Directed Evolution as a Method of Thinking in the Era of Informational Civilization

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Abstract

Directed Evolution, a new application of TRIZ has been in development since the mid 1980s (at that time, under the temporary name *TRIZ Forecasting*). In 1994, Ideation International offered the name Directed Evolution (DE)™ for complex of works related to management (control) of technological evolution. The most comprehensive theoretical results of the research in DE were reported at TRIZCON 1999 followed by a set of articles[1].

The following paper presents the recent theoretical and methodological findings resulted both from further consideration of DE philosophy and potential in a global scale and practical experience gained during conducting DE in chemical, automotive, consumer products, software development and other industries[2].

The paper explains the vital role of DE application in the global processes of managing the evolution (controlling the future), and includes step-by step DE process, selected simplified tools suitable for conducting DE on systems of medium complexity, bibliography and the list of frequently asked questions.

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[1] *TRIZ in Progress, Part 2*. TRIZCON 1999, The First Symposium on TRIZ Methodology and Application. March 7-9, 1999. The Altshuller Institute for TRIZ Studies, Worcester, MA, 1999. Also, see in TRIZ in Progress 1999, Ideation International, 1999. About evolution of organizations, see Zlotin, Boris, et all. *TRIZ Beyond Technology*. The Second Annual AI Conference Proceedings. The Altshuller Institute for TRIZ Studies, Worcester, MA., 2000, p. 135. See also at www.triz-journal.com, January 2001. For more, see the Bibliography.

[2] Nine full-scale and several Express DE projects have been completed, several other projects are in progress.

Introduction

Last April (2000), a significant though almost unrecognized anniversary took place. Over twenty years ago, Alvin Toffler, well-known American sociologist and futurist published his famous book *The Third Wave*[3]. We have got acquainted with the book's main ideas back in Russia, mainly through extremely negative references of communist philosophers, usually serving as perfect indicators that the book was really good. However, we have got a chance to explore the depth of Toffler's ideas only after arriving to United States, and it didn't take us long to recognize strong links between the picture of the Third Wave drawn by Toffler, and TRIZ.

The main ideas of the Third Wave

Alvin Toffler assumes the existence of three waves of human civilization:

- Agricultural
- Industrial
- Informational

The main features if each wave one can see below.

Agricultural wave

The First (Agricultural) Wave started about 10,000 years ago and has the following features:

- Individual production, mostly simple mechanical technologies
- Utilization of renewable natural resources
- Life in harmony with the nature, consuming resources "willingly" offered by nature
- Self-provision with food and first need products
- The main driving force is very slow and incremental accumulation of knowledge and skills, increasing wealth, number of people, etc.
- Main conflicts are around resources, primarily for the land suitable for agriculture
- Mentality based on traditions, religion and common sense
- Lack of accumulated information, communication is mostly through personal contacts; information is stored in human heads
- Low concentration of people, the majority of people live in small communities; lack of cross-influence of remote groups; large traditional family which at the same time represent a production unit
- Children are educated in the process of participation in the adult life
- Individual management (ruling) when most of decisions related to people are made individually (like king's Solomon Judgment)[4].

[3] Alvin Toffler, *The Third Wave*. Bantam Books, 1991.
[4] Certain traditions, customs and rules exist, however, they leave a lot of space for individual decisions.

- Relatively simple life resulting in limited number of political or other decisions that have to be made to manage life and traditional hierarchical systems of power capable to handle it

Industrial wave

The Second (Industrial) Wave started approximately 300 year ago, it has been established through numerous and bloody conflicts with the First Wave civilization and continues today. Its main features are as follows:

- Mass production of consumer products and services. Complex technologies integrating mechanics with electrical power, electronics and relatively simple chemistry (non-organic, limited polymer technologies)
- Mass standardization, unification and synchronization[5] of various aspects of life and industry including production, life styles, etc. Increasing dimensions of machines, equipment, buildings, organizational growth, etc.
- Fast growth of utilization of non-renewable resources
- People seek dominating the nature. The society, certain organizations or even individuals become so powerful that can endanger humanity and/or the whole biosphere.
- Self-provision is practically impossible, creating high dependence from the market
- The main driving force of evolution at this stage is constantly increasing division of labor and specialization of people, organizations, regions, etc.
- The main conflict is between producer and consumer divided by the market.
- Mechanistic mentality. Attempts to interpret the world complexity via simple and based on formal logic mechanistic scientific, philosophical, social, psychological, etc. models.
- Information becomes a source of evolution and serves as a structure for integrating and standardizing the society. Development of means for independent accumulation of information, emerging of mass media.
- Concentration of people and industries in cities with high density of various flows.
- Emergence of large human organizations, including nations and countries. Nuclear highly mobile family, increased difference in functions performed by men and women at home and in industry producing increased difference in mentalities.
- Removal of children from adult life, standard education in public schools (industrial way of education).
- People management is on a mass basis (versus individual), that is, based in the principle of the equal responsibility before the law and is strongly regulated by law. It allows standardization of the majority of situations and applying standard solutions.
- Centralization of political institutions; emergence of large parties, corporations, etc. Development of governing elite in every facet of human life.
- Increased complexity of society, dramatical increase in the number of decisions that have to be made by various management; emergence of complex bureaucratic structures.

[5] Millions of people were working under the same schedule ("banking hours").

Informational wave

The Third (Informational) Wave started in 1950s-1960s and continues growing conflicting more and more with the Second Wave. Some of the parameters of the Third Wave are close to the First Wave while maintaining most of the features of the Industrial Wave, in particular:

- Combination of mass and individual production. Complex technological sphere based on biochemical, electronics, nuclear, genetic engineering, special materials, utilization of resources of ocean, space, etc.
- Reduction of industrial machines, buildings, organizations in size with utilization of new technologies.
- Emergence and enhancement of "smart" equipment[6], that is, systems that are capable to collect and work with information, and make certain decisions targeting the best performance.
- Enormous diversification of products, services, market sectors; adaptation of products to meet requirements of relatively small groups of consumers.
- Reduction of standardization, unification and synchronization of private life and industrial environment.
- Reduction in utilization of non-renewable resources.
- Quest for harmony between human civilization and nature (instead of dominating it); however, non-stop increasing of power of society, certain organizations and individuals increases endangering human civilization and biosphere.
- People become more self-sufficient, less dependent on the market.
- The main driving force of evolution is continuously increasing quantity of information and links between different activities.
- Main conflicts are between various groups of people.
- Mentality is based on systemic approach, environmentally sensitive behavior, non-mechanistic understanding of reasoning, acceptance of non-linear evolution, system equilibrium and disturbance of haphazard events; feedback, snowball effects, etc.
- Further increasing role of information, development of means allowing every individual to share information worldwide; practically unlimited access to information (Internet).
- Parallel processes of differentiation and integration in society. Formation of numerous (relatively small) organizations based on various interests, on one hand, and global organizations (corporations) on the other hand. Weakening of nuclear family, emergence of multiple models of a family.
- De-urbanization, that is, reduction of people concentration in gigantic cities, move to suburbs, converting an "electronic" house into a small production unit.

[6] For example, "smart truck", smart house", "smart security system", etc. Industrial Wave has provided people with numerous strong servants, which have saved people time and physical energy, allowing to spend more time for education, cultural and social activities, etc. Informational Wave is making these servants smart, saving intellectual energy required for their management. How this energy might be spent? Perhaps, for creativity?

- Individualization of education and moving it closer to the real life while at the same time stretching education through the entire life time.
- People management (ruling) based on combination of mass and individual influence and judgment (especially, individual informational influence). Utilization of marketing approaches directed to achieve win-win situation via negotiations and other feedback based techniques.
- Further increasing complexity of life, the number of decisions that have to be made by various management making any bureaucratic structures of the Second Wave ineffective and creating a need in new methods of managing the society when more people are getting involved in decision making process.

