TRIZ - Roots, Structure and Theoretical Base

Introduction

From its inception, TRIZ as a science has been driven by the practice of innovation. All improvements, enhancements and advancements to TRIZ described below have resulted from our accumulated, extensive experience as TRIZ practitioners (involving more than 5,000 problems) and educators (more than 6,000 students have been taught). The main objectives for the advancements were as follows:

- To overcome the weaknesses of the methodology (see below)
- To explore new areas (including non-technological ones) for applying TRIZ
- To enhance the existing tools and develop new ones
- To make TRIZ appropriate for mass use and education
- To enhance the theoretical base of TRIZ and link it with other sciences

According to these objectives, we have divided the descriptions of these advancements into two chapters:

A. TRIZ Philosophy and Theoretical Base

B. TRIZ Tools and Applications

We have also divided the entire TRIZ history into two distinguishable eras, as follows[1]:

Classical TRIZ	TRIZ as it underwent development led by Genrich Altshuller in the former Soviet Union (from the mid-1940s to the mid-1980s).
Contemporary TRIZ. Phase 1	TRIZ during *perestroika* in the former Soviet Union (from the mid-1980s to the early 1990s).
Contemporary TRIZ. Phase 2 0r Ideation TRIZ (I-TRIZ)	TRIZ as it penetrated the Western world (beginning in the early 1990s).

These approaches are used for the following purposes:

- To draw the most complete picture possible of contemporary TRIZ.
- To emphasize the achievements that we believe are vitally important for disseminating TRIZ throughout the world, and which we readily share with anyone interested in providing value to their customers and friends.

[1] *Brief History of TRIZ.* TRIZ in Progress. Transactions of the Ideation Research Group (TIRG), Ideation International Inc., 1999, Appendix 1.

TRIZ Philosophy and Theoretical Base

Vision: What is TRIZ?

Names and definitions

Trying to define or even give a name to a rapidly-evolving science is no easy task. The first name given to TRIZ in the 1950s was *invention technique*. A decade later it was changed to *Algorithm for Inventive Problem-Solving (ARIZ)*. The name *TRIZ* first appeared in Genrich Altshuller's correspondence during the 1970s. However, it became obvious in the early 1980s that this name was again falling short in conveying what it represented. Various new names such as *Theory of the Evolution of Technological Systems*, or *Theory of the Evolution of Systems* (to address non-technological applications as well), and *Systematic Innovation* were used or considered at that time. However, it became obvious that there was no reason to continue changing the name, given that the name TRIZ had become somewhat known. Following this tradition, and in recognition of Altshuller's unprecedented accomplishments, we decided to keep the Russian language based acronym, introducing *TRIZ* to the United States and to other western countries.

Definition by analogy

A new subject can be defined by establishing analogies with known subjects (systems). As well as being helpful in providing an understanding of the new system, analogies also allow the direction of the system's evolution to be described. The following well-defined subjects could serve as analogies for TRIZ: biology, math and art[2].

The *biological analogy* helps convey the understanding that technological evolution depends on the current overall technological and market situation rather than on a specific inventor (although this is not so obvious). Nevertheless, if Alexander Graham Bell had not been born, the name of the inventor of the telephone would be Elisha Gray. In any event, it is hard to believe that without Edison we would work with our computers in candlelight. It is important to mention that we are not talking about bionics here, that is, applying solutions prompted by Mother Nature to technology. What we have in mind is a high level analogy based on the patterns of evolution applicable to any system[3].

From the *math analogy*, the following considerations are the most valuable:

- TRIZ, like math, is a general-purpose science, that is, it can be applied to any human activity facing problems related to evolution (science, technology, medicine, etc.).
- TRIZ must have its own axiomatic base.
- TRIZ can be learned and used on various educational levels, from kindergarten to post-doctoral education.
- TRIZ-based software must be user-friendly enough to be utilized with or without some minimum amount of TRIZ (i.e., specialized) education.

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[2] *Analogies for TRIZ.* TIRG, 1999, Appendix 2.
[3] Further details are given in Part 2, presented by Dr. Zainiev.

