different science. For example, a mechanical problem may be solved by applying chemistry.

Fifth level solutions are based on new discoveries of rules of nature that have to be made to eliminate a contradiction.

Conclusion from this analysis is very important. The higher level a solution the more significant improvement of the system or cost reduction. The higher level a solution the more possible alternatives. Generating as many ideas as possible and work through all of them to find the best solution of a problem is good enough for finding first level solutions but is not effective to obtain solutions higher than first level. Background of the problem solver connected with problem very often is not enough to find high level solutions. There is a necessity for a new kind of knowledge and skills. They are the basis for definition of contradictions and their elimination. They have to help to connectcontradiction elimination and necessary knowledge in physics, chemistry, engineering, etc. TRIZ problem solving tools satisfy these requirements. TRIZ was created for solving complex inventive problems to create second and higher level solutions.

TRIZ Problem Solving Tools based on the Laws of Engineering System Evolution include:

The Principles and the Chart for Eliminating Engineering Contradictions.
The Substance-Field Analysis.
The Standard Solutions for Inventive Problems.
The Algorithm for Inventive Problem Solving.
Special Methods.

<u>The Principles and the Chart for Eliminating Engineering Contradiction.</u>

Analysis of more than 40,000 high level patented solutions conducted by Genrich S. Altshuller helped him to derive the primary kinds of engineering contradictions and basic ways of eliminating them. He called these basic ways the Principles for Eliminating Engineering Contradictions. The set of the principles consists of 40 principles, and most principles are composed of several steps.

The Chart for Eliminating Engineering Contradiction identifies more than a thousand basic kinds of engineering contradictions and suggests up to four of the most suitable principles for eliminating each of them. It helps to define the engineering contradiction(s) of one's problem and choose appropriate principles for eliminating them. The chart includes two lists of the system's 39 basic characteristics each. The first list comprises the system's characteristics that might be improved in problem solving. The second list comprises the system's characteristics that might be deteriorated by changes associated with improvement of the system. A pair of characteristics combined from these two lists is the base of the particular engineering contradiction. It means that by improving the characteristic of a system chosen from the first list, it deteriorates the other characteristic of the system chosen from the second list.

The chart is very easy to use. To solve a problem one has to define a characteristic of one's system which one wants to improve and choose a proper characteristic from the first list. One should define the technique of the improvement and characteristic(s) of one's system deteriorated by thisway of improvement. Choosing appropriate charac-teristic(s) from the second list, one finds principles suggested by the chart for eliminating engineering contradiction of each chosen pair.

The Substance-Field Analysis.

G. S. Altshuller created a special language for describing engineering systems, engineering problems and their solutions. This language is the Substance-Field Analysis.

Any engineering system, engineering problem and its solutions is described by a Substance-Field Model. The Substance-Field Model of the simplest workable engineering system consists of three elements, two substances, S1 and S2, and a field F.

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          F
           \
S2-------->S1
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S1 is an object. S2 is a tool.
--------> shows useful action S2 at S1.
F is a field of the action S2 at S1.

The word "substance" is used in the broadest meaning. It may be any item of an engineering system, a whole system, or any item of a system's environment. The word "field" is used in its broadest meaning as well. It indicates the nature of action and may be mechanical, thermal, or electric, etc.

A Substance-Field Model is a graph. If a function of a substance S2 (tool) is described using two words, a verb and a noun, so in the Substance-Field Model of the system a verb is shown by the field F and a noun by the substance S1. The description of a function by the Substance-Field Model helps one better understand it.

The Substance-Field Model describes only one function of a tool (S2), although it may have several different functions. Modeling breaks the tool (S2) into separate functions and, therefore, helps one better study a system. Any engineering system more complex than the simplest one is described by a number of the simplest Substance-Field Models and their combinations.

Substance-Field Models display very clearly the mechanism not only of any useful function but also of any harmful function.