Transition

It is important to realize that transition from one wave to another is an incremental process including three main stages:

- Accumulation of new elements and approaches within the frame of previous wave; preparation for transition
- Actual transition in the most developed countries. This transition is usually accompanied with total structural crisis connected with destruction of existing social structures. Historically, the humanity had an opportunity to watch only one such transition from the First Wave to the Second one and it was very painful.
- Other countries that were left behind are catching up with the new wave. This stage was also associated with enormous number of casualties (with rare exceptions).

Today, the humanity is on a verge of transition to the Third Wave civilization, and there is a serious chance that this transition might be as painful as the previous one. However, there is a hope that this time it can be done in a much smarter way. We believe that the new science TRIZ can seriously contribute in this crucially important task to make a smooth transition.

To better understand the role of TRIZ in the Third Wave civilization, we would like to consider in-depth additional aspects of evolution partially mentioned by Toffler, that is, methods of managing (controlling) the process of evolution targeting certain goals (results) that should be achieved. Or, in other words, methods of managing the future.

Historical overview and main assumptions

Managing (controlling) the future: a need and possibility

One of the most important human needs is a need to foresee and control his/her future that was reflected in various myths and religions and originated a variety of fortune telling. People want to have a predictable future not just because of curiosity, but rather for the purpose of being able to make proper adjustments and to control their lives. There are three aspects that people would like to control the future of:

- Personal life
- Business
- Humanity

Control of personal life

Psychologists define two types of stress:

- Active – when an individual is in control of the situation. Active stress is stimulating and actually healthy.
- Passive – when an individual cannot influence the situation. Passive stress is destructive and unhealthy.

Hundreds years ago, future was much more predictable then today[7], when unexpectable things will definitely happen given the fact that an average person during his/her life goes through several different types of training and education, changes many times job, residency, friends, etc. Plus unpredictable technological progress bringing in our life electricity, automobile, computers, Internet, and else…

At the same time, there were always people that managed to control their future, adjusting the future to their own vision: Alexander the Great, Julius Caesar, Benjamin Franklin, Albert Einstein, Thomas Edisson, Bill Gates…These people have been considered as geniuses. Is it possible that a normal human being can do something like they did? The following examples can prompt the answer:

> Can one extract a cube root of 9834752345624563476? A thousand years ago nobody could do it. 500 years ago one should be a genius to do it. 50 years ago it would require long and hard calculating work. Today, it is enough to enter the number in a calculator and just push a button!
>
> 100 years ago one could reach 75mph speed probably falling into the deep canyon. Today, the same speed could be easily reached in a car moving along the freeway.

[7] 500 years ago a son of a farmer knew that he would become a farmer, too; a son of a shoemaker was preparing to become a shoemaker, and a son of a knight was trained to become a knight, if of course, something unexpectable doesn't happen. Actually, even unexpectable was enough predictable: it could be illness, a war, robber attack, etc.. Usually, an individual didn't travel around further than 7 miles from hi/her place of birth.

Assumption

Whatever a genius can achieve because of his/her talent, lack, intuition, etc., a normal human being can do even better having effective and convenient tools. The ability to control our own lives depends on appropriate tools.

Control of business

Every day millions of new businesses emerge in United States. However, only dozens of thousands survive over the first three years and only hundreds from those become real large. Chrysler was on a verge of crash in the end of 1970s; one of the largest airlines Pan American went out of business… On the other hand, McDonalds and Kentucky Fried Chicken went global; in spite of recent troubles Microsoft is still powerful; numerous Internet companies continue growing, IBM and Hewlett Packard have been stable for decades...

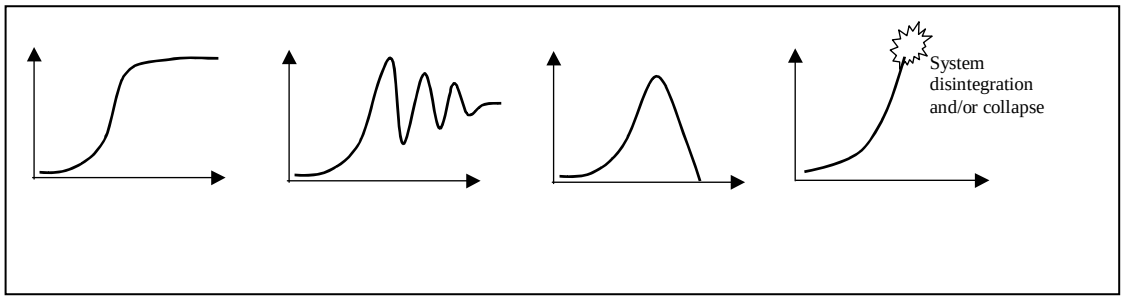
Why the survival percentage is so small? There are numerous books on economics, management, marketing, etc. containing valuable recommendations on how to establish, grow and assure high efficiency of business, how to win competition. However, not everybody who followed these recommendations could succeed. Why? Typical answers: lack of talent, luck, opportunity…

Assumption

Whatever one group of people can achieve as a result of combination of knowledge, talents and efforts, another group can do even better having effective and convenient tools. The ability to control the future of a business depends on appropriate tools.

Control of the future of humanity

Since the 17th century, the humanity has been growing exponentially. Number of people on Earth, available sources of power, rate of utilization of resources has been quickly increasing. However, any exponential growth could be dangerous, as the end of the process is unknown. There are four theoretically identified versions of the end (see pictures below). As one can see, only the first of them could be acceptable. How to assure it?



Let us consider the following analogy. The evolution of humanity could be considered as a train, which is constantly moving with increasing speed and growing in size. This train in the past struggled with pit holes and canyons – geological catastrophes, extinction, death of old civilizations, Europe depopulation as a result of epidemics and crusades, witch hunting, world wars, economic crises, etc.

Nobody knows where the train is moving or what can happen ahead because there is no windows in the train motorist cabin. One can hardly see limited portions of the road through few gaps and holes, and these views move very fast. Besides, one cannot be sure that it was a real road, not distorted reflections…There are many levers, steering wheels, switches and buttons in the cabin, however, nobody knows their purposes (an innocently looking button may initiate an explosion liquidating the whole human race).

There are many drivers in the cabin each trying to control his/her own part. They are mostly smart and honest; however, they cannot efficiently communicate and are afraid to trust one another. Besides, there are many monkeys in the main cabin. They look like drivers but they are playing their own games and do not care about the train in a bit.

If the humanity wants to survive, the most important objectives are:

- Create windows and unveil all possible ways forwards and potential obstacle for hundreds years to come
- Figure out the purpose of each lever, button, switch, etc.
- Learn how to choose the most effective and safe way(s) and how to quickly solve zillions of problems emerging on the way
- Reveal monkeys and get rid of them

It is quite possible that to assure safe and smooth way the direction should be slightly changed or the train should be rebuilt and/or should gradually slow down. Obviously, it can make certain people unhappy, however, could be critical for survival.

There are additional dangers associated with informational nature of the Third Wave. The humanity has passed trough four informational revolutions in its evolution, and every one of them was associated with a serious social crisis.

Informational revolution #1: hundreds of thousand yeas ago

The first informational revolution happened when Homo Sapience acquired the possibility of communication through language. Articulated speech provided people with the capability to coordinate actions, accumulate and transfer information from one individual to another and eventually to next generations via verbal (versus genetic) way. This advantage has determined the evolution victory of those who succeeded in acquiring the skill of speech and diminishing of others. It can very well be a reason why the Cro-Magnon man had survived over the Neanderthal one.