By the *art analogy* it is shown that TRIZ is not in competition with natural creativity. The more creative an individual is, the more beneficial TRIZ can be for him or her. The formula of success with TRIZ is as follows:

$$R = P_c \times P_{kn} \times (1+M) \times (1+T)$$

Where:

R = Results

P_c = Personal capabilities, including natural creativity, an open mind, a love of exploration, etc.

Pkn = Professional knowledge

M = the Theory (philosophy) of TRIZ

T = TRIZ Tools

As in art, where various methods and techniques allow an individual to move to higher achievements and push forward the limits, TRIZ helps the "average" individual handle problems that would otherwise be suitable only for geniuses, while the geniuses can then respond to higher-level challenges.

The place of TRIZ in the world of creativity. TRIZ functions (known and unknown).

Originally, TRIZ was created for the purpose of solving inventive problems. In this regard, TRIZ competes with the *trial-and-error* method and its enhancements such as *brainstorming*, *Morphological Analysis*, *Lateral Thinking*, and others creativity techniques. However, there is a big difference with TRIZ.

As shown in the Creative Methods Overview[4], TRIZ is the only methodology that contains the following:

- Innovation Knowledge base
- Evolutionary Directed techniques

Additional tools (including analytical tools recently developed by Ideation; see below) that, together with the knowledge-base tools, support the entire innovation process (including problem definition and formulation), are available in TRIZ.

TRIZ is based on the study and application of the patterns of evolution of various systems – technological (such as machinery, manufacturing processes, etc.), scientific theories, organizations, works of art, and so on. Based on these patterns, methods for searching for creative solutions have been developed; these methods include three basic components:

- The logical analysis of a given system and its problems. This enables the user to understand the essence of the problem and to reveal the non-obvious contradictions that hinder the solving of that problem.
- The application of a special knowledge base that includes the most effective methods of problem solving along with examples of the application of these methods.

[4] *Creative Methods Overview*. Appendix 3.

- A means for overcoming psychological inertia in the process of problem solving.

Usually, a newly born system has specific function(s). In the process of evolving, however, new functions can be invented – and these are often more valuable than the original one(s). As a result, various modifications to the system develop, creating new market sectors[5].

For example, the computer was developed as a system for calculation. Later, computers were equipped with keyboards, enabling users to type instructions. Still later, convenient word processors were offered, which resulted in the situation we have today where the majority of computers are used as word processors rather than calculators.

New functions of TRIZ other than problem solving have been discovered, and many of these might be more important than problem solving, such as[6]:

- The formation of a new way of thinking
- A fast and effective method of transferring knowledge
- Stress reduction, etc.

Mission: managing the future

In his well-known book entitled *The Third Wave*,[7] Alvin Toffler suggested that human history be regarded as the superposition of two waves: agricultural and industrial. He showed that the third wave, which is strongly connected with information, is coming, and warned readers about the potential *future shock* that can result from such drastic changes.

Using the wave idea, the history of humanity can be presented as a set of waves of smaller or larger scale, where each provides control of some important facet of life, such as: safety; the exchange of information; protection from an unfriendly environment; the environment itself; food; labor and trade; social and economic systems; health, the management of natural resources; power sources; etc.[8]:

We believe that the need to control human destiny is the next wave to be satisfied. There is no doubt that people are seeking it: the predictions of psychics have always been in demand. Every individual, company, country, and mankind as a whole aspires to be prepared for the future in order to succeed.

Technological progress, together with specific advantages, causes negative consequences. It makes no sense, however, to try to stop this progress. A better way would be to control and direct it. Accordingly, an effective tool, based on TRIZ, has been developed that can help predict and direct evolution[9]. The TRIZ methodology is absolutely essential in order to handle the next wave of managing the future.

Classical TRIZ

[5] Further details appear in Part 2, presented by Dr. Zainiev.
[6] *Secondary Functions of TRIZ*. TIRG, 1999, Appendix 4.
[7] Alvin Toffler, *The Third Wave*. Bantam Books, 1991.
[8] *Waves of control*. TIRG, 1999, Appendix 5.
[9] For more detail, see Part 2.

Dates and events

The complete history of TRIZ, its main ideas, tools and applications, has not yet been written. For over four decades, TRIZ was developed and disseminated mainly via correspondence between Genrich Altshuller and enthusiasts of TRIZ. Rare meetings and occasional publication, often appearing in difficult-to-obtain magazines, also contributed to this development. Some of this older material has been lost or is without dates, signatures, etc.

