Managing Innovation Knowledge

The Ideation Approach to the Search, Development, and Utilization of Innovation Knowledge

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Introduction

The oft-quoted expression "TRIZ is based on technology rather than psychology" is a direct translation from the Russian. This declaration was made by Genrich Altshuller to underscore the difference between TRIZ and the many other creativity techniques, which were based on the thinking and/or behavioral patterns of successful inventors. Altshuller was the first person who, as early as the 1940s, refused to embrace an unreliable, unrepeatable, and personality-dependent psychological approach to creativity. He instead chose another way, one based on an analysis of the *results* of creativity in technology – that is, inventions. This approach allowed Altshuller to form his conclusions on the basis of information in patents and other sources of technical information documenting the human innovative experience. This accumulated knowledge of the most successful inventive practices resulted in the following discoveries, which form the cornerstones of TRIZ[1]:

- Definition of an inventive problem
- Levels of invention
- Patterns of invention
- Patterns of technological evolution

In his examination of the patent fund, Altshuller recognized that the same fundamental problem (i.e., contradiction) had been addressed by a number of inventions – but in different areas of technology. He also observed that the same fundamental solutions were used over and over again, often separated by many years. Consider, for example, the following problems:

- Removing the stems and cores from bell peppers
- Cleaning air filters
- Unpacking parts wrapped in protective paper prior to assembly
- Splitting cracked diamonds along microscopic cracks

In each case a similar solution was used: some quantity of the product (peppers, diamonds, etc.) was placed in an air-tight chamber, the pressure inside the chamber was increased slowly, and then dropped abruptly. The sudden pressure drop creates a pressure difference inside and outside the product, resulting in an "explosion" that splits the product.

[1] G. S. Altshuller, *Creativity as an Exact Science* (Gordon and Breach Science Publishers, 1984).

As mentioned previously, these inventions occurred in different areas of technology and at different times. Yet the fundamental problem that characterizes these inventions is the same, and was solved in the same way. Clearly, if the latter inventors had known of the earlier solutions, their tasks would have been much more straightforward. Unfortunately, however, the inter-disciplinary barriers made such an exchange of knowledge virtually impossible.

Altshuller reasoned that knowledge about inventions could be extracted, compiled and generalized in such a way that it was easily accessible by inventors in any area. Embarking on this work, he gave birth to the first ***innovation knowledge base.***

Levels of Innovation Knowledge Bases

To be more precise, it must be acknowledged that the first actual innovation knowledge base began with the first documented invention or, even earlier, with the first trade "know-how" transferred from father to son. To date, the world patent library contains millions of patents categorized according to patent classification. This library holds little value for inventors (or potential inventors), however. In the above example, the likelihood that an inventor trying to solve the diamond-splitting problem will find a solution patented in the food industry is next to zero. Given this, we can categorize the "innovation value" of this initial innovation knowledge base at Level 0.

The first useful innovation knowledge base began as a card file that contained descriptions of selected inventions. The criteria for selection required that an invention be:

- Representative (i.e., similar inventions existed in different areas of technology)
- Powerful (providing significant benefits at low cost)

Given the fact that the bell pepper invention corresponds to over several dozen similar inventions (analogs) across many technological domains, and that it is sufficiently powerful, it is considered an effective illustration.

Clearly, there are far fewer inventions that meet the above criteria – perhaps numbering in the thousands versus the millions of inventions contained in the "original" innovation knowledge base. It is obvious as well that an individual possessing such a card file can be much more productive, and thus it represents the first innovation ***knowledge-base tool***, with an innovation value of Level 1. Following Altshuller, other TRIZ practitioners and researchers began compiling their own invention card files and exchanging among themselves the information they contained.

Despite the dramatic decrease in the number of patents to search (and thus the relative speed with which patent could be evaluated), the effectiveness of this first knowledge-base tool was still limited as it lacked an adequate structure and/or search "engine." The main challenge in utilizing the selected inventions was in recognizing the analogy between problems that seemed unrelated because they occurred in different industries and were described using different terminology, yet were similar in a general sense. Accordingly, the next step in the evolution of this knowledge base was made by abstracting (generalizing) the "essence" of each invention, omitting the details that related to a specific industry. For example, all five of the inventions mentioned above may be described in the following general manner: "Place a certain amount of the product into an air-tight container; apply gradually-increasing pressure; then quickly drop the pressure. The pressure difference inside and outside the product results in a type of explosion that splits the product." In this case, these five inventions can serve as illustrations of the more general principle. This approach resulted in the creation of the succeeding (Level 2) knowledge-base tools such as the 40 Innovation Principles, 76 Standard Solutions, and collections of Effects and Phenomena.