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    F
     \
S2~~~~~~>S1
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S1 is a product. S2 is a tool.
F is a field of the harmful or undesired action S2 at S1.
~~~~~~~> means a harmful action.

Like any type of models, Substance-Field Model reflects in particular viewpoint the most important relationship of properties and interactions of a studying system and sacrifices the others. Substance-Field Analysis allows description by Substance-Field Models an initial system, the final system and the chain of alteration caused by the action S2 at S1. It is possible to describe the mechanism of a function.

Substance-Field Model of a harmful action is the Substance-Field Model of a problem. It is possible to describe by Substance-Field Model any possible deterioration that can be caused by desired improvement of something in a system. Such a kind of Substance-Field Model shows the heart of the contradiction.

The chain of immediate interacting substances is shown by a chain of Substance-Field Models. They display the function tree of a system and show both useful and harmful functions. The Substance-Field Analysis improves understanding of useful and harmful functions and their performance of each item of a system. They help not only understand the performance of a system but also define problems associated with it.

The Substance-Field Analysis includes rules of the Substance-Field Model building, changing and transforming. The Substance-Field Analysis is not only the convenient language for describing engineering systems but also is the tool to define and study a problem. It helps overcome pre-conceived notions and understand what is wrong, why it is wrong, and ways of improving it.

The importance of the Substance-Field Analysis for problem solving in engineering may be compared to symbolism in mathematics. The symbols are free from the restrictions that have been associated with words and particular problems.

The Standard Solutions.

There are many problems that are described by the same types of Substance-Field Models. Their solutions are described by the same Substance-FieldModels as well. The most important different Substance-Field Models of problems and ways of transforming these Substance-Field Models to the Substance-Field Models of problems' solutions were created from a study of the most effective solutions of complex inventive problems. These trans-formations were called the Standard Solutions for Inventive Problems. Each Standard Solution has confirmed a great number of good inventions. The Standard Solutions based on the best inventors' experience. Applications of the Standard Solutions mean using this experience consciously.

To solve a problem, one has to define the Substance-Field Model of the problem, identify the same Substance-Field Model of Standard, and use the Substance-Field Models of its Standard Solutions. It is not necessary to define the engineering contradiction connected with desired improvement of a system. Application of the Standard Solutions shortens time and effort of problem solving by suggesting readily available high level solutions' Substance-Field Models, which are based on the elimination of contradictions.

A set of 76 Standard Solutions includes 5 classes of Standard Solutions:

1. Increasing the performance of an engineering system.
2. Eliminating harmful actions.
3. Further improvement of an engineering system.
4. Eliminating problems in measurement.
5. Eliminating new problems caused by application of Standard Solutions.

Standard Solutions reflect the Laws of Engineering System Evolution. Applying them not only reveals Substance-Field Models of the all best alternatives but also predicts the development of one's system.

Algorithm for Inventive Problem Solving

The Algorithm for Inventive Problem Solving is one of the main TRIZ problem-solving tools. It is a program that consists of a set of clear rules based on the Laws of Engineering System Evolution. The Algorithm for Inventive Problem Solving is a guide for thinking. One should follow it step by step. A complex problem needs many steps to be solved. The Algorithm for Inventive Problem Solving divides a way of problem-solving in simple steps. They incrementally change a problem and make it simple to solve.

First, one should analyze the engineering system where one wants to improve something and define a problem that is worth solving. One should imagine the ideal system. The ideal solution is an approach to the Ideal System. One should seek to improve one's system without any complication of it or deterioration of anything in the system.

Often, something prevents one from reaching the ideal solution, or improvement of something in the system causes the deterioration of something else. Sacrifice is common, but not in problem-solving by using TRIZ. One has to define the engineering contradiction connected with reaching the ideal solution of the chosen problem.

The cause of an engineering contradiction is a physical contradiction. A physical contradiction is the opposite requirements to the same characteristic of the system. One has to define the physical contradiction.

The Algorithm for Inventive Problem Solving does not permit any compromise. One has to eliminate the physical contradiction. The Algorithm for Inventive Problem Solving has the set of principles for physical contradiction elimination.
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The only way to obtain the Ideal Solution is to use the resources of the system. The Algorithm for Inventive Problem Solving has special steps to study the resources of a system. Algorithm for Inventive Problem Solving demands eliminating physical contradiction by using the resources of the system. Resources are the basis for improving what one wants without any deterioration, complication or sacrifice something else of the system.

The Algorithm for Inventive Problem Solving is a means of overcoming preconceived notions in a field of a problem and possible ways of solving. The first, the Algorithm for Inventive Problem Solving, as a step-by-step program, is a great means itself to overcome preconceived notions. It also includes additional methods and special steps.

The Algorithm for Inventive Problem Solving has adapted a collection of physical phenomena, knowledge in chemistry and other data to applications in problem-solving by the Algorithm for Inventive Problem Solving for eliminating physical contradictions.

According to the Algorithm for Inventive Problem Solving it is not necessary to generate asmany ideas as possible and then select the best one. It is enough to reach the only best solution, the Ideal Solution. The way for approaching the solution is broken into simple steps. Steps change a problem, help one approach closer the heart of a problem, the physical contradiction, and then eliminate it. Algorithm for Inventive Problem Solving has steps for further improvement of obtained solutions.

The Algorithm for Inventive Problem Solving was created for solving high level problems in engineering. It has proven to be the most effective method in complex problem solving not only in engineering but in any field. It is possible because of the similar laws of evolution of systems of different fields of human activity. The only difference in application of the Algorithm for Inventive Problem Solving for different fields is the resources one draws upon.