We have made an attempt to collect the available information, mainly relying on our extensive personal correspondence with G. Altshuller. Our intent is to transfer this correspondence to the Altshuller Institute (after removing information related private issues).

The summary of dates and events[10] includes a brief history of the main TRIZ tools and applications, evolution curves, etc. We would appreciate any comments, corrections and additions related to the subject.

Assumptions and definitions

We define the Classical TRIZ era as a period that started in the mid-1940s, when Altshuller began his research on creativity. He undertook a new, scientific approach to the process of generating inventive ideas. This approach was based on the utilization of the accumulated knowledge of human innovation as documented in the patent library and revealed in the history of technology. Among the basic discoveries he made along the way, the most important are:

- Any technical system develops according to certain patterns
- The patterns of evolution for different systems have much in common
- The patterns of evolution can be unveiled through researching the evolutionary history of a system (for the area of technology, this evolutionary history is contained in the patent library)
- Based on these discovered Patterns of Evolution, universal methods for searching for new ideas can be developed

For over four decades, Altshuller led all development in TRIZ. In the mid-1980s he stopped working on technological TRIZ, judging that this part of TRIZ was complete. At the same time, Russian *perestroika* finally allowed TRIZ to be utilized for commercial purposes, and the first TRIZ customers came into being as a result. The need to better serve their customers forced various TRIZ schools and individuals to start adjusting TRIZ to the new requirements. The commercialization of TRIZ meant that there was no longer a free informational exchange. We believe that this was the beginning of new era in TRIZ.

The main accomplishments during the Classical TRIZ era that could serve as a foundation for further development can be summarized as follows:

In the area of basic concepts:

- Revealing and utilization of the Patterns of Technological Evolution
- Ideality as the main target of a technological (engineered) system's evolution

[10] See TIRG, 1999, Appendix 1.

- The emergence and amplification of contradictions in the process of a system's evolution; revealing and resolving contradictions in the process of solving problems
- A systemic (multi-screen) approach
- A structured and systematic (step-by-step) approach to the problem-solving process
- Utilization of formal problem models
- Transfer of knowledge (concepts) through the development of an innovation knowledge base
- Utilization of "operators" (principles, standard solutions, etc.) derived from the best innovation practices, to direct the problem-solving process
- Direct utilization of methods for reducing psychological inertia

In the area of tools and education:

- 40 Innovation Principles and Contradiction Table
- ARIZ
- Separation Principles
- First system of Patterns of Evolution
- Substance-Field Analysis
- Standard Solutions
- Selected Innovation Examples
- Effects
- Course elements for the development of a creative imagination
- Life strategy for creative individuals

The most important result of the Classical era is that Altshuller set out to develop a method that would help technical individuals handle difficult technological problems. In fact, he accomplished much more than this, revealing the basic patterns and principles of evolution and creativity that are applicable to any field of human activity requiring creative solutions. He also succeeded in systematizing these patterns and principles, making them available for wider use. However, TRIZ remained half-science, half-art, requiring extensive education and practice as well as exceptional commitment.

Contemporary TRIZ

Revision of assumptions and basic concepts

As mentioned earlier, the commercialization of TRIZ in the former Soviet Union, followed by the marketing of TRIZ in the United States, forced us as a united group of TRIZ professionals to begin working on transforming TRIZ into a methodology suitable for mass utilization. The first step was to articulate the main limitations of Classical TRIZ, which are as follows:

- Insufficient rigorousness of TRIZ tools (i.e., many analytical skills required for successful application of TRIZ tools had not been transformed into documented rules, algorithms and recommendations).

- Only a limited amount of the TRIZ knowledge base had been documented and was available for study and use.
- Each tool had been developed separately.
- Problems of different types had to be treated differently — there were no clear recommendations for which tool should be used for what type of problems/situations.
- The tools did not support all stages of the problem-solving process. For example, problems had to somehow be pre-formulated in TRIZ terms before the tools could be applied.

As a result of the above limitations, TRIZ was characterized by the following:

- Considerable education (from 100 to 250 hours) was required to effectively utilize TRIZ.
- Extensive practice (from 1 to 5 years) was required to become self-sufficient in applying the methodology.
- Making TRIZ available for mass utilization posed an insurmountable challenge.