The 40 Innovation Principles had no structure. Rather, they were simply a list of recommendations in no particular order. Moreover, they represented a mixture of at least three different types of principles, as follows:

- Non-obvious recommendations such as inversion or converting a harm into a benefit
- Recommendations for forcing a system's development according to the Patterns of Technological Evolution discovered later (for example, segmentation, self-service, etc.)
- The most frequently applied physical effects such as thermal expansion and utilization of films and flexible shells.

The collection of Effects and Phenomena were structured, but the structure reflected the sciences from which they were derived (physics, chemistry, etc.) and had nothing to do with the needs of an inventor.

To make the knowledge-base tools useful for invention purposes, each was supplied with its own search engine: the Contradiction Table for the Principles, and a functional table for the Effects.

The 76 Standard Solutions was the first tool to be structured according to an inventor's needs (e.g., problem type or desired improvement), although in a very general way. Also, the first attempts to utilize a multi-step process ("chain") in applying a knowledge base were introduced with this tool. For example, those solutions called "Class 5" solutions contained recommendations for increasing the ideality of an obtained solution via the "smart" introduction of substances and/or fields required to implement the solution.

The next logical step – to a Level 3 innovation knowledge-base (the Systems of Operators) – was skipped in the evolution of knowledge-base tools within the classical TRIZ framework. As will be shown later, the development of a complex, net-like structure was hardly possible without computers, which were unavailable at that time. Instead, in parallel with the development of Level 1 and 2 tools, the most powerful (Level 4) knowledge-base tool started being developed, namely, the Patterns of Technological Evolution.

The System of Operators as a Level 3 Innovation Knowledge Base

The Operator as a creative recommendation for system transformation

The definition of an Operator, along with the main prerequisites and requirements for the development of the System of Operators, were addressed in the paper "An Integrated Operational Knowledge Base (System of Operators) and the Innovation Workbench™ System Software." This paper was originally prepared in 1992 for publication in an issue of the *Journal of TRIZ* devoted to the Kishinev School. It was pulled from publication, however, due to a related patent pending. This article has been recently translated and is offered here, together with this paper.

The objectives for the development of the System of Operators were the following:

- Create an integrated knowledge-base tool structured in a way that allows the user to quickly identify that portion of the entire knowledge base relevant to the problem at hand.
- Elucidate and integrate the unique experience accumulated by TRIZ practitioners in solving problems utilizing TRIZ tools and approaches (the "associative chain" approach)

In 1992, the name "Operator" was chosen to avoid confusion with various elements of existing TRIZ knowledge-base tools (Innovation Principle, Standard Solution, Separation Principle, etc.). For the purposes of integration, an Operator denoted any type of system transformation, including the 40 Principles and Standard Solutions. Today, we have a better understanding of the nature of the Operator as a means for creative (i.e., non-obvious) system transformation versus one for direct knowledge transfer.

An Operator is considered creative if its recommendation:

- Helps in overcoming psychological inertia (Example: The Operator "inversion" is applied when frozen sand is overcooled, rather than heated, to unload it from a car.)
- Offers a different view of the problem (Example: Facilitating the transportation of a heavy object via the utilization of slippery pads rather than trying to reduce its weight.)
- Offers a solution that contains a resolved typical potential contradiction or secondary problem before it is even revealed (Example: Making a part asymmetrical helps reduce its weight without the very likely result of sacrificing mechanical strength.)
- Offers a typical resource to solve a problem (Example: The utilization of available substances suggests making a corrosion test sample into a container for the acid in order to eliminate the need for a testing chamber.)
- Suggests an evolutionary step (Example: "Dynamization" makes the system more universal and represents a new system generation.)

How Operators can grow

Another important issue related to the System of Operators was the categorization of all known Operators into three groups[2]:

- Universal, i.e., applicable to any problem. Examples are inversion and partial/excessive action.
- Semi-universal, or General (i.e., applicable to many situations). Examples are those Operators useful for eliminating a class of harmful actions.
- Specific (i.e., specialized). Examples are Operators that constitute methods for dispensing a substance.

This categorization turned out to be very important, as it has shown the future direction of the growth of the Operators. For example, it is almost impossible to discover new universal

[2] Boris Zlotin and Alla Zusman, "An Integrated Operational Knowledge Base (System of Operators) and the Innovation Workbench™ System Software," 1992 (in Russian). See the English translation on the scientific channel of our web site, www.ideationtriz.com.