Informational revolution #2: Five-six thousand years ago

The second informational revolution is associated with written language (cuneiform, papyrus rolls, etc.). This invention has resulted in:

- Accurate posting of information (absolutely necessary attribute for commercial relationship)
- Centralized political power over the society
- Reliable links between generations, accumulation of accurate information, precise formulas for laws and religious dogmas.

Altogether, the advantages described above have ensured establishment of stable countries and commerce. Other nations and/or tribes that had not created or acquired the written language had been conquered or assimilated by more "literate" ones.

Informational revolution # 3: 550 year ago

The third informational evolution is associated with invention of printing, which has provided with opportunity to quickly disseminate information throughout masses of people and make information to play the central part in social changes. Invention and wide implementation of printing (together with other social, economical and demographic events) has resulted in increasing social role of information producers (at that time religious reformers). Reformation was spreading like a snowball causing numerous bloody wars resulted in elimination of millions of people and property. For example, during the Thirty-year war in Germany (1618-1648) the 18 million population was reduced to approximately 4 millions.

Informational revolution # 4: 150 year ago

Progress of economics and technology in the second half of the 19th century (mass production of paper, modernized printing equipment, introduction of high volume papers and magazines, railroads, telegraph, etc.) provided with availability of mass education and access to information by the end of the century. In turn, it has produced enormous amount of partially educated people seeking for intellectual consumption bringing to life cheap newspapers, evening education, public lectures, various associations, groups, social theories, parties, sections, etc. Altogether, it has resulted (the first time in the history) in the society overloading with information leading to dissemination of various superstitions, theosophy, weird philosophical systems, dangerous social theories (like fascism or various forms of Marxism), etc. Insufficient education has made numerous people victims of demagogues (they has learned how to absorb information but were lacking the ability to analyze, think things through. Revolution in Russia, Nazism in Germany, Muslim fundamentalism could be named as results of this informational explosion (of course, together with other reasons).

Upcoming informational revolution #5

Today, we are on a verge of the fifth informational revolution propelled by new informational technologies. Given the results the previous revolutions, we can expect the following from the recent one:

- Changes in the way we live, work, do business (eCommerce!), resulting in serious (and always painful) social changes
- Possibility of emergence and spreading dangerous social theories, religions and/or superstitions
- Spreading out dangerous knowledge
- Possibility of emergence of socially dangerous associations
- Disturbance of privacy
- Damage to countries that do not have an effective access to information (because of limited or no access to Internet or lack of English language)
- Degradation of languages (other than English)

Assumption

Uncontrollable (haphazard) evolution of humanity is becoming the highest danger in the informational era. Until now, this evolution has been realizing through numerous

historical haphazard events and actions of outstanding leaders. It is time to make the evolution manageable, which can be done only if appropriate and effective tools of control become available, and the humanity survival depends on development of these tools.

Managing the future and creativity

Essence of management is making numerous decisions. In complex situations (incomplete data, large amount of interconnected and mutually dependable factors, lack of strings to produce required influences) there is no the only one and obviously best solution (otherwise the situation is not considered as a complex one). Therefore, decision making in such ill-defined situations requires analysis of possible variants, their adaptation or invention of new ones, that is, requires *creativity*.

> Evolution is inseparable from creativity. We assume the definition of creativity (innovation) as creation of new things and concepts in any facet of human life including various tools and products; methods of teaching, curing or advertising; military, political or economic strategies; theories and pieces of art, etc.
>
> Creative capabilities in chosen area (politics, technology, arts, business, etc.) plus motivation, desire and enormous hard work were the ones that differentiated geniuses and famous leaders that have been shaping the history of humanity. It means that the matter of managing the future depend on methods of creativity.

Methods of managing the future

First Wave

Social evolution and methods of managing creativity during the First (Agricultural) Wave

During the First Wave, new objects have been created through utilization of ancient method of physical exploration of variants (Trial-and-Error Method, TEM).

> Some of these creations that has been found (Indian canoe, Chinese junks, Polynesian catamarans, old Russian sail boats, etc.) are surprisingly perfect; each line or detail seems to have the best possible shape. However, the archeological studies have showed that in the beginning (or close to this period) they were much worse. Traditionally repeating the same shapes, numerous builders have been yet introducing certain changes, some of which were fatal and have disappeared together with unsuccessful realizations, while the others stuck. It was a very long way similar to natural evolution.

TEM was utilized to create first silicon knives and bows, guns and mills, buildings and boats, methods of effective agriculture, education, etc. However, acceleration of technological and social evolution made the physical TEM less and less suitable as it was not possible building thousands of variants to create the best steam engine or speedy cruiser. TEM has exhausted its resources and had to be replaced with more effective method.

First Wave model of managing the future – a cycle

During the First Wave era, management of the future was rather limited for the following main reasons:

- Because of ineffective methods of creativity, the evolution was very slow; people could hardly notice any changes at all during their lifetime
- Future of an individual primarily depended on situation at birth[8]

As a result, the main means of managing the future was a pray "Give us this day our daily bread". Control was mostly local and oriented on small tasks: what and/or when to plant for the farmer, with whom and when to fight or cooperate for a ruler. Basically, the main model of controlling the future during the First Wave was a *cycle*, as life was repeating itself through generations requiring addressing standing alone small events.

Conditions that have stimulated transition to the next, Second Wave

The First Wave has created very important conditions for development of methods of creativity suitable for the next wave:

- Work of numerous unknown inventors has transformed TEM into the method of experiments and helped accumulate enormous amount of empirical information in all areas of human activities
- Work of religious scholiasts and philosophers has resulted in development of a powerful technique of logical analysis and conclusions

Both these conditions were developing independently; their combination, that is application of logical (including mathematical) analysis to empirical knowledge has originated the science of industrial era.

Second Wave

Social evolution and methods of managing creativity during the Second (Industrial) Wave

During the Second Wave, scientific methods of searching for new ideas based on building and studying various mental models (theories, hypotheses, etc.) have been dominating. These methods allowed learning about the future system long before it was actually built and included (but not limited to) inexpensive rapid prototypes (models) which behavior allowed making certain assumptions about the future behavior of the real system, etc. Science has made possible searching for the best design or the best method of managing economics via utilization of calculations and targeted research playing the main part in unprecedented acceleration of the industrial growth.

[8] As it was mentioned earlier, a farmer's son would become a farmer, and so on.

However, it is important to understand that science of the Second Wave was effective mainly in the area of optimization of already generated ideas and concepts. In the area of searching for brand new ideas, the slightly modified TEM has been still in use.

> Facing the problem that does not have ready solutions, an innovator is struggling with it, asking him/herself: "What if I do it this way?… Not good… May be, that way? Or …? This exploration of variants usually starts from apparent ones, slowly moving into direction of more wild. After hundreds of variants that have been explored without success, a desperate innovator may be saved by chance; for example a tee kettle might prompt an idea to utilize steam or boiling water…
>
> The history of innovations demonstrates that the amount of trials necessary to guarantee the solution may vary from dozens for simple problems to billions for the most difficult ones. Thousands of professionals could be involved in solving complex problems for decades until a genius arrives. Almost all inventions (including non-technical ones)[9], crucial for the Second wave society have been made by a rather limited circle of people[10] that had inherited exceptional creative capabilities[11].
>
> The history of technology also demonstrates that solutions to important problems are often late, causing the losses that is difficult to calculate. For example, Alexander Flemming, an inventor of penicillin insisted that his invention could be made 20 years earlier and could save not less that 20 millions of lives – and it is a count for one invention only!

Second Wave model of managing the future - railroad

During the Second Wave era, strategic planning became the main means of management of the future.

> Strategic planning including decision making and realization of sequential pre-determined actions targeting achievement of certain goals, was effective enough in the mostly linear and rather slow changing environment of the industrial era. It was still possible to assess availability of necessary resources, potential useful and harmful consequences of decisions and make timely arrangement for prevention of undesired events. Certain adjustments and corrections of plans were also common. In line with strategic planning, various long-term programs, laws, rules, constitutions, legal systems, etc. defining group and individual behavior in pre-determined situations have been developed.

The basic model of management (control) could be defined as *"railroad"* model (analogy: people are siting inside the train; they cannot influence the route determined by authorities that know better where people should go).

Conditions that have been stimulating transition to the next, Third Wave

Surprisingly, industrial methods of management have been turning up less and less effective with the growth of industrial era.

> Plans could be destroyed by conflicts of interests (wars, for example, always destroy plans of at least one side; more often of both). Unforeseen circumstances have been forcing plans'

[9] Like new way of financing; methods of sale, marketing and advertising; organizational innovations, scientific theories, etc.
[10] Fractions of a percent of the entire human population.
[11] Like James Watt, Thomas Edisson, Albert Einstein, Henry Ford, John Maynard Keynes, etc.

> corrections making them rather a rule than exception. Organizations established for the purpose of enforcement of plans realizations (both on public and private levels), underwent uncontrollable growth and bureaucratization while results were becoming more and more poor. Rules and regulations were swelling as a result of numerous additions, explanations and interpretations, their complexity went over any reasonable limits originating an army of lawyers…

Ineffectiveness of classical innovation process based on "insights" of a handful of exceptionally talented individuals became obvious by the end of 1940s.

> Growing industry, science, other areas of human activities were demanding more and more ideas in continuously shrinking time frame. Increasing pressure has often resulted in stress and even psychiatric damage to inventors requesting new more effective methods of creativity.

Alex Osborn[12] was one of the first individuals responding to this request. He invented Brainstorming – an effective method of group creative activity. Other methods, similarly based on special psychological stimulation, have followed[13]. This direction has reached its peak in works of de Bono and his school[14].

Third Wave model of managing the future – car race

The main features of the Third Wave complicating management of evolution are as follows:

- Significant increasing of society's complexity including increasing number of various groups and organizations with different (often with opposite) interests and goals; increasing number and variety of links between groups and individuals resulting in the following consequences:
  - Sharp increase in number of decisions that have to be made in less time
  - Decisions are always based on certain solutions. Sometimes, possible solutions are not available; they have to be generated first; in other cases, too many variants of solution exist making the choice very difficult
  - An enormous amount of information has to be assessed to guarantee the best decision
  - Decisions and/or actions produce hardly predictable side effects, influence decisions/actions of other groups and/or individuals that might bounce back changing deviations in planned results
- Significant increase in informational noise, lack of necessary information
- Accelerating emergence of new entities and concepts (organizations, technologies, theories, etc.)
- Significant increase in amount of energy and other resources controllable by certain organizations and/or individuals increasing in turn the risk associated with certain decisions

[12] Osborn, A.F.,1963, *Applied Imagination.* New York: SCRIBENER's SONS.
[13] Zusman, Alla, *Creative Methods Overview*. In TRIZ in Progress, 1999, Ideation International, p.85.
[14] Edward de Bono, *Lateral Thinking*, Penguin Books

As it was mentioned earlier, management (control) assumes producing numerous decisions. Deployment of the Third Wave era creates numerous complex and unique situations making all known solutions unacceptable. Because of that, one cannot rely on constantly growing power of Internet and enhancing search engines to deliver solutions – the most critical ones are not going to be there[15].

In this situation, decisions are made via selection from several potential variants (sometimes with vague understanding of selection criteria), or modification (adaptation) of typical solutions to a specific situation, or, more often inventing the best variant. In all events, including selection in uncertain conditions, adaptation or invention, creative work is required making the need in creativity more and more critical factor in all human activities.

Currently certain methods based on combination of well-defined goals and substantial freedom and initiative in making creative decisions by employees are accepted and effectively utilized in selected cutting edge organizations. These methods should become the main management tools during the Third Wave era.

The main model of control for the Third Wave – *car race* on an unfamiliar broken terrain (analogy: the destination is defined, however everybody can select his/her own route and make decisions how to avoid obstacles, what speed to keep, level of risk and safety, when to stop for rest. It is a matter of personal decision to participate in the race individually or as a part of a team or teams, etc.).

Assumption

Creativity becomes the most important component in any human activity during the Third Wave era. It becomes necessary for the country, corporation and individual for planning and controlling its destiny and actual survival. The deficit of creativity will become the main obstacle on the way to progress and therefore enhanced creative methods should become the main tools of managing the evolution.

Knowledge based approach to creativity – TRIZ

At approximately the same time with Alex Osborn, Genrich Altshuller developed the foundation of the Theory of Inventive Problem Solving (TRIZ)[16] - an approach based on research in the area of history of technology and utilization of patterns of evolution and other knowledge extracted from statistical studies of inventions accumulated in the past. To date, over 50 years of practical utilization and theoretical research have allowed the following conclusions:

---

[15] From our experience, this statement happens to be one of the most difficult to accept by contemporary technologists and scientists. It is usually more acceptable for artists, businessmen and high level executives. The reason might be that contemporary engineering and scientific education emphasizes role of knowledge while lacking acquiring skills of creative work.

[16] Russian language based acronym. See selected *TRIZ Bibliography* and *The Brief History of TRIZ* in TRIZ in Progress, 1999. Ideational International.

- Creativity can be taught to any average individual allowing solving complex creative problems fast and with confidence
- Both evolutionary (knowledge based) and psychological approaches are compatible and effectively complement one another

TRIZ is based on the following assumptions:

- Emergence and implementation of innovations are not haphazard (as it might look), but rather are governed by certain general patterns of evolution of artificial[17] systems
- These patterns can be revealed through studies in the history of innovations in various areas, including history of technology, arts, social life, etc.
- Revealed patterns could be purposefully used for:
  - Prediction of possible ways of evolution and potential dangers associated with evolution
  - Fast and effective resolution of creative (inventive) problems

[17] We refer to an artificial system as any system created by humans including:

- Technical systems – any machine, device, equipment, manufacturing or other processes related to design and production, materials utilized, etc.
- Social systems – various groups of people, organizations and associations, management systems, legal systems, etc.
- Intellectual systems – religious and philosophical concepts, scientific theories and hypotheses, arts, etc.
- Service systems – education, medicine, entertainment, etc.

Directed Evolution

Main definitions and historical overview

As it was mentioned earlier, TRIZ allows teaching everyone how to solve problems. However, effective problem solving is necessary but not sufficient for managing the evolution. In addition, a real master of his/her own destiny should be able to perform the following functions:

- Analyze existing situation, evaluate its pluses and minuses, conflicts and basic resources of evolution
- Identify the main trends of evolution, possible scenarios and select desirable ones
- Identify potential dangers and problems that can arise in the process of evolution
- Formulate and solve creative problems that have to be resolved to ensure achievement of the defined goals, overcome obstacles and prevent undesirable side effects
- Control deviations and reveal new dangers along the way; introduce appropriate corrections to the plans in timely fashion.

Starting as a technique for technological problem solving, for the next four decades TRIZ became the most powerful source of knowledge and tools for controlling technological evolution. During the next fifteen years, its approaches and methods have been extended in non-technical areas including the area of social evolution and evolution of organizations[18]. In fact, TRIZ while maintaining its old name, has transformed into the *Theory of Evolution of Artificial Systems (TEAS)* based on which it became possible to develop a new methodology for managing (controlling) evolution named *Directed Evolution DE)*™.

> The roots of Directed Evolution ascend to the mid-1950s, when an approach for reckoning the future named *Technological Forecasting* [19]has been under development. In the mid-1970s it resulted in establishing non-related techniques such as trend exploration, morphological modeling, the Delphi process and several others, all of which were based on probabilistic modeling of future characteristics of various systems.
>
> Since the mid-1970s, an entirely new approach, called *TRIZ (Technological) Forecasting*, has been in development. This is based on the pre-determined Patterns of Evolution discovered within the TRIZ methodology through the analysis of hundreds of thousands of innovations spanning different areas of technology. Utilizing selected TRIZ tools developed over time, one can generate an idea(s) helpful for the development of the next product or process generation.
>
> Unlike traditional Technological Forecasting, the TRIZ Forecasting process is guided in accordance with the Patterns of Evolution and actually "forces" the system's highly-probable future development by inventing it before it would otherwise occur naturally. For example, the

[18] Zlotin, Boris, et all. *TRIZ Beyond Technology*. The Second Annual AI Conference Proceedings. The Altshuller Institute for TRIZ Studies, Worcester, MA., 2000, p. 135. See also at www.triz-journal.com, January 2001.
[19] Martino, J.P. *Technological Forecasting for Decision Making*, 2nd edition, North-Holland, 1983. Jantsch, Erich. *Technological forecasting in perspective.* London, 1972

Pattern of Evolution Toward Increased Dynamism and Controllability states that in the course of development, technological systems evolve from rigid structures into flexible or adaptive ones.

An illustration of this pattern is the development of aircraft structures from rigid wing designs to variable-geometry wing designs. Following this direction, a design engineer working on a new generation of a medical tool is encouraged to consider the possibility of using flexible materials to gain new adjustment capabilities.

Numerous patterns and more detailed descriptions – called "Lines" – provide the user with predicting power.

Since the mid-1990s, TRIZ Forecasting began a transformation into *Directed Evolution*. This is a systematic approach aimed at identifying a comprehensive set of potential scenarios of evolution of:

- Products/services/processes
- Technology
- Organizations or enterprises
- Industries
- Markets
- Societies
- Civilization

Directed Evolution is based on an extended set of Patterns/Lines of Evolution, as well as other tools developed by the Ideation Research Group.

While sharing a similar general goal, three approaches – that is, Traditional Technological Forecasting, TRIZ (Technological) Forecasting, and Directed Evolution – yield different results, and each employs unique tools by which to achieve its objectives. Consequently, the outcomes obtained by applying these approaches to foreseeing prospective technological advances are also different. Generally speaking, the main question to be answered via the approach of each application is illustrated by the following[20]:

Approach	Main question
Traditional Technological Forecasting	"What is going to happen with my product or process parameters?"
TRIZ (Technological) Forecasting	"What change(s) should be made to move my product or process to the next position on a specific pre-determined Line of Evolution?"
Directed Evolution	"Which evolutionary scenario should be selected from an identified comprehensive set of scenarios to make it a winner?"

In other words, Directed Evolution replaces guess work of forecasting with strategic decision making based on potential scenarios of evolution built on fundamental knowledge about proven patterns of evolution, and implementation (actions taken) in accordance with decision(s) made.

[20] For more detail, see *TRIZ in Progress, Part 2*. TRIZCON 1999, The First Symposium on TRIZ Methodology and Application. March 7-9, 1999. The Altshuller Institute for TRIZ Studies, Worcester, MA, 1999. Also, see in TRIZ in Progress 1999, Ideation International, 1999.

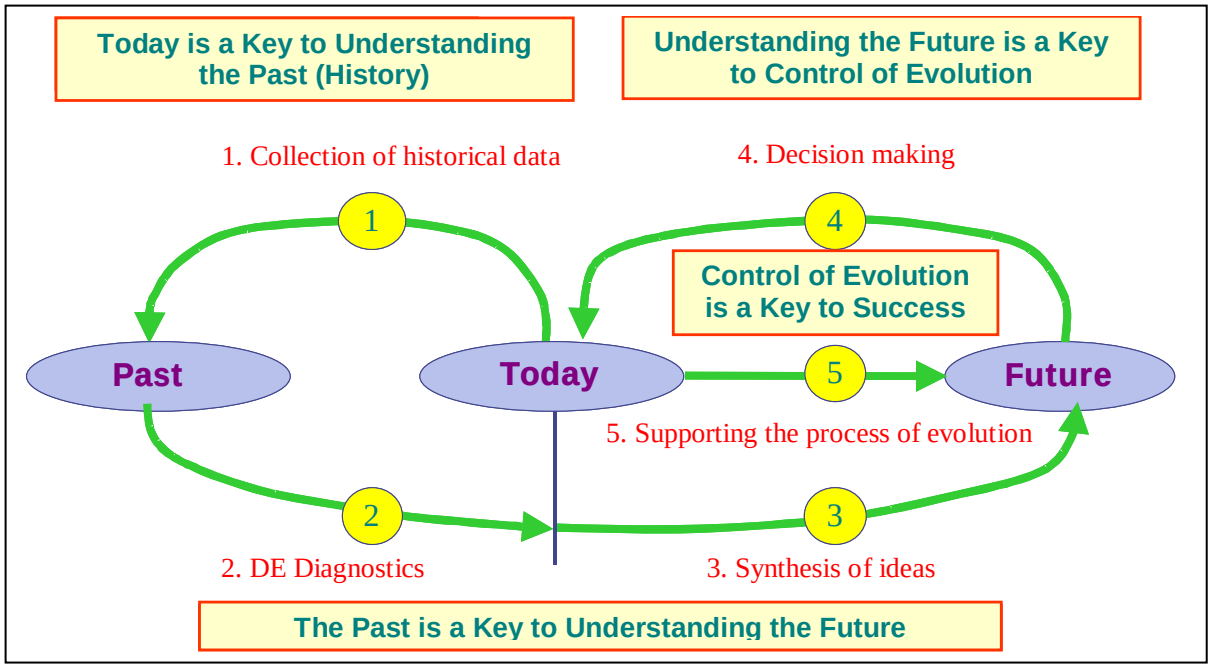
The theoretical foundation of Directed Evolution includes postulates[21] and other information based on the history of evolution of technology and other areas of human activity, presented in the form of trends, patterns and Lines of Evolution.

Directed Evolution (DE) includes a set of tools (methods, algorithms, techniques, knowledge base, software, etc.) supporting the following results:

- Analysis of history and current situation of a given system, revealing basic patterns of its evolution in comparison with general patterns of evolution.
- Strategic planning, including identification of long-term objectives and next pre-determined steps according patterns/lines of evolution. Invention of main new features of the future generation.
- Revealing potential obstacles in evolution, dangers, undesired side effects and other problems that might arise or sharpening in the process of evolution (Failure Prediction[22]).
- Fast resolution of problems that have to be resolved to achieve goals and elimination of problems that emerged in the process of evolution.
- Selection of innovations for implementation based on marketing, technical, social and other trends and patterns of evolution).

Given the above, we believe that DE represent the methodology and a way of thinking belonging to the Third Wave allowing individuals, organizations, nations and the entire humanity manage (control) of their own destiny.

General schema of Directed Evolution



[21] TRIZ in Progress 1999, Appendix 13. Ideation International, 1999.
[22] Failure Prediction is another TRIZ application developed in Ideation International. For more detail, see Kaplan, Stan, Ph.D., Svetlana Visnepolschi, Boris Zlotin and Alla Zusman. *New Tools for Failure and Risk Analysis*. Ideation International, 1999.

The picture above illustrates the general schema of DE process including the following five stages:

- Collection of historical data
- DE diagnostics
- Synthesis of ideas
- Decision making
- Supporting the process of evolution

In reality, certain deviations from the general process are possible depending on the following factors/conditions:

- Project size (DE for an individual, organization, specific product or process, etc.)
- Area (industry, market, social system, etc.)
- System (DE object) nature and age
- Customer's marketing and/or technological position and objectives
- Availability and accessibility of information
- Current marketing situation
- Current situation with intellectual property related to the project

Every DE stage consists of steps, supported by appropriate means (analytical and/or knowledge base tools) allowing for analysis and/or conclusions.

Below one can see the steps' description in more detail. All techniques and algorithms mentioned could be utilized for systems rather small (for example, for simple products or an individual). For large-scale projects more complex computerized processes and tools are appropriate[23].

Stage 1. Collection of historical data

The main objectives of the stage

The main objectives of learning about the system are:

- Accumulate data for further work
- Reveal positive and negative trends in the evolution of the given system. Revealed trends are going to be utilized for further comparison with general patterns/lines of evolution known in TRIZ and for identification of deviations (disturbances)

[23] Ideation TRIZSoft™ including Innovation Workbench (IWB) system, Failure Analysis Software System, Failure Prediction Software System, Knowledge Wizard.

Work to be completed

Learning about the given system includes the following studies of:

- System structure: its sub-systems, super-systems and their evolution
- System functioning: useful and harmful functions and their evolution
- Problems, contradictions and other obstacles in the process of the system evolution
- Production problems, contradictions and other obstacles related to the production process evolution
- Adjacent and other related systems in the process of evolution
- History of the main ideas: main discoveries, inventions, improvements, product line evolution and other changes
- Market: sectors, typical users' profile, customer expectations and their evolution
- History of related organizations: competitors, vendors, etc. and their evolution
- Resources belonging to the system, their changes in the process of evolution and new resources involved

The historical study is conducted through assessment of patent and other information, interviewing Subject Matter Experts in the given and related areas.

Tools and techniques utilized

The following tools and techniques are utilized during the Stage 1:

- DE Questionnaire
- DE Failure Analysis
- DE Problem Formulation

DE Questionnaire[24]

DE Questionnaire is based on TRIZ System Approach (Analysis) and represents a structured set of sequential questions with the following purpose:

- Collect and document information about the given system and its environment
- Identify and fill the gaps in our knowledge about the system and its environment
- Initiate thinking process from the patterns of evolution prospective
- Reduce psychological inertia

As it was mentioned earlier, each step is supported with appropriate means (analytical and/or knowledge base tools) allowing for analysis and preliminary conclusions

DE Failure Analysis

This module is optional and allows for revealing root causes of various facts and/or phenomena (useful and/or harmful) based on TRIZ approach to Failure Analysis (TRIZ

[24] For more detail, see Appendix 1

application). This approach involves transformation of "investigation" problem into an inventive one[25].

Problem Formulation

Problem formulation is another analytical tool (technique) based on TRIZ System Approach, rooted in Genrich Altshuller's multi-screen model of creative thinking[26]. It allows transforming complex (often net-like) information about the system, pieces of which usually exist in minds of different people and thus rather disconnected, into a well-organized map (graphical diagram) reflecting cause-effect relationships between system elements and its environment in the form of "knowledge net". Utilization of problem formulation technique allows further transformation into an exhaustive set of specific Directions for further analysis and development of recommendations for their realization[27].

Problem Formulation can be completed manually[28] or with the utilization of software module named Problem Formulator™[29].

Stage 2. DE diagnostics

The main objectives of the stage

DE diagnostics is the "heart" of the process. Its main objective is to identify possible directions of the given system evolution and formulate all problems and issues that have to be addressed to actually realize this evolution. This stage has to address the following issues:

- Successful and unsuccessful (abandoned, rejected, failed, etc.) ideas, concepts and/or events in the given system evolution
- Potential dangers and/or failures that might happen with the system in the future
- Problem that should be resolved to ensure the system evolution in desired direction

Work to be completed

DE Diagnostics includes:

- Comparison of historical data with patterns/lines of evolution including
  - Mapping historical data along known patterns and evolution lines

[25] See Appendix 2. For more detail see in Kaplan, Stan, Ph.D., Svetlana Visnepolschi, Boris Zlotin and Alla Zusman. *New Tools for Failure and Risk Analysis*. Ideation International, 1999.
[26] G. S. Altshuller, *Creativity as an Exact Science* (Gordon and Breach Science Publishers, 1984), 117-123.
[27] For more detail, see Zlotin, Boris and Alla Zusman. *Managing Innovation Knowledge*. TRIZ in Progress 1999. Ideation International, 1999, p. 123. See the same article on www.ideationtriz.com or www.triz-journal.com
[28] See Appendix 3.
[29] Problem Formulator module is included in the following Ideation TRIZSoft: Innovation WorkBench (IWB), Knowledge Wizard and Knowledge Wizard Millennium.

    - Positioning the given system on patterns and lines of evolutionBuilding lines of evolution for the given system
- Revealing missing and future steps (opportunities for improvement) including
    - Missing steps on general evolution lines
    - Future steps on general evolution lines
    - Wrong directions, dead ends and stalemate in evolution
    - Functions' deficiencies
    - Unresolved contradictions, secondary problems, etc.
    - Customary inconveniences
    - Psychological inertia, tunnel vision, unreasonable restrictions, etc.
- Extrapolating lines of evolution for the given system into the future including
    - Prediction of highly probable future steps in evolution of the given system
    - Definition of ways and conditions for realization of these steps
    - Definition of limitations for realization of these steps

Tools and techniques utilized

The following tools and techniques are utilized during the Stage 2:

- Analysis of evolutionary resources
- S-curve Analysis
- Patterns/Lines of evolution
- DE Failure Prediction

Analysis of evolutionary resources

Analysis of evolutionary resources helps unveil various (including hidden) resources that can be utilized in the system evolution.[30]

S-curve analysis

S-curve analysis is based on extended (six main stages) S-curve[31], and targets identification of evolutionary position of the given system. Knowing the specific position and utilization of dedicated knowledge base[32] allows identifying the correct directions for development and typical mistakes that have to be avoided at this stage of evolution.

Typically, the S-curve analysis involves the following steps:

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[30] See Appendix 4.

[31] For more detail, see Ideation's course material for TRIZ specialists, 1998. See also in: TRIZ in Progress, Part 2. TRIZCON 1999, The First Symposium on TRIZ Methodology and Application. March 7-9, 1999. The Altshuller Institute for TRIZ Studies, Worcester, MA, 1999. TRIZZ in Progress 1999, Ideation International, 1999, p.33.

[32] An example of s-curve analysis see in Zlotin, Boris, et all. *TRIZ Beyond Technology*. The Second Annual AI Conference Proceedings. The Altshuller Institute for TRIZ Studies, Worcester, MA., 2000, p. 135. See also at www.triz-journal.com, January 2001.

1. Building S-curves for the main system parameters
2. Building S-curves for influential sub-systems
3. Evaluating the system's position on the S-curves based on:
   - Number of patents
   - Citations
   - Organizational features
   - Market lines of evolution
4. Revealing the main mistakes typical for the given stage of evolution, and revealing the "correct" directions for development
5. Revealing "bottlenecks" – sub-systems that hold back further development and force the system into maturity

Patterns/Lines of evolution

A set of Patterns and Lines of Evolution represents the main tool for identifying potential directions for evolution[33].

DE Failure Prediction

This module allows for prediction of potential failures and dangers based on TRIZ approach to Failure Prediction (TRIZ application)[34]. This approach involves transformation of "prediction" task into an inventive one.

Stage 3. Synthesis of ideas

The main objectives of the stage

The main objective of the stage is generating ideas that will actually allow the given system move to the next evolutionary step. Obtained ideas are typically address the following issues:

- New functions, applications and markets for the system
- Various ways and methods related to:
  - Providing the system function
  - Preventing the system harmful or undesired effects
  - System production, delivery, using, maintenance etc.
  - Integration of the changed system into various super-systems

Work to be completed

[33] See Tutorial material for TRIZCON 2001.
[34] Appendix 5. For more detail, see Kaplan, Stan, Ph.D., Svetlana Visnepolschi, Boris Zlotin and Alla Zusman. *New Tools for Failure and Risk Analysis*. Ideation International, 1999.

At this stage, numerous inventive problems that have been formulated on previous stages have to be addressed. The work involves:

- Analysis of all ideas obtained on previous stages and formulation of secondary problems
- Structuring, organizing and prioritizing problems formulated earlier
- Actual problem solving

Tools and techniques utilized

The following tools and techniques are utilized:

- Ideation Inventive Problem Solving Process (IPS)
- Ideation brainstorming

Ideation IPS

The **Ideation Process** for IPS is a comprehensive, software-based[35] problem-solving process incorporating the Ideation/TRIZ Methodology (I-TRIZ) and its analytical and knowledge base tools. The Ideation Process is designed to support you in analyzing a problem situation and developing innovative **solution concepts**, and consists of the following stages:

1. Innovation Situation Questionnaire
2. Problem Formulation
3. Prioritize Directions
4. Develop Concepts
5. Evaluate Results

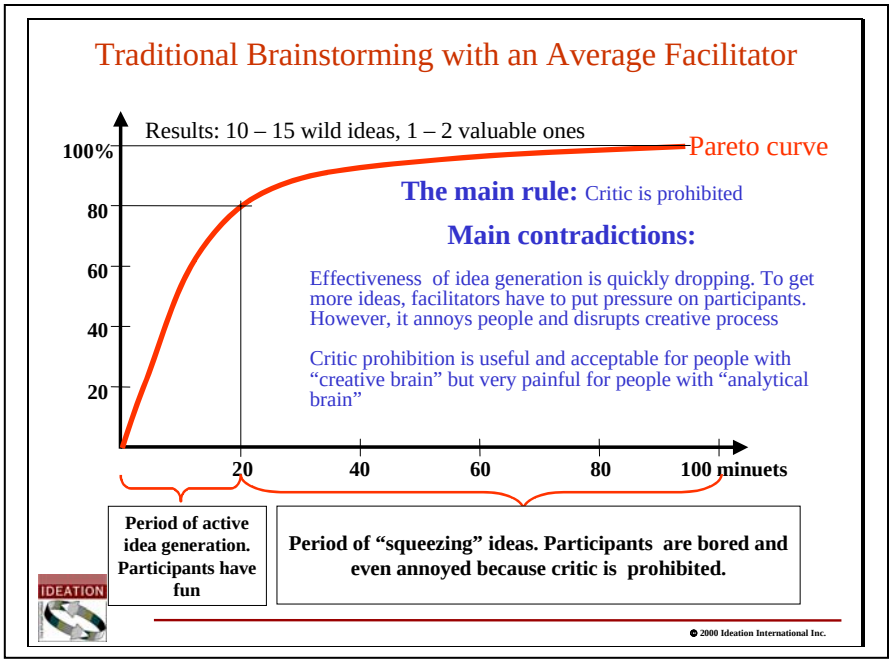
Manual utilization, a simplified Ideation Problem Solving process can be recommended[36].

Ideation Brainstorming

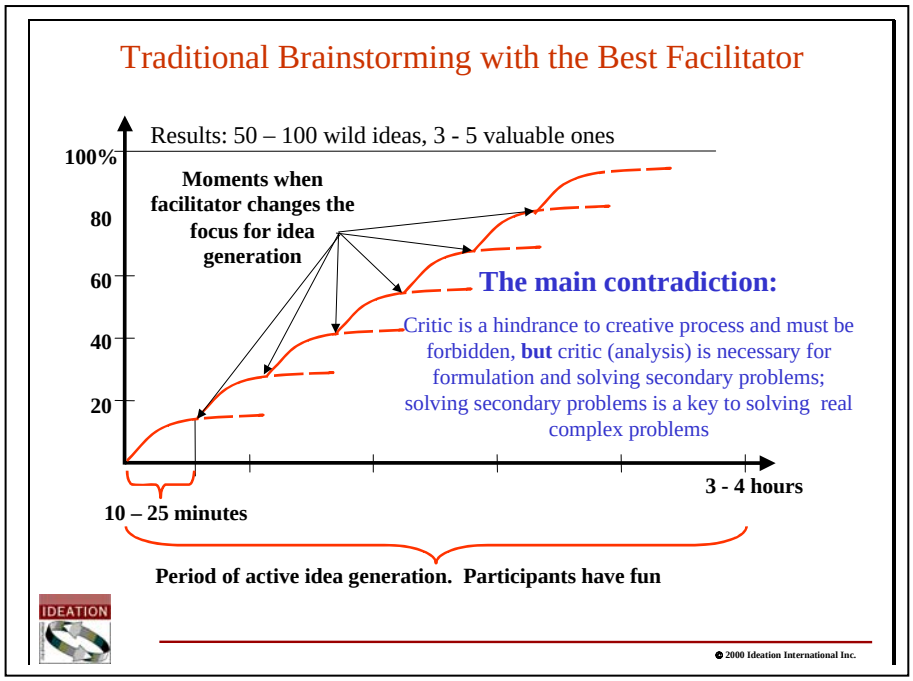
Ideation Brainstorming is a modification of traditional Brainstorming based on utilization of Ideation IPS and (optionally) TRIZSoft to support the team facilitation process[37].

Traditional Brainstorming has substantial deficiencies (see the picture below). One of them is that people are usually quickly exhausted with ideas and are getting tired and even annoyed because any critic of ideas is prohibited.

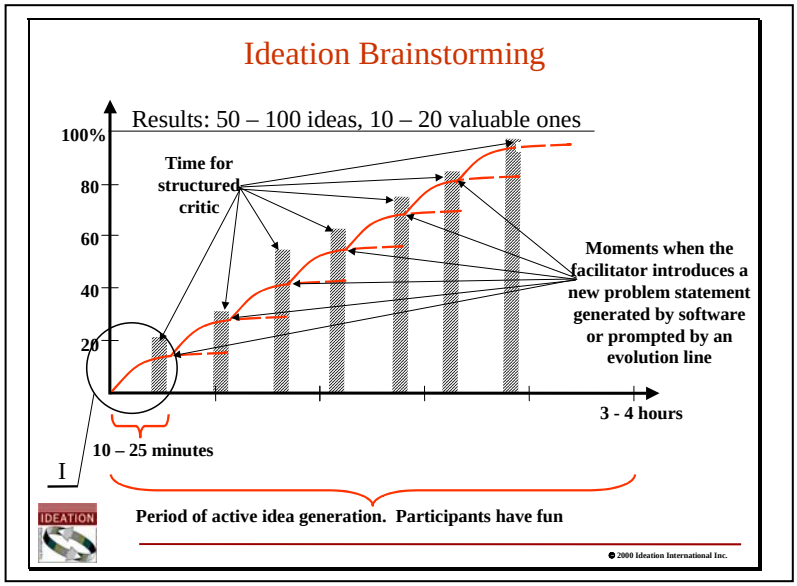
[35] IWB Software for technical problems, Knowledge Wizard Millennium software for all others.
[36] See Appendix 6. Also, Ideation Ideator Software can be utilized to support simplified problem solving process.
[37] See Appendix 7. Also, see in TRIZ in Progress 1999, Ideation International, 1999, p. 246.



This drawback can be partially eliminated if a very creative facilitator is in place:



Ideation Brainstorming allows overcoming all problems associated with the Traditional Brainstorming as it integrates the brainstorming environment with rigorous problem solving process (see the picture below).



Stage 4. Decision making

The main objectives of the stage

The main objective of the stage 4 is to prepare all necessary material for making decisions on direction(s) of the given system evolution. If the previous stages are usually completed with the participation of Subject Matter Experts in the area of design, production and utilization of the system, during this stage sale, marketing, financial personnel should be involved. It is also very important that decision making people will be involved at least on the final part of the stage.

Work to be completed

The following work has to be completed:

- Concept development including:
  - Integration of compatible ideas into concepts, each of which represents a certain variant of system evolution
  - Dividing developed concepts into groups their compatibility point of view:
    - Incompatible
    - Compatible
    - Complementary
  - Dividing developed concepts into groups from the time table point of view:

    - Short terms (improvement)
    - Middle term (next generation)
    - Long term (future generations)
- Building potential scenarios (step-by-step) of evolution including
  - Formulating the evolution goals, strategy and sequence of their achievement
  - Developing action plan
  - Identify resources required
  - Protect intellectual property
- Introduce necessary corrections to the strategy and action plans based on:
  - Prediction of potential obstacles and disturbances along the way
  - Prediction of potential negative results of the actions and formulation of secondary problems
  - Solving all new problems unveiled
  - Introduce appropriate changes to the evolution scenario(s)

Tools and techniques utilized

The following tools and techniques are utilized:

- Ideation Brainstorming
- Ideation Inventive Problem Solving
- Patterns/Lines of evolution
- DE Failure Prediction
- Analysis of evolutionary resources

Stage 5. Supporting the process of evolution

Why good intentions so often lead to hell? Every driver knows that when driving even along the straight freeway one cannot set the steering wheel free for more than several seconds – the microscopic deviations will accumulate and the automobile will slip from the freeway…

Similarly, when moving to certain goals, it is not sufficient to have good plans and effective control of their completion – there always be unexpectable deviations. Because of that, the previous four stages that are usually completed in relatively short period are just a preparation to the main stage – Support of the evolution process, which involves continuos monitoring and process corrections when needed.

The main objectives of the stage

The following aspects have to be closely monitored during the evolution:

- Prediction and watching possible deviations, changes in the system environment, including:
  - Changes in climate, demography, social psychology, fashion, etc.

    - Changes in politics and economics (recessions, periods of growth, crises, etc.)
    - New scientific discoveries and inventions in other areas that can relate to the given system
- Prediction of deviations, analysis of plans versus actual
- Solving inventive problems related to:
    - Utilization of deviations as a resource for goals achievement
    - Neutralization of deviations, compensation and protection from their influence
- Correction of scenario(s)

Work to be completed

The following work should be completed:

- Organizational measures to ensure Continuos Directed Evolution process including
    - Educating personnel in DE application
    - Establishing a special infrastructure to support DE implementation
- Controlling the evolution process including
    - Identifying and controlling critical points
    - Timely revealing deviations and documenting new problems (technological, marketing, social, etc.)
    - Promptly solving new problems and integrating new solutions into the scenario(s) of evolution
- Refining DE recommendations including
    - Reviewing basic concepts on a regular basis (one-two times per year for fast growing business; once in two-three years for stable, mature businesses)
    - Introducing corrections, refinement and adjustments to DE scenario(s) after serious changes (breakthrough) in social, marketing or technological areas.

Tools and techniques utilized

The following tools and techniques are utilized:

- DE Failure Prediction
- DE Failure Analysis
- Ideation Inventive Problem Solving
- Ideation Brainstorming
- Patterns/Lines of evolution

Teaching DE

DE tools, techniques and other elements that could be continuously utilized in daily activities

The following tools, techniques and other elements could be recommended for daily utilization.

- Prediction of possible variants of the future evolution of a given system based on universal/general patterns of evolution (10-20 patterns/lines)
- Prediction of potential failures (based on Failure Prediction application)
- Revealing root causes or mechanisms of various phenomena (based on Failure Analysis application)
- Inventive (creative) problem solving
- Reduction of psychological inertia

Teaching children

To date, a substantial experience has been accumulated in teaching children creative techniques and their application in daily life, mainly in the former USSR[38]. The results have definitely shown achievement of higher self-esteem, better learning capabilities, overall positive changes[39].

It is absolutely obvious that children education has to become the main method of DE basics wide scale implementation. Eventually, children should benefit from the following results:

- Better understanding of internal and external world
- Increased personal safety
- Enhanced capabilities to learn
- Increased self-esteem and confidence

Teaching adults

To date, a substantial experience has been accumulated in teaching various elements of TRIZ, which is a part of DE at the same time, to adults (former USSR, USA, other countries). It is quite possible to transform these separate courses into an integrated course *Management of the evolution (future)* if the compatibility of various courses provided by different educators is ensured. Such coordination could be done by Altshuller Institute for TRIZ studies, for example.

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[38] Recently, two projects are in progress in Iowa and Michigan.

[39] Zlotin, Boris, et all. *TRIZ Beyond Technology*. The Second Annual AI Conference Proceedings. The Altshuller Institute for TRIZ Studies, Worcester, MA., 2000. See also at www.triz-journal.com, January 2001.

The most important, that college students will learn about evolution of the system(s) in the area they are going to master. The normal academic environment is the most suitable for including special courses on creative problem solving, evolution analysis, etc.[40]

Teaching professionals

Obviously, with the growth of informational civilization and implementation of DE practices, a substantial amount of DE experts will be in demand. Professional DE work requires serious knowledge and skills in the following areas:

- Area to which the given system belongs (for example, automotive, medicine, investment, etc.)
- History of evolution of the most general artificial systems (science, social, technology, arts, etc.)
- DE tools and techniques (patterns/lines of evolution, inventive problem solving, Failure Analysis and Failure Prediction, control of psychological inertia, etc.)
- Communication and facilitation skills
- Utilization of various methods of searching and analyzing information
- Computer skills

Software support of DE process

To date, a set of software supporting certain DE stages are available[41]:

- IWB-2000 – supporting Ideation Problem Solving and Ideation brainstorming processes. Partially supports work with selected patterns/lines of evolution.
- Failure Analysis Software system – support the process of revealing root causes and mechanisms of various phenomena (negative or positive).
- Failure Prediction System Software – supports the process of predicting potential risks, dangers and/or failures.
- Knowledge Wizard Millennium – support the process of business situation assessment and decision making, and generation of creative solutions in the area of business and management.

Express DE of DE application evolution

We have applied the Express DE process to our subject – DE application and have cone to a conclusion that in the next 25 years DE will become an inherent part of the world life with the following features.

[40] One project with biomedical engineering graduate students at Vanderbilt University is in progress (see at www.ideationtriz.com).

[41] Currently, complex software to support the entire DE process is in development. We expect releasing this product in 2001.

- DE becomes a conventional science with a status similar to math. There exist DE research centers, labs, conferences etc.; monographs, dedicated magazines, newspapers websites and other sources of information are established.
- DE specialists are working professionally guiding development and evolution, predicting and preventing any failures and/or undesired effects, quickly and cost effectively solving problems in any facet of human life (social life, technology, science, business, management, art, etc.) in
  - Government organizations
  - Enterprises
  - Education centers (schools, universities, continuous education, etc.)
  - Medicine, entertainment, recreation,etc.
- Systems to support DE applications within organization have been established (similar to 6-sigma system).
- DE professional society with numerous chapters for scientists, teachers, practitioners, forecasters, etc., has been established.
- Each individual has some DE knowledge (similar to mathematics – from elementary principles for most people to high level for DE professionals).
- DE is taught in:
  - Kindergartens (the simplest elements, as ideality, resources application and elements of Creative pedagogy and Creative Imagination Development (CID), etc.)
  - Schools (DE for individual life and evolution, including working with contradictions, DE modeling, main patterns and evolution lines, CID, simple creativity software, etc.).
  - Universities (DE for individuals, organizations and technologies, including complete DE knowledge)
  - DE post-graduate courses – DE research work.
- DE helps learning other disciplines (elements of creative pedagogy, history of evolution, prevention of psychological inertia, etc.).
- DE is used in numerous software (games, educational and working tools for children, adults and professionals).
- DE helps