Work on lifting these limitations required that certain assumptions be revised that were inherent to Classical TRIZ and which hindered its dissemination, especially in the Western world. These assumptions were analyzed and reconsidered, with the following results[11]:

Classical TRIZ	Contemporary TRIZ
TRIZ is a "stand-alone" methodology; it has nothing in common and cannot collaborate with the Trial-and-Error method and its psychology-based enhancements.	TRIZ must absorb the best of other techniques, and must work together with other related techniques.
Everyone should become creative.	Everyone should be taught to solve creative problems. The educational process should be supported by appropriate tools (including software tools)
The development of technological TRIZ is complete; everyone involved with TRIZ should work on the development of creative individuals.	Technological TRIZ is in an early stage of development and must accommodate the needs of the customer.
People need inventions. Invention is always better than a conventional solution, and a high-level invention is better than a low-level one. The main mission of TRIZ is to allow people to invent at the highest levels.	Orient the development of TRIZ toward the high market value of solutions.
TRIZ has been developed, and must continue to develop, based on the knowledge embodied in patents. (Documented patents were a valuable	TRIZ should develop based on patents, on the history of technology (as a history of implemented inventions), and on the experience being gained by TRIZ

[11] *Revision of Classical TRIZ assumptions*. TIRG, 1999, Appendix 6.

resource that significantly facilitated early TRIZ development).	professionals.
The evolution of technology is governed exclusively by the Patterns of Technological Evolution. Follow these and you will always be successful.	Two processes guide the evolution: generation of new ideas capable to change products and processes, and selection of the best ones by the market.
The Patterns of Evolution must be based exclusively on high-level inventions.	Patterns of Evolution should reflect all steps of the evolutionary process including the ones required drastic changes and incremental ones as well.
TRIZ should focus on revealing and resolving contradictions, that is, concept development.	TRIZ must support all steps of the problem- solving process, including problem definition, formulation (reformulation), evaluation, and planning for implementation.
While solving a problem, an individual must look for the one, near-ideal solution (global ideality).	Target an exhaustive set of solutions, then select the best ones based on local resources (local ideality).
Focus on changing the way people think rather than on supplying people with appropriate working tools.	Orient the development of TRIZ on both tools and changing the way people think.
Ignore the psychological issues associated with the creative process.	Integrate psychological issues into the problem-solving process to help people adopt new ideas.
TRIZ is based on the world patent library and thus is suitable for any country or group of people.	TRIZ must be adjusted to various cultures and mentalities.

Additional basic concepts accepted for contemporary TRIZ

The revised assumptions allowed the list of basic concepts accepted by Classical TRIZ (see the section entitled *Assumptions and definitions*) to be extended in the following manner:

- Contemporary TRIZ is a living science and is continually developing.
- A comprehensive approach to the enhancement of systems within the entire range of complexity (including small improvements to parts and assemblies of an existing system, and the development of the generation of a system) and over the lifetime of a system (from concept development through engineering, implementation and exploitation).
- The complementary nature of the “human” and “machine” ways of being creative, combining the verbalized creative processes implemented in software and the intuitive processes inherent to the human mind.
- The two main directions in TRIZ development:
  - A way of thinking that provides an individual with the means to enhance his/her personal creative capabilities
  - A science that provides an individual with a set of working tools and processes to support the creative problem-solving process and assure successful results.

- The different ways by which TRIZ can be introduced: through educational institutions and through the adoption of TRIZ by industrial companies.
- Conditioning the growing TRIZ market via development of a range of tools suitable for different groups of potential customers, from customers having only slight interest in TRIZ to those ones wanting to become TRIZ professionals. Different and gradual (if necessary) TRIZ implementation through:
  - The utilization of well-defined (and simplified, when necessary) TRIZ-based processes and tools.
  - Learning the TRIZ methodology (at various levels of depth) to increase the efficiency of using TRIZ tools.
  - Professional utilization of TRIZ.
- Applying the TRIZ theoretical base and problem-solving experience to other domains, including non-technical ones (business, management, politics, markets, etc.).
- Utilizing TRIZ as the basis for developing creative education methods to teach conventional subjects.
- A complete restructuring of TRIZ for computerization purposes.