Operators such as those mentioned above, however, it is relatively easy to expand the area of specialized Operators. The normal way this expansion is achieved is by adjusting universal or general Operators to specific needs. For example, at the present time we are ready to introduce a group of specialized Operators for eliminating various types of leakage (gas or fluid). Several other groups of Operators are in the process of development.

Net-like structure and associative chains

Another important feature of the System of Operators is its net-like structure. It is well-known that Genrich Altshuller made his discoveries and developed numerous tools by analyzing the wealth of the patent fund without using any particular methods and/or tools. Basically, Classical TRIZ was founded on inventions that were made without TRIZ and represented the elucidation of the best *intuitive* innovation practices.

By the early 1990s, when we began working on the System of Operators, the situation had changed dramatically: there were thousands of TRIZ users and hundreds of inventions that had resulted from the utilization of TRIZ. We therefore had a unique opportunity to take the second step: verbalizing the phenomenon called “TRIZ intuition” or the “TRIZ way of thinking.” By observing and analyzing the process of solving problems with TRIZ, we realized that the process is one of making a specific chain of associations. Consider, for example, that one must find a way to protect an object from overheating. An Operator recommends introducing a substance that will draw off the excessive heat. At this point, one might decide that the solution has been found. However, an experienced TRIZ practitioner will not be satisfied. He/she will likely understand that this solution is not the ideal one, since an additional substance must be introduced into the system, increasing its complexity. To make it more ideal, one should consider so-called “smart” ways of introducing a substance without actual introducing it, or, to at least withdraw the substance as soon as it has fulfilled its function. The next step will then be to consider the methods of withdrawing a substance. One way to facilitate withdrawal is to transform the substance into a mobile state: gaseous, fluid, granular, etc. Let us assume the gaseous state sounds promising to our inventor. Now he/she can consider ways to achieve this necessary transformation, such as phase transformation (e.g., evaporation), combustion, chemical reaction, etc. It would also be beneficial to facilitate the transition utilizing a resource such as excessive heat. Summarizing these steps, we have the following:

1. Introduce a substance to withdraw excessive heat
2. Withdraw the substance after it has absorbed the heat
3. . . . via substance transformation into a mobile state
4. . . . via evaporation
5. . . . via the utilization of excessive heat

Now the solution is fairly clear: introduce an easily evaporated substance that will disappear while protecting the overheated object. It is obvious that such way of thinking allows one to enhance the initial idea in the direction of higher ideality and feasibility.

TRIZ practitioners know that it takes years of experience to achieve their level of qualification. However, because associative chains model the way of thinking of the best TRIZ practitioners, the TRIZ novice can become as effective as the experienced TRIZ practitioner if these chains are built ahead of time and incorporated into a ready-to-use tool. The System of Operators is such tool, containing thousands of links that help the user navigate through the system. These links create a net-like structure whose development would be nearly impossible without a computer.

More is Not Necessarily Better, or, How to Increase the Value of an Innovation Knowledge Base

All "value levels" for an innovation knowledge base can be seen on the following chart:

Value Level 4 →	Patterns/Lines of Technological Evolution
Value Level 3 →	System of Operators
Value Level 2 →	40 Innovation Principles Separation Principles 76 Standard Solutions Effects
Value Level 1 →	Selected Inventions (innovation examples)
Value Level 0 →	Patent libraries and other sources of technical information

According to this chart, it is relatively easy to increase the number of knowledge units on Level 1 (for example, by simply including in the base any invention available on Level 0). This doesn't empower the knowledge base very much, however. Furthermore, moving inventions from Level 0 to Level 1 or 2 without proper screening for innovation usefulness creates informational "noise." For example, including the effect "super fluidity of liquid helium" into the innovation knowledge base makes little sense, for the following reasons:

- It requires very complex equipment
- There are few situations in general engineering when this effect is applicable. However, in those special situations where it can help engineers, they are usually aware of it and thus the benefit of knowledge transfer is negligible.

As a result, adding the above effect would only render the search for solutions longer, and without an eventual "pay-off."

It seems that working at the higher levels requires the highest degree of TRIZ qualification and experience, and results in the increased value of the knowledge base at a much higher rate. These crucial factors encouraged our choice to develop the System of Operators and extend the Patterns/Lines of Evolution. To date, over 400 Operators and 300 of Lines of Evolution have been developed.