<u>S-curve life-line of product or technology.</u>

The S-curve is a graph that shows the increase of a system's performance during its life. Understanding of the S-curve life-line of a product or technology doesn't help to improve a product or create a new one but it is very important to design a company's strategy.

The first stage. At first, the idea of a new product, or a new invention very often is not workable. It is necessary to put a lot of effort, to find many high level solutions and invest a lot of money to make it commercially feasible. At this stage, improving a new product's performance is very slow and rather expensive. Very often it req-uires fundamental research.

The second stage. As soon as the system becomes workable the rate of increasing its effectiveness goes up. There is no need for as much fundamental research as in the first stage. A smaller investment in this stage improves the system much more than the same input in the first stage.

The third stage. The development of any system has its limit. Increasing the power of a propeller plane cannot increase the speed adequately. Approaching the system's limit, the rate of increase of its performance is related to input slowing. Any additional input cannot give significant changes. Level of the solutions for improvement the system lowers. Producers make a lot of money due to great output and very often they do not anticipate any significant changes.

Richard Foster described in detail his study of the advantages of understanding and the dangers of ignoring S-curve life-line of products and technologies for the best U.S. companies[2] 10 years after publishing the first version of the set of the Laws of Engineering System Evolution in the Soviet Union. He showed that changes occur too suddenly for companies that believe in their efficiency but forget to increase system's effectiveness. He showed that the best companies "assume that as risky as innovation is, not innovating is even more risky." Innovation is inevitable.

It is known that often the same inventions are created by different inventors at the same time, independently. These facts not only prove guiding of the development of products and technologies by the Laws of Engineering System Evolution but also means that the next product with better performance and higher limits beats the competition if another company produces the new product first. The best way is to let a company's new product compete with its previous one. "Intel came to recognize that if it didn't bring out products that would make its older ones obsolete, someone else would. "Our goal", joked executive vice president Craig Barett, "is to be the best possible cannibal in the world and to eat our children as fast as we can[3]"

Innovation is manageable. The most reliable and effective way to renew a product or technology is to predict their development and new ones according to the Laws of Engineering System Evolution. They say not only all directions for improving the existing system but also give suggestions about all new ones that will win competitions in the future. These recommendations are not words. They are inventions that may be patented and to be the most reliable base for a company's strategy.

Effectiveness of TRIZ does not mean that it can help one to solve any complex problem. It is not possible to improve a system significantly when it approaches its limit. In this case TRIZ can help predict the new system that will change the existing one.

Analysis not of one's problem but one's system helps change viewpoint on the system and chooses problems that worth solving to improve one's system.

Anyone practicing Value Management or involved in Quality Improvement would benefit from applying TRIZ. TRIZ is a significant additionto existing techniques. TRIZ substantially changes analysis of a system, problem definition, problem solving and further development obtained solutions. TRIZ tools and methods are the same in any field of engineering and in any industry. TRIZ as a basis of engineering creativity increases effectiveness of work and results dramatically.

From the very beginning of his work G. Altshuller has been trying to interest the Soviet Union authorities. In 1950 he was repressed after writing a letter to Stalin with proposals to improve inventors creative activity and was sent to a labor camp near Syktyvkar in the North of the Soviet Union. He continued his work on TRIZ there. He got freedom only after Stalin's death. Government authorities did not help him in spreading TRIZ except for a very short time in 1968 when they sponsored the first TRIZ seminar.

In 1956 G. Altshuller published the cornerstone ideas of TRIZ[4]. The first version of The Algorithm for Inventive Problem Solving was published in 1959. In 1968 he conducted the first five-day seminar. Since that time TRIZ have been develop-ing by Altchuller's school. Many seminars and workshops have been conducted and many books have been published by G. S. Altshuller and some of his pupils[5,6] . The Soviet Union Association of TRIZ Specialists was established in 1989 and G. S. Altshuller is its President.

The first Value Analysis Project was started in the Soviet Union in 1977. At that time there were specialists in TRIZ applying TRIZ tools and methods for complex problem solving.

Since it became possible to establish private companies and cooperatives in the Soviet Union, TRIZ firms have been established in many cities of the Soviet Union.

TRIZ has proven by practice to be a reliable method for solving complex problems quickly and effectively and significant addition to Value Management and Quality Improvement techniques.

Companies believing that people are their most important resource for renewal could gain much more. TRIZ would increase creativity of their engineers and management dramatically. Studying TRIZ changes one's way of thinking in problem solving and system development. Imagination of one's Ideal System, definition of the contradictions that prevent one from approaching it, and ways oftheir elimination are milestones in TRIZ creative thinking. Any participant of TRIZ seminars can become a successful inventor. The creative motivation of most participants of TRIZ seminars and workshops increases dramatically. They could renew not only products and technology but also themselves.

CONCLUSIONS

TRIZ is a new science. It required a lot of training to be used effectively. TRIZ accumulated and organized the best human experience in inventing, complex engineering and design problem solving, and improving products and technologies. TRIZ Tools and Methods based on the Laws of Engineering System Evolution help one not only avoid wasting a lot of time and effort in improvement of one's products and technologies but also increase effectiveness of work and results dramatically. It is a unique method for predicting development and new products and technologies. It is a way to create effective patents. It is the most reliable guide for power creativity.

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