Basic directions established for research and development

The following basic directions for research and development have been established and followed for over a decade:

- Theoretical base of TRIZ, in particular:
  - Axiomatic foundation of TRIZ
  - Revised and extended system of Patterns/Lines of Technological Evolution
- Appropriate analytical tools (methods, processes, etc.) and knowledge-base tools to help control the evolution of technological systems (including problem solving)
- New approaches to TRIZ computerization
- New applications
- Theoretical foundation and practical methods of applying TRIZ to the evolution of non-technical systems (business, management, political, etc.) and problem solving
- Solving scientific problems
- Applying a TRIZ approach to the creative teaching of conventional school disciplines

Advancement of the TRIZ theoretical base

Definitions

The theoretical base of TRIZ includes the following general elements:

Name	Definition
Knowledge	Collection of information extracted from available sources of technical and other information, which has been generalized, structured and organized (provided with an appropriate search engine). Serves as a basis for developing concepts,

	algorithms, methods, and theories.
Concept/model/ approach	Important findings that were (or can be) placed in the foundation of a method or theory.
Algorithm	A set of sequential steps constructed on the basis of developed theory and/or experience.
Method	A set of concepts, algorithms, rules and knowledge compiled for the purpose of achieving specific results. Serves as the basis for the development of various tools, including software tools.
Theory	A comprehensive system that includes all the above elements, explains and predicts facts and events, and generates additional knowledge and practical results.

Each of the above elements is addressed below (in reverse order).

Theories and theoretical elements (new developments and contributions)

Listed here is a brief summary of the theoretical developments accomplished to date as well as those that are currently in progress.

Name and short description	Start-Finish	Outcome (actual or expected)
Evolution of Technology and Directed Evolution (DE). Retrospective and perspective study in the evolution of technology, targeting the control of technological evolution[12]	1978, in progress	Successfully applied to problem solving and DE applications
Innovation Operators. Recommendations based on abstracted and generalized creative solutions repeated through various areas of human activity[13]	1989, in progress	System of Operators embedded in the Ideation software family of innovation tools: released and in development
Problem Formulation. Functional cause-effect analysis of a problem situation, focusing on interactions between harmful and useful functions and targeting the identification of all possible (exhaustive) solution paths (Directions for Innovation)[14]	1989, in progress	Problem Formulator™ software module
Evolution of Organizations. Retrospective, perspective study in the evolution of various organizations (from	1985, in progress	Expected to contribute to the development of new software tool(s) and analytical services

[12] Partially published [A9,A16,A15,B2]. More detail can be found in Part 2, presented by Dr. Zainiev.
[13] *System of Operators*. TIRG, 1999, Appendix 7. *Managing Innovation Knowledge*. Appendix 8.
[14] Managing Innovation Knowledge. TIRG, 1999, Appendix 8.

small companies to societies), targeting the control of an organization's life cycle[15]		
TRIZ and Pedagogy. Retrospective, perspective study in the evolution of educational approaches, targeting the development of a creative pedagogic system[16]	1982, in progress	Expected to be a base for the development of methods and courses in the creative education of children and adults, as well as various tools and games
Theoretical base for development of TRIZ software products. Approaches and methods for successful computerization of TRIZ[17]	1989, in progress	Utilized in the development of Ideation software products
Theory (methodology) of science. Study in the evolution of science. Contributions to the philosophy of science[18]	1982, in progress	Recommendations for enhancing the development of a science and generating scientific ideas. Method for solving scientific problems and making discoveries
TRIZ as a science. Analysis of TRIZ axioms and postulates. Linkage of TRIZ to other sciences[19]	1981, in progress	Placement of TRIZ among other scientific studies

Methods (new developments and contributions)

Name and short description	Start-Finish	Outcome (actual or expected)
Revealing of tasks. Revealing hidden problems and opportunities for system improvement[20]	1982, in progress	See relevant application below
TRIZ and Value Engineering. Introducing TRIZ into the creative stage of Value Engineering Analysis[21]. Combining Value and Quality Engineering based on TRIZ[22]	1977, in progress	Successfully utilized in Value Engineering application
Development of creative imagination. Program for increasing creative	1975	Successfully utilized in the creative education of children