Direct Search as an Alternative to the System of Operators

Back in the 1940s, Genrich Altshuller defined five levels of invention. Approximately 20 years later he calculated the percentage of inventions existing at each level in the patent fund, as shown below:

Level	Description	%
1	Apparent solutions	32
2	Small improvement	45
3	Invention inside paradigm	18
4	Invention outside paradigm	4
5	Discovery	< 1

It is well known in TRIZ that knowledge-base tools like the Innovation Principles and Standard Solutions help users obtain inventions of level 2 and 3, respectively. Because these tools are actually tools for knowledge transfer from one area of technology to another, the reverse statement can be made: inventions of level 1 to 3 (which constitute more than 90% of inventions, according to Altshuller's patent search) are transferable as well. In other words, for any given problem, there is more than a 90% of chance that a similar problem has already been addressed somewhere, at some time. The question now becomes: how can the relevant patents or other appropriate information be accessed?

The problem of searching invention information is not much different from that of searching any other information, therefore, known approaches can be used – for example, using key words. Two serious problems should be mentioned, however:

- Only relatively recent patents are available for electronic search
- Use of typical Internet browsers such as Yahoo, Infoseek, etc. for complicated searches is an extensive job that carries no guarantee of success.

Recently, development and utilization of new types of intellectual (semantic) browsers has begun, offering the following capabilities:

- Identification, in the presented textual material, of the most significant words and word combinations describing the problem in the best possible way
- Utilization of special semantic dictionaries that enable analogs and equivalents to be found for selected expressions, and key word clusters (instead of key words) to be compiled
- Searches for relevant clusters in given sources of information, and estimates as to the probability of relevance of the obtained material.

Basically, a machine replaces the human's understanding of the meaning of the text with an analysis of word combinations contained in the text. Let us consider a hypothetical example. We describe a problem of cooling a large, underground transformer. The analyzer, finding mention of the words "transformer," "ground," "electrical energy," and "cooling," might find that ground is associated with ground water, that the Earth is a porous substance, and thus that the water for cooling the equipment can be moved by way of an electrical field: electro-osmosis. (As it happens, a patent exists for the method just described – the example is still relevant, however.) Although modern browsers are adequate for finding articles describing things similar to what the user has requested, or finding patent citations, they are not yet "intelligent" enough to provide this level of performance when dealing with creative problems, due to the following reasons:

- While it is very difficult to create a detailed and accurate problem description, success depends almost entirely on the accuracy and correctness of this description. Moreover, to compile such a description one must accurately and correctly formulate an inventive problem, which is often as difficult as solving the problem itself.
- To create a useful problem description, much depends on the individual's linguistic and professional capabilities. Further, a language barrier (the necessity of using a second language rather than one's native language) makes the situation even worse. And lastly, a time factor (i.e., the situation wherein search materials were written 10-20 years ago or more) can complicate the situation as well.
- The effectiveness of a browser depends on the volume and accuracy of its semantic dictionary. The federal government and private companies have already spent millions of dollars on research and development of semantic thesauruses, however, the results are still far from satisfactory.

Combining alternative systems

Two alternative systems for Innovation Knowledge Management were described above: the System of Operators as an internal (built-in) representation of knowledge based on the TRIZ analysis of past and present worldwide innovations and TRIZ experience (knowledge base); and a direct electronic search (external knowledge base). As usual, each has its own advantages and disadvantages, as follows:

System of Operators:

Advantages

- Provides a powerful TRIZ approach that offers carefully selected, well-proven, and "purified" innovation knowledge, independent of techno-logical domain.
- An easy and quick system for exploring the knowledge base, organized according to the problem solver's needs, i.e., in the form of a menu system.
- Represents the acquired human innovation experience since the

Disadvantages

- Updates require the work of TRIZ specialists to screen new patents and producing new Operators
- Due to the high level of abstraction, additional creative work is required for implementation

dawn of mankind

Direct electronic search:

Advantages

- Very recent inventions are available for search
- No special preliminary work on Operators is required

Disadvantages

- Recent search engines (browsers) are dependent on terminology and language proficiency
- Only relatively recent inventions (patents) are available for electronic search.
- Searches based on word clusters are hundreds of times more complex and thus time consuming

The TRIZ approach to dealing with alternative systems recommends that we consider integrating them, targeting the elimination of negative features while conserving (or even improving) positive ones. The results of the work in this direction undertaken by the Ideation Research Group are described below.