Classical TRIZ and OTSM as a scientific theoretical background for non-typical problem solving instruments

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Abstract

This paper presents the structure of Classical TRIZ (the Theory of Inventive Problem Solving created by Genrich Altshuller) and OTSM (the Russian acronym for the General Theory of Powerful Thinking, proposed by Altshuller in several papers and letters to the Russian TRIZ community between 1975 and 1986). In brief, the model comprises a key problem to be solved by the theory and the assumptions established to solve it. A set of fundamental models based on these assumptions was developed as the theory evolved. Practical instruments were then developed on the basis of these models (i.e. within the framework of the original assumptions). The System of Instruments was also used to evaluate the theory and develop it further. The model of an applied scientific theory was used to study TRIZ and develop OTSM.

Keywords

TRIZ, OSTM, Problem Solving, Thinking, Creativity, Theory, Axiom, Postulate, Model, Instrument.

INTRODUCTION

TRIZ provoked much discussion from the outset. [1]. It was between 1946 and 1949 that it first appeared as a technique for invention. [2]. In his very first publication Altshuller described the way the technique was evolving. The program was fully completed in the mid 80s. Altshuller proposed the development of several new branches of Classical TRIZ: the Theory of Engineering Systems Evolution (Russian acronym – TRTS), the Theory of Creative Personality Development (Russian Acronym – TRTL) [3], and the General Theory of Powerful Thinking (Russian acronym - OTSM) [1,4,5,6]. In 1986 Altshuller started to try out a new methodology for teaching TRIZ. Its main feature was the development of a storyline for a fairy tale based around a given element. In order to carry out these assignments students had to use TRIZ and its instruments. Unfortunately Altshuller did not develop this educational technique further. In the course of teaching TRIZ a wide variety of training programmes were developed or adapted and modified as need arose. A branch of TRIZ was developed to facilitate the transfer of the TRIZ body of knowledge. Educational techniques further influenced the evolution of TRIZ and, as mentioned above, occasioned the development of new branches.

A historical analysis of the evolution of engineering systems, coupled with the process of TRIZ training, helped to reveal that there was a consistent pattern. This led to them being oganised into a system of postulates, models, and objective laws through which problem solving instruments could be developed. Altshuller and his students applied these to real life, thereby ascertaining any weaknesses that needed addressing while, at the same time, continuing to study the evolution of engineering systems.

Step by step the technique evolved into the Algorithm of Invention and Innovation - ARIZ. Critics now accepted that it was possible to develop a technique for invention but rejected the idea that algorithms could be used for invention and innovation. The mid 70s saw the appearance of the Theory of Inventive Problem Solving (Russian acronym – TRIZ). It was first produced in 1975 in manuscript form [7] and later published as a book [8]. Opponents now accepted the possibility of algorithms of Invention and Innovation but refused to accept that it was possible to create a scientific theory of Invention,

Creativity and Innovation [9]. This discussion is still ongoing. In this paper we present our perception of Classical TRIZ and OTSM as scientific theories, their structure, and our vision of the evolution of TRIZ and OTSM.

1 WHY DO WE NEED SCIENCE AND WHAT IS THE STRUCTURE OF AN APPLIED SCIENTIFIC THEORY?

Throughout our research we have posed this question to many scientists, researchers and TRIZ experts, from a variety of different disciplines from all over the world. Most of them have found it difficult to answer straight off. Searching through the various encyclopaedias - Britannica, Webster, Brochause & Efron, Wikipedia, Encarta etc. - shows that there are a lot of different opinions that correlate with each other in some ways but differ in others.

Based on this research we offer the following answer to the question above: science and scientific knowledge can explain the basic fundamentals of a working system that helps human to obtain desirable results with less trial and error. Science can achieve a more reliable prediction than human trial and error without scientific knowledge. When design engineers develop bridges or architects plan new buildings they use scientifically developed instruments to dramatically reduce the element of trial and error, leading to more rapid achievement of the desired result. The better the scientific theory the better the instruments, and the less the trial and error the greater the potential for the complexity of the desired object.

In order to reduce the amount of trial and error scientific theory needs to answer certain questions or solve certain problems or contradictions that are the root causes of the main problem. Therefore, the first and the most important part of a certain scientific theory is the Question to be answered or the problems to be solved by the theory. These questions and problems are the starting points for many scientific theories. Sometimes different theories propose different answers to the same question, as was the case with the question about the nature of light. In fact both theories are now accepted by the scientific community world-wide.

In order to answer these questions or solve these problems certain assumptions have to be made from which to create the theory. Usually these assumptions appear in the course of the development of the theory and are called postulates or axioms. They define the scope of the application of the theory.

An applied scientific theory must have a set of component instruments with which to put it into practice and evaluate its own quality. The more effective the function of these instruments within the framework of the theory, the better the theory itself.

In order to create the instruments, the theory needs a set of fundamental models that can be used to describe the elements and processes of the particular kinds of systems with which it is concerned. This set of models should be based on the postulates or axioms relevant to the questions or problems that the theory is required to answer or solve.

Thus, in our opinion, a mature applied scientific theory should have at least four main components:

1. The problem to be solved by the theory: the problem can be presented in the form of a question to be answered by the theory and is thus <u>the subject</u> of the theory;
2. A set of Postulates or Axioms that show what assumptions have been made in the course of the development of the theory. The axioms or postulates describe <u>the scope of</u> <u>the application</u> of the theory.
3. A set of fundamental models on which the theory operates in order to describe the elements and processes of the systems that are being considered by the theory – i.e. <u>the objects</u> of the theory;
4. A set of instruments to enable the theory to <u>be applied in practice</u> and <u>evaluated in terms of efficiency</u>.

The purpose of our paper is to invite open discussion on the scientific background of Classical TRIZ in order to help researchers to develop a greater variety of modern and more efficient branches of Classical TRIZ. OTSM is just one example of an additional branch that we use to apply the proposed model of Applied Scientific Theory. Initially OTSM was developed to extend the efficient application of Classical TRIZ to a variety of non-engineering fields, particularly the area of Education. Over the last few years OTSM has also been developed in the direction of dealing with problematic complex interdisciplinary situations. These can present several hundreds of problems and contradictions. A good example would be the question of sustainable development in a city or local region. This would include not only engineering, but a complex of interrelated social, economic and environmental issues.

2 CLASSICAL TRIZ AS AN APPLIED SCIENTIFIC THEORY

2.1 The key problem to be solved by Classical TRIZ.

One of the most widely accepted stereotypes of creative (non typical) problem solving is that one has to generate as many different solutions as possible before being able to select the right or appropriate system of solutions. However, such creative problem solving methods and recommendations do not usually provide users with selection criteria. On the one hand we hear it recommended that selection should be left to the experts. On the other hand, research carried out by Genrich Altshuller and Igor Vertkin [3] shows that the more innovative a solution is, the more resistance it will face from the experts as well as the general community. The less innovative an idea is, the more readily it is accepted by the experts. Research conducted by Richard Florida into the areas of the USA where most innovation occurs revealed that the local populations were much more open to unusual ideas than elsewhere. [10]. So tolerance is key to innovation. Historical research carried out by Altshuller and Vertkin shows that experts become increasingly intolerant in their evaluation of an object the more innovative it happens to be. This means that we need to be cautious about the conclusions of experts. They have already killed or at least set back a large number of innovations. This is also confirmed by the experience of expert TRIZ practitioners who have been applying it for over 20 years. The jury is still out on the question of objective criteria for the evaluation of innovation. This dramatically decreases the efficiency and effectiveness of traditional creative problem solving methods.

As TRIZ started to evolve, Altshuller reached the conclusion that in order to increase the efficiency of a creative (non-typical) problem-solving instrument it was important to decrease the amount of wasted trial and error, and simply generate good and useful ideas instead. This conclusion led to the subsequent question of how to simply generate useful ideas that could help to solve an inventive (creative; non typical etc.) problem.

Inherent in this problem was the following contradiction that was able to be formulated following Altshuller's ARIZ rules [11]:

in order to obtain a satisfactory solution for a non typical problem we have to carry out a lot of trial and error, but that takes time if we are to come up with the best one.

On the other hand:

in order to reduce the amount of time taken to arrive at the right solution we need to reduce the volume of trial and error - but this decreases the likelihood of obtaining an appropriate solution.

According to the ARIZ rules for identifying the Ideal Final Result (IFR), we can formulate IFR and the key problem for the above contradiction thus:

it is necessary to develop a problem-solving method that leads us directly to an appropriate solution with a much reduced amount of trial and error (or preferably no trial and error at all) so that we do not need to spend time on making a selection.

How can this be done?

It was precisely to answer this key question and to resolve the inherent contradiction that Classical TRIZ was developed. For this the traditional scientific method was applied: the gathering of existing information, analysis of that information and the discovery of certain patterns that could help answer the question and solve the problem. Eventually several postulates were formulated. In 1979 G. Altshuller refers [12] to the two main postulates of classical TRIZ taken from among several others that were considered during the course of Classical TRIZ evolution:

1. The Postulate of Existing Objective Laws that drive the evolution of engineering systems.
2. The Postulate of the Evolution of an Engineering System as a sequence of contradictions and their resolutions.

   The need for a third postulate concerning the importance of the peculiarities of a given problem was proposed at the beginning of 1997 by Kim Khadeev during our discussion about Classical TRIZ and OTSM. Later, in July 1997 the third postulate was accepted by the author of Classical TRIZ and consequently adopted.

3. Postulate of a specific situation: the peculiarities of a given situation should be taken into account in the course of the problem solving process.

   The third postulate seems far more obvious than the first and second. Furthermore it is as implicit a part of ARIZ as are the other two. But it is important nevertheless to mention it clearly and separately. As soon as we started using it in our classes there was a marked improvement in the efficiency of our TRIZ training. Above all these three postulates appear as a complete system comprising the most general and therefore universal instruments for problem solving. This complete system of postulates is also useful for the continuing research and the development of the OTSM version of Classical TRIZ.

   Basically, the system of the Classical TRIZ Postulates helped to obtain the TRIZ answer to the key question as to how to avoid wasteful trial and error and develop more predictable positive results – whether for invention or innovation.

   We can dramatically decrease the amount of wasted trial and error if we consciously use the Objective Laws of Engineering Systems Evolution. They require taking into account the restrictions of a given situation and, most importantly, showing problem solvers the point that they should focus on and how to identify the contradictions that underlie it. Clear formulation of those contradictions substantially decreases wasteful trial and error. Our experience shows that if a person clearly understands all three of the postulates their problem solving skills can be improved dramatically even without learning TRIZ. Further teaching in TRIZ and especially ARIZ can help people to apply those three postulates even more efficiently and precisely so as to obtain satisfactory solutions through decreasing fruitless and time consuming trial and error.

   It is important to stress that the more developed a scientific theory is, the less trial and error needs to be carried out by the user in order to obtain a satisfactory result. Theories about thinking and problem solving are no exception.

2.2 The three Fundamental Postulates of Classical TRIZ

As we mentioned above postulates can be used as the most general problem solving instruments. One more function of postulates (assumptions) is to define the scope of the theory and the effectiveness of its instruments.

Postulate of objective laws

Engineering systems evolve not randomly but according to certain laws of evolution. These laws can be identified and used for problem solving.

Classical TRIZ considers the problem solving process as a process of transition of a given engineering system to the next level of its evolution. This system of laws was published in 1979 in Russian and in 1984 in English. [8].

Postulate of Contradictions

In the course of its evolution an engineering system has to overcome a certain set of contradictions. To progress to the next stage it has to resolve the contradiction that prevents it from evolving and which is usually considered to be a problem. It is possible to develop special instruments to handle contradictions and resolve problems. These instruments need to be based on the Laws of System Evolution.

Therefore each non-typical (inventive, creative) problem needs to be formulated as a contradiction to be resolved.

Postulate of the specific situation

Each Inventive (non-typical, creative) problem arises within its own individual context. Identifying and defining the features specific to it helps to clarify its scope and identify what needs to be taken into account in the course of solving it.

This reduces the area of research that a problem solver needs to cover and enables him or her to follow a step by step process to the development of a satisfactory solution. This is what is meant by the Postulate of the existence of Objective Laws and the Postulate of Contradictions; i.e. problem solving needs amongst its components the means to investigate the peculiarities of a specific situation as part of the step by step approach.

We have to stress here, that postulates and all other instruments of Classical TRIZ help the problem solver to reduce the area of research; they do not provide an immediate solution in itself, but the means to build up to it. Classical TRIZ helps problem solvers not to look for the solution but to create it slowly but steadily with minimal useless trial and error. OTSM has taken this principle further.

At this point we have to state clearly that neither TRIZ nor OTSM based Instruments pretend to replace any area of professional expertise. TRIZ and OTSM provide us with the meta-knowledge necessary to help problem solvers reorganize - not replace - their existing professional knowledge in such as way as enable them to solve the problems they wish to address.

The next statement is attributed to Albert Einstein: "*The problems that exist in the world today cannot be solved by the level of thinking that created them.*" TRIZ and OTSM based instruments are dedicated to helping problem solvers change their level of thinking. The three postulates of Classical TRIZ play a pivotal role in this process.

2.3 Two Fundamental Models of Classical TRIZ

Scientific theory needs instruments or language with which to describe components, systems & the theory being dealt with. In TRIZ this function is performed by the System Operator model. The System Operator helps the problem solver to present and review elements of the problem in relation to each other on various levels (Hierarchy Dimension) for various purposes (Anti-system Dimension) and in the context of various processes (Time Dimension).

Applied theory is dedicated to the efficient implementation of certain changes. Change being a process, applied theory needs a process model which can enable the theoretical study to be put into practice. In our case it is a problem solving process.

Below you will find a brief presentation of both the models developed by Genrich Altshuller.

System Operator (SO)

To describe the processes and components of a problem Altshuller proposed the model of the “System Operator”. He also called it a Complete Schema of Powerful Thinking. Altshuller used to use 18 “screens” to explain what in the framework of Classical TRIZ is considered to be powerful thinking. Somehow it was transformed by modern TRIZ users into a 9, 5 or even 3 screen schema… The original 18 screen operating system is the best way to start with an explanation of this complex model.[7]. but the number of screens does not, in fact, need to be limited to 18. Depending on the given situation there could be many more screens that the problem solver might bear in mind. Sometimes, for practical purposes we may need to use more screens and dimensions.

For instance the Time Dimension often needs to be split into several sub-time dimensions. The hierarchy depends on the goals we are trying to achieve by solving problems and in the process we may formulate the function of a system and identify the level that can be considered as a starting point for defining Super-systems and sub-systems. The Anti-systems dimension has two sub-dimensions: Anti-System by Function and Anti-system by Functioning.

That is why for practical purposes it is better to talk about 3 dimensions:

(1) Dimension of Hierarchy;

(2) Dimension of Time;

(3) Dimension of Anti-systems.

Each of these dimensions has sub dimensions. That is why in the course of OTSM evolution the System Operator model appears in a more advanced form directed towards the solution of complex interdisciplinary problems.

The Classical TRIZ System Operator underlies the structure of ARIZ . Altshuller often referred to the ARIZ System Operator being part of a continuum....

ARIZ is an instrument designed for the practical application of this theoretical model. The second model that underlies ARIZ is a TRIZ model of a problem solving process.

The TRIZ Model of the problem solving process

Altshuller described the model of the problem solving process in [13]. In this paper Altshuller also referred to the five fundamental steps of the TRIZ based problem solving process:

1. Description of an initial problem situation.
2. Transition from the problem situation to a problem to be solved.
3. Transition from the problem to be solved to an Ideal Solution.
4. Transition from the Ideal Solution to a Physical Solution.
5. Transition from the Physical Solution to an Engineering Solution.

This paper was written about ARIZ-71 in 1975. In it Altshuller wrote that these steps needed to be developed further. In ARIZ-77 and later ones including ARIZ-85-C we can see the further development of the problem solving process. For instance between step 2 and 3 two more steps appear: (a) Transition from the Problem to be solved to a model of the problem and (b) Analysis of the model.

For certain historical reasons in the later stages of TRIZ evolution Altshuller focussed on the steps between 2 and 5. He intended to develop a special instrument for the initial description of a problem and for selecting the problem to be solved. In OTSM these kinds of instruments were developed further: the New Problem Technology and especially the Network of Problems which lies at its core.

Several more steps appeared in the problem solving process after a paper (in the form of a manuscript) was disseminated within the Russian TRIZ community. This Altshuller called the Public Laboratory of the Invention Theory (Russian acronym – OLTI- pronounce [oltee]). Two more steps were added to the end of the process, following the achievement of a satisfactory engineering solution - namely: © developing the solution further in order to enlarge and discover new areas for its application; (d) reflection on what the problem solving process had entailed and how satisfactory had been the solution that had been obtained, and what had been the difference between the theoretical process and the real problem solving process in each specific case. We should stress that the reflection stage is very important for the further improvement of both the skills of the individual problem solver and for the general development of a problem solving theory and its practical instruments.

Finally the complete TRIZ model of the problem solving process appeared as a process of 9 fundamental steps. The instruments of Classical TRIZ, applied in various combinations, bear out each of these fundamental steps.

3 THE INSTRUMENTS OF CLASSICAL TRIZ

TRIZ appears as a theoretical background to the development of practical instruments for non-typical, creative problem solving. We consider a problem to be a ‘creative’ one when it needs to be solved by creativity – i.e. by the development of some new kind of trick where no existing ‘typical’ solution is known. Typical solutions appear in the course of the evolution of any given body of professional knowledge. Someone in the past has been faced with creative problem and by trial and error has discovered a creative solution. Initially it appears as the professional secret of the Inventor but eventually it becomes widely known and accepted as a ‘typical’ or standard solution. In the course of their professional training new professionals learn those typical solutions as “ready to use” and apply them in their everyday work. Sooner or later new non-typical (creative) problems appear and the cycle repeats itself so that each non typical – creative - solution becomes typical and ordinary. This is how creativity gets “killed”: sooner or later every originally creative, non-typical solution becomes routine and familiar. It is the same with many areas of every field whether it be engineering, management, or the arts. In the case of the latter that is how, for instance, new styles come into fashion.

Throughout its history Classical TRIZ experts have been called on by top rate professionals faced with non-typical problems to which they have wanted speed solutions. Frequently, a problem that at first glance seems to be non-typical (creative) turns out, when examined by TRIZ experts using TRIZ based instruments, to be a standard typical problem. This is because TRIZ based typical solutions can be widely applied to a variety of fields of human activity. A good example of this is when mainframe computer developers were faced with a problem of mismatch between the speed of human thought and work and the high speed of a computer. They saw it as a huge creative problem because the potential of working with computers was limited by the delay in human reaction time. The solution that was considered as a breakthrough by professionals now looks like a very ordinary typical solution even for TRIZ beginners – separation in time and the convergence of several tasks that Mainframe computers can perform “simultaneously”. This means that while the computer was waiting for the reaction of User 1 the computer was working on the task of User 2 or 3 or whatever… As soon as User 1 reacted, the computer switched back to the his or her task and was able to postpone the other tasks until User 1 needed time for the next reaction.

This example shows how a problem that can appear as a creative one to one person can be seen as typical and routine by another. Based on this some people say that TRIZ kills creativity – but this could not be further from the truth. TRIZ and some of its modern branches just move creativity onto the next level of evolution, opening up new horizons for creativity. Altshuller’s ARIZ is one of the best known instruments for this purpose. But it could not work efficiently without TRIZ instruments for TRIZ-typical problems.

It is difficult to list all the Classical TRIZ based instruments in this short paper but some are presented under [14] with a brief background and history to each.

3.1 The Instruments for TRIZ typical problem solving

First of all we have to re-state that we consider a problem as typical when it can be solved by general rules; i.e.

IF … (a description of a problem)…..

THEN … (a general description of a typical solution for the given problem ...

Today perhaps the best known Classical TRIZ based instrument for TRIZ typical problem solving is Altshuller’s Matrix of Technical Contradictions. However, very few people know the fact that in 1986 Altshuller had concluded that this instrument was a big mistake and dead end as far as TRIZ evolution was concerned and he was very disappointed and sad for the 7 years that he had spent developing it. As a result we find no reference to this matrix in the latest version of ARIZ. Altshuller decided to move the matrix out of the TRIZ based toolbox. Why was this? - Because a new powerful system of TRIZ instruments had appeared.

The System of Standards replaced the Matrix. TRIZ Standards are better matched with all the other instruments of Classical TRIZ and especially with ARIZ and Altshuller’s system of the Laws of Evolution. The System of 76 TRIZ standards better matches the Laws and appears to be a more precise instrument for applying the general Laws of system evolution to practical needs. The Laws can still be used as one of the typical instruments of TRIZ for improving a system but negative effects are not known. The laws can also be considered as an element of TRIZ based forecasting. The Implementation of the Laws of evolution as a tool for forecasting is an oversimplified approach and the user needs to be careful when using them. To improve the quality of a forecast some other TRIZ instruments need to be used, but not only relevant to TRIZ .

The above Matrix, the Law and Standards and some other TRIZ instruments can be considered as instruments for TRIZ Typical problem solving. These include a set of pointers of effects. The pointers are a directory of fundamental scientific knowledge conveniently organized for engineering problem solving. Some other TRIZ based instruments for typical problems are less general which is why we are not referring to all of them here.

3.2 ARIZ – an instrument for handling a problem that is non typical even for experienced TRIZ practitioners

ARIZ could be considered as a systems integrator for the whole of the Classical TRIZ body of theoretical knowledge and all the instruments dedicated to its practical implementation.

The first versions of ARIZ had a special part that was dedicated to the transition from an initial problem to a problem to be solved. However, Altshuller eventually arrived at the conclusion that this sub-function in the complete Classical TRIZ based problem solving process should be developed as a separate instrument - as an Algorithm for identifying a problem to be then solved by ARIZ. That is why this part is absent in ARIZ-85-C. Some other modification of ARIZ was planned by Altshuller, but they were not carried out for certain historical reasons. That is why Parts 6-7-8-9 look relatively weak compared with parts 1-2-3-4-5.

Version ARIZ 85-C [11] was considered by Altshuller as the end point of a previous S-curve of ARIZ evolution and the starting point to a new S-curve of ARIZ and the whole Classical TRIZ evolution. We need to ask ourselves why.

First of all according to Altshuller the 76 System of TRIZ standards covered more then 90 percent of all the real life engineering problems faced by TRIZ experts in the mid 80s. That means that most of the problems that appeared as non-typical for professionals were able to be considered by TRIZ experts as TRIZ typical problems. In order to implement Standards efficiently it is necessary to apply the first part of ARIZ-85-C: transition from a problem to a model of the problem. For beginners it is difficult to implement the standards directly without ARIZ, because the description of a problem can involve several aspects and fields which make it difficult to define. We obtain a much clearer description of a problem once part one is completed and the problem solver obtains a description of the Model of the Problem. The Model clearly identifies a Product and a Tool and the interaction between them. This model can be easily transformed into a Substance Field (Su-Field) model of a problem and then a System of Standards can be used to arrive at a general description of a conceptual solution. This means that to develop ARIZ further we have to collect a set of problems that cannot be solved with this version of ARIZ. This how Altshuller's ARIZ evolved.

The second point is that the procedure of problem solving (Parts from 1 to 5) was far better formalized than it had been in previous versions. He proposed to focus on the evolution of ARIZ: parts 6-7-8-9. This allowed the discover of something new that had been obscured by the fuzziness of the ARIZ steps.

Out of these two points appeared the third; though the last it was not the least in that Altshuller considered ARIZ-85-C a turning point leading to a new stage of ARIZ and the entire Classical TRIZ evolution. He named this new generation of Classical TRIZ the 'General Theory of Powerful Thinking' (Russian acronym – OTSM).

What was this third point?

As soon as the first and second parts had been adequately formalized it became clear that underlying them was part 3 and that in order to improve the level of formalization of the next generation of ARIZ this part had to be paid special attention to. Why was this?

The answer becomes clear if we remember that parts 1 and 2 are mostly analytical. However, in part 3 of ARIZ-85-C in addition to the analytical components, there increasingly appear others that call for synthesis in order to create a satisfactory solution. Before part 3 ARIZ used a linear or circular structure to link all the steps. Part 3 started a new line of ARIZ evolution. In Part 3 we can see that the user has to maintain several lines of analysis according to each of the data points that replace the X-elements in step 3.2. This greatly stimulates the idea generating process. Altshuller himself stated that this parallel analysis was a innovation that needed further development and which might be the point at which computers could support the human thinking process.

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All the above, plus numerous success stories about the application of TRIZ to non-engineering problems led to the development of OTSM. One of the starting points was part 3 and the parallel analysis that started to appear there. This resulted in the OTSM Problem Flow Technology and later on to an OTSM Problem Flow Networks approach that could be considered as a poly-ARIZ for complex interdisciplinary problems.

The proposed model of an applied scientific theory structure was used to study Classical TRIZ in order to understand the deep links between the Theoretical models of Classical TRIZ and its practical instruments and was very helpful in applying them. The same model of a scientific theory was used deliberately in order to develop OTSM. We have organized our research to answer the four following questions: (1) what is the key question to be answered by OTSM; (2) what should the system of axioms be; (3) to what extent should the two fundamental models of Classical TRIZ be developed and (4) what influence would those theoretical conclusions have on the instruments of Classical TRIZ, and what new instruments could be developed on the lines of a new theoretical basis?

4 THE STRUCTURE OF OTSM AS A SCIENTIFIC THEORY AND ITS CORRELATION WITH CLASSICAL TRIZ.

It took a lot of time to understand TRIZ as a scientific theory and present it in the structure we have provided above. It was necessary to keep the strong points of Classical TRIZ while improving on the weak points and adding new positive points. It helped to develop OTSM and its instruments. We consider this chapter as one more example of the implementation the structure of a scientific theory as an instrument to develop new applied theory. This chapter should be also considered as result of the Classical TRIZ application for self-improvement.

4.1 The key question to be answered by OTSM

In the fall of 1984 Altshuller proposed a key problem to be solved by OTSM - thinking about how each of the infinite numbers of known and unknown problems could be formulated into a canonical form so that the typical solution process could be applied in order to obtain a satisfactory solution. As usual, Altshuller exaggerated the problem according to the Classical TRIZ rule of exaggeration of a problem and its desirable result. This general rule, as with the postulates, helps to narrow down the research area and discover the roots of a problem. All the TRIZ based instruments were used to clarify the key problem to be solved by OTSM. In the beginning it seemed it would be impossible to solve the problem but Altshuller provided an example from real life – the history of the instruments for solving quadratic equations. Initially it was an Art, but as soon as the Viet Theorem was proved, it became routine work that could be done on a computer even without the aid of a human. So the key question for OTSM was reformulated in the following way:

what should be the conical form for the description of the problem and what should be the canonical solution procedure? In the course of the research an underlying contradiction was identified:

the rules for then OTSM instruments needed to be general enough that they could be universally applied, but then general rules provide us with over-generalised solutions that are of little use when applied to specific problems.

On the other hand:

in order to be able to obtain a specific solution to a specific problem, the OTSM instruments would need to be very specific, but specific rules are not universal.

The IFR for the contradiction was formulated according to the rules of ARIZ-85-C:

The rules of the OTSM instruments for problem solving needed to be most general and therefore universal, but they also needed to be usable in obtaining a very specific solution for a very specific problem.

As soon as the key problem was formulated in this way a typical Classical TRIZ solution was immediately able to be implemented: each component of a system has one property but the system as a whole has opposite properties. A good example of this would be a metal watchstrap: each of its components is not flexible but the watchstrap as a whole is flexible.

For the OTSM instruments: each of the instruments had to be very general and therefore very universal, but the system of instruments should be able to be used to obtain very specific solutions to very specific problems.

Based on this conclusion some further research was done and the most general canonical form for the description of a concept solution was proposed: *Certain parameters of certain elements should obtain certain value for certain specific conditions.* Thus the most general canonical problem appears as a question: how can these elements, parameters, values and specific conditions be identified in the course of the problem solving process? Finally the key question to be answered by OTSM was reformulated this way: how can a description of a specific problem be transformed into the description of a specific satisfactory solution?

To answer this question we started to develop general typical and universal procedures. As in Classical ARIZ each of the steps of the procedure appears as very general but the procedure as a whole helps the user transform the initial problem description into a description of a specific satisfactory solution.

The complete procedure is known today as the Problem Flow Networks Approach. It integrates all the other instruments of OTSM and Classical TRIZ into a unified system.

In the course of the research into the canonical procedure three axioms of classical TRIZ were reviewed and transformed into a set of OTSM Axioms. The two main models of Classical TRIZ were revised and developed further in order to fit modern requirements for an Efficient problem solving method [15]. A system of OTSM instruments was also simultaneously developed based on those Axioms and models [5, 6]. All of them are going to be presented as separate papers. Here we are presenting them only very briefly.

4.2 OTSM Axioms

In order to answer the key question, a set of assumptions was made and presented as a system of OTSM Axioms. The system consists of one fundamental Axiom – the Axiom of Models (Descriptions) and two groups of Auxiliary Axioms: (1) Axioms that describe the model of the thinking process for solving problems efficiently. (2) Axioms that describe the uses of the problem solving model of the world where problems arise.

The main axiom of OTSM – the Axiom of Descriptions: we use subjective models of objects we are thinking about. These models have their limitations when produced in the mind of an individual problem solver. To solve a problem we need to change the way we view it; i.e. change the stereotypes we have in our minds when we approach it.

In this way we manage to change our understanding of the problem. By replacing our initial description with a different model we are able to simplify the problem solving process by removing the stereotype which can in itself part of it, and can stand in the way of a solution. We therefore need certain assumptions (axioms) for dealing with the descriptions of the elements of a problem and thinking of a solution. Below we provide just the names of axioms that belong to these groups:

Axioms that describe the model of the thinking process efficiently enough for problem solving: (1) Axiom of Impossibility; (2) Axiom of root of problems; (3) Axiom of reflection; (4) Axiom of process.

Axioms that describe the uses of a problem solving model of the world where problems arise: (1) Axiom of Unity; (2) Axiom of Disunity; (3) Axiom of Connectedness.

All of those axioms can be used as the most general instruments in the cases where specific instruments cannot be used for certain specific problems. These axioms are the most general rules for problem solving. Based on these and the two main OTSM models specific instruments have been developed for different stages of a problem solving process.

Let us consider as an example of one of them – the Axiom of root of problems.

This axiom appears as a result of the research and revision of the Classical TRIZ system of axioms. It combines all three of them into one: the root of any problem is a contradiction between human desire in relation to a certain specific problem and the objective laws that drive that situation.

Some situations exist because of objective laws that link various events to each other. But for certain reasons certain individuals or groups of people are not happy with a given situation and want to change it. For instance we need to make a piece of metal float in water or fly it in the sky. According to the laws of Archimedes metal can neither float nor fly. But humans wanted to make it fly and float. Some inventors discover the other way around the law of Archimedes and solved the conflict between human desire and objective natural law so that now we have metal that can fly and float. Classical TRIZ and OTSM supply problem solvers with instruments that are helpful in developing other ways round objective natural laws.

An important conclusion was arrived at during the course of OTSM development for this axiom. In order to solve a problem we need to find which objective natural law contradicts our desire and use it to develop another way around. This is a general recommendation and it underlines some more specific instruments which are along the continuum of ARIZ evolution. It is important to mention that the Idea of Technical Contradictions appears at the very beginning of TRIZ evolution. Understanding that a certain Physical Contradiction underlines each Technical Contradiction seems obvious today for TRIZ learners. But we have to remind ourselves that between these two important notions of Classical TRIZ lay 30 years of research. Today discovering physical contradictions is a mainstream of the Classical TRIZ problem solving process. In OTSM the Axiom of the Roots of the Problem combines all three postulates of classical TRIZ and underlines the whole OTSM problem solving process.

4.3 The two Fundamental models of OTSM

In the course of OTSM research two main models of Classical TRIZ were also revised and developed further. Firstly the System Operator was enhanced and obtained several more dimensions. Later it appears as a Fractal ENV model for the description of the various elements of a problem. This model is also used for various OTSM based instruments. The same thing has happened with the Classical TRIZ Model of the problem solving process.

The OTSM based ENV model for Elements and Process descriptions

At the beginning of the research we used the model that is well known in Philosophy and Artificial Intelligence: Object-Attribute-Value. Eventually we discovered that this model does not fit all the requirements of the instruments used for problem solving. This model was therefore later replaced by the ENV Fractal Model that contained the advanced OTSM System Operator and was a better match with the other OTSM problem-solving instruments. ENV means: Element – Name of feature – Value of the feature.

When we describe a tomato we usually say that the tomato is red, round and eatable. For the problem solving process it is better to say something in line with everyday language and thinking. It goes something like this: The element TOMATO has a feature that is called Colour and a specific value of the feature is red but it could be green, yellow or black. Based on the ENV model several other rules and instruments were developed. For instance the ENV classification of principles for resolving contradictions is called in Classical TRIZ a Physical Contradiction. This transformation helps us to identify several more principles that mostly appear in non engineering problem solving.

The ENV model was also used towards the end of the 80s to develop an alternative way for defining function as used in the experimental version of Invention Machine software. Since then it has developed further and is better matched better with all the other instruments of OTSM.

The OTSM fractal model of problem solving process

As we mentioned above ARIZ-85-C started a new S-curve of ARIZ evolution. Part three appears as several parallel lines of analysis according to whatever are the chosen resources. Further research was done and we came up with the conclusion that the 9 step linear model of the problem solving process that was proposed in Classical TRIZ was not sufficent for dealing with complex interdisciplinary problems. According to the TRIZ law of transition to a super system the model of classical TRIZ appears as a component of a more general model of the super-system. The OTSM model considers a problem solving process as a non linear fractal process of the transformation of an initial description of a problem description into the description of a satisfactory conceptual solution. This means that we form some parts of the general image of a solution at the beginning and then step by step makes it more and more specific. The OTSM problem-solving process treats each problem as a set of problems and each of those problems has nested problems like a Russian Matroshka (Nested Doll). This model has a multidimensional tree structure. Each branch of the tree is similar to the Classical TRIZ problem solving process. A detailed description of the model will be presented in a separate paper.

4.4 The Instruments of OTSM

As in Classical TRIZ the OTSM axioms and two main models underline all the OTSM instruments. Initially the OTSM toolbox had four main OTSM technologies: New Problem Technology; Typical Solution Technology, Contradiction technology; Problem Flow Technology.

The New Problem technology helped to clarify a problem and choose a problem to be solved. As soon as the problem was reformulated the Typical Solution Technology could be applied. Where Typical Solution technology did not provide us with the description of a satisfactory solution Contradiction Technology had to be used. Where the problem could not be solved with the Contradiction Technology then the Problem Flow technology had to be used.

This toolbox was working well enough, but the beginning of the 90s saw the start of the appearance of complex problems containing lot of problems, many of them nested. This initiated a new S-curve of OTSM instruments. Real life problems required that the tools work with hundreds of problems, each of which could have a set of contradictions. For example the following:

1. how to make a large or small company develop and acquire sustainable innovation?
2. how research into a complex object should be organized in the research centre or how Ph.D. research could be carried out?
3. what should be done to develop a sustainable energy region that is unaffected by fluctuations in the fossil fuel market?

It could be difficult to apply traditional instruments of Classical TRIZ and the four main OTSM technologies to these kinds of problems. As a response to this requirement the OTSM Problem Flow Network Approach was developed [4].

4.5 Some further directions in OTSM evolution

In the course of OTSM research we came up with the conclusion that in the world of rapid change it is important to switch from problem solving, that is more or less random, to problem management – a permanent systemic process of managing the flow of problems in an organization in a more structured manner. This approach could be easily integrated into the Knowledge Management approach that has become popular over the last few years, so the past experience of an organization can be used to inform future needs. This convergence of OTSM based Problem Management with Knowledge Management could be useful for many organizations including: businessness, educational institutions, research centres and public authorities etc.

OTSM seems to hold out great promise for developing instruments for permanently structured problem management, which is becoming increasingly important.

Finally, in our world of rapid change it also requires a permanent flow of innovation. But innovation is a very painful and risky process that now needs to become a permanent and structured for organizations seeking sustainable development and growth and future survival. That is why we are now working on transforming OTSM based instruments from instruments for problem solving to instruments for problem management and even further – to instruments for sustainable systemic and structured innovation.

5 SUMMARY

In this paper we have proposed a general structure of applied scientific theory.

This model of applied scientific theory has been used to study and evaluate Classical TRIZ. This has been helpful for attaining a deeper understanding of Classical TRIZ and its instruments.

The proposed model of applied scientific theory was used in order to develop the new theory of OTSM. This model is now being used to develop OTSM further and transform it from problem solving to problem management and into an instrument for sustainable innovation.

Our study shows that the model of applied scientific theory could be used for the study of existing theories and for developing new ones.

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