[15] Partially published [A27, B10].
[16] "Creative Pedagogy," *Journal of TRIZ*, V2, No 2, 1991 (in Russian). For the English translation, see TIRG, 1999, Appendix 9.
[17] Partially published [A27]. More detail can be found in Part 2.
[18] Partially published [A23]. Also, see TIRG, 1999, Appendix 10.
[19] Partially published [A16, A23]. Also, see TIRG, 1999, Appendix 10.
[20] *Revealing new tasks for system improvement*. TIRG, 1999, Appendix 11.
[21] Published [A9, A16].
[22] *Value Quality Engineering*. TIRG, 1999, Appendix 12.

capabilities based on special Operators. Contributions to the development of training courses[23]		and adults

Algorithms (new developments and contributions)

Name and short description	Start-Finish	Outcome (actual or expected)
First step-by-step process for the integrated application of various TRIZ tools for solving practical problems. Use of this process for educational purposes[24].	1985	Resulted in the Ideation Process, embracing all necessary stages for successful problem solving, starting from identification of the problem up to and including creating an implementation plan

Concepts/Models/Approaches (not part of theories/methods mentioned above)

Name and short description	Start-Finish	Outcome (actual or expected)
Concept and approach to evaluation and development of a company's Intellectual Capital[25]	1994, in progress	
Axiomatic Approach to TRIZ[26]	1995, in progress	

Knowledge (not part of theories/methods mentioned above)

- Classification of all available resources according to:
  - Type
  - Availability
  - Location[27]

Collection of creative solutions (numbering in the thousands) in technology[28]

TRIZ tools and applications

The need for enhancement

[23] Partially published [A15].
[24] Published [B2].
[25] *Managing Intellectual Capital*. To be published.
[26] *Main Postulates of TRIZ*. TIRG, 1999, Appendix 13.
[27] For more detail about the structure of resources, Ideation's TRIZSoft™ family of software tools
[28] Most have been included in Ideation's TRIZSoft™ family of software tools

The utilization of TRIZ tools for solving real-life problems began almost in parallel with their development. All useful approaches, rules and recommendations were immediately tested by the TRIZ author, G. Altshuller, and then by his students and colleagues. Every time he developed a new tool, Altshuller intended that the new tool would be more powerful than the existing ones and would be able to replace them. For various reasons, however, this did not happen.

The sequential introduction of new tools prompted the following questions about their use: "Which tool is most effective for which situation?" "Is it necessary to learn all the tools?" As practical results in applying the tools accumulated, it became evident that each tool had a different effectiveness depending on the level of solution, the required time to learn and use the tool, and the advantages and limitations of the user[29]. As a result, a great deal of time and effort was required for a TRIZ practitioner to be able to confidently apply numerous tools.

Another consideration is that concept development (idea generation) was always in the main focus of Classical TRIZ. Most of the tools mentioned above (Innovation Principles, Separation Principles, Standard Solutions, Effects, etc.) represent sets of recommendations for changing a technological system within which a problem resides in a way that will cause the problem to disappear. It was also shown that each of these tools works with a specific problem model (for example, the Contradiction Table is used with problems that have been formulated in terms of conflicting parameters or technical contradictions; the Separation Principles work well with problems formulated as Physical Contradictions, etc.). However, the highest challenge was to reformulate (i.e., remodel) the problem to a format where *any* tool could be applied. Although two other Classical TRIZ tools – ARIZ and Substance-Field Analysis – were intended to help one build a problem model or to transform a problem into one that could be described by a typical (standard) model, the successful solving of real-life problems required extensive experience.

As mentioned earlier, newly developed tools were tested on real-life situations. This was carried out in a limited fashion, however, due to the lack of practical application for TRIZ at that time. When *perestroika* opened up a market for TRIZ in the former Soviet Union, the need for the organization and advancement of these tools became significant. This need became even stronger in view of the inevitable introduction of TRIZ to the Western world.

[29] Comparative Analysis of the Ideation TRIZ Methodology Tools. TIRG, 1999, Appendix 14.

Enhanced and newly developed tools

The first attempt to develop a road map for the utilization of TRIZ tools was made in 1985[30]. This attempt was later enhanced (Fig. 1). Starting in 1991, the following developments related to TRIZ tools were carried out in parallel:

- Enhancement of existing tools based on accumulated practical experience
- Embedding existing tools into a typical problem-solving process
- Structuring the existing tools to better fit this process
- Integration of existing tools to avoid confusion caused by multiple tools
- Development of "missing" tools to provide complete support of all steps in the problem-solving process

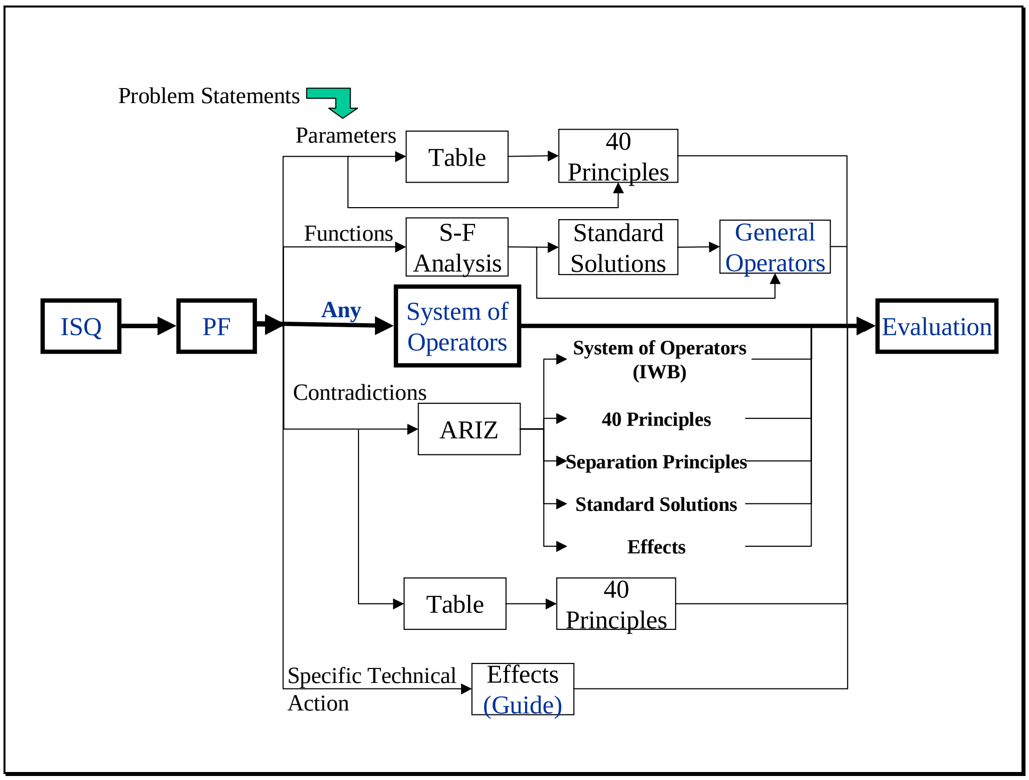

Fig. 1. TRIZ Tools Map

This extensive work has resulted in the following accomplishments:

- All Classical TRIZ tools have been divided into two groups: analytical and knowledge-base tools[31]
- The Ideation Problem-Solving Process has been developed and includes the following steps:
  - Problem definition and documentation
  - Problem formulation

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[30] *A method for solving real-life problems*, presented at the TRIZ conference, Petrozavodsk, 1985. See also [A16].
[31] *Managing Innovation Knowledge*. TIRG, 1999, Appendix 8.

- Identification and categorization of Directions for Innovations
- Development of solution concepts
- Evaluation and planning of implementation

- New analytical tools have been developed to support the missing process steps, as follows:
    - The Innovation Situation Questionnaire (ISQ)[32] is used to facilitate the understanding and documenting of the problem-at-hand
    - Problem Formulation is used to analyze a problem and develop an exhaustive set of potential Directions for Innovation
- Enhancement of the following existing analytical tools:
    - ARIZ
    - Substance-Field Analysis
- Development of a new integrated knowledge-base tool called the System of Operators.

Listed below is a brief summary of tool development and enhancements that have been accomplished or are in progress.

Analytical tools

Name and short description	**Start-Finish**	**Outcome (actual or expected)**

ARIZ-92[33]
• Division of existing steps into more detailed ones
• Addition of parts for manual problem formulation
• Introduction of extended Help system with numerous templates and selection menus
• Restructuring into the following booklets:
  • Explanation notes and glossary
  • Main steps
  • Collection of appendices
  • 11 case studies for training
	1989-1992	Smoother and faster learning, fewer mistakes in utilization
		
		Improved capability for computerization

[32] See [B2].
[33] "Problems of ARIZ Enhancement," *Journal of TRIZ* V 3, No1, 1992 (in Russian). See the English translation in TIRG, 1999, Appendix 15. Also part of handbooks entitled *Ideation methodology* and *TRIZ specialist training materials*.

ARIZ-95 A version of ARIZ-92 compatible with the IWB software system	1995	Provided for utilization in conjunction with the IWB
Substance-Field (S-F) Analysis[34] • Addition of model transformations with respect to time • Combining of S-F Analysis with process analysis • Introduction of a list of general fields (MeThChEM) • Development of a modified System-Field Analysis		Extension of ways to utilize Substance-Field Analysis. Partially used in the IWB system
Problem Formulation[35] New method for developing different problem statements, revealing an exhaustive set of directions for solution (Directions for Innovation)	1989-1992	Utilized in the development of the Problem Formulator software module

Knowledge-base tools

Name and short description	**Start-Finish**	**Outcome (actual or expected)**
Lines of Evolution[36]	1981, in progress	See DE application
System of Operators[37] Newly developed and integrated system, which subsumes all TRIZ principles, methods, and standard solutions, and more.	1989, in progress	Utilized in the Ideator, Improver, Eliminator, and IWB software tools
Innovation Guides[38]	1991, in progress	Utilized in the Ideator and IWB software tools

34 Partially published [A9,A15,A16,A17,A18,B2,B12].

35 TIRG, 1999, Appendix 8. Also, see in [B9].

36 See Part 2.

37 TIRG, 1999, Appendices 7 and 8.

38 For more detail, see the Ideation TRIZSoft™ family of software tools.

Enhanced and newly developed applications

The following is a brief summary of enhanced and newly developed applications.

Name and short description	Start-Finish	Outcome (actual or expected)
Anticipatory Failure Determination (AFD)[39] Newly-developed method for systematically identifying and preventing system failures and other undesired effects and their causes.	1978, in progress	To date, AFD has been applied to various systems, including: • Production failures • Helicopter safety • Chemical plants safety • Mining industry • Business security • Automotive manufacturing processes • Appliances • Others
Directed Evolution. [40] Newly-developed process for utilizing Patterns/Lines of Evolution to develop an exhaustive set of scenarios of future system development and to create patent fences based on these scenarios	1978, in progress	To date, elements of DE have been applied to the following systems: • Water immersion pump • Guns • Lift cranes • DNA sequencing • Various chemical processes • Consumer products • Selected automobile sub-systems
Problem solving. Various enhancements, including the development of a systematic process for problem solving	1985-1994	Utilized in the Ideation Process for Inventive Problem Solving. Over 100 projects[41] have been completed in the U.S. related to the following industries: • Automotive • Medical • Appliances • Chemical • Consumer products

[39] *Anticipatory Failure Determination*. TIRG, 1999, Appendix 16. See also [B5, B10].
[40] See part 2.
[41] The typical project is associated with multiple problems that need to be addressed

		• Electronic industry • Software development • Aerospace • Textile industry • Oil and gas production and exploration • Telecommunications • Transport
TRIZ Value Engineering Analysis.[42] Various enhancements, including the development of special groups of Operators (Idealization, Reduction) and additional recommendations for using the Ideation approach for traditional Value Engineering	1977, in progres s	Utilized in projects for cost reduction, including (but not limited to): • Electrical machines and technologies • Pumps • Chemical processes • Automotive design and production • Tooling industry • Consumer products • Appliances • Agricultural machines and technologies
Revealing hidden problems and opportunities for system improvement[43]	1978, in progres s	Successfully utilized in training manufacturing personnel to find problems to be solved. Expected to be part of a general method for continuous product/process improvement. Successfully utilized in training Ford CIRS teams.

[42] Published [A9, A16].
[43] TIRG, 1999, Appendix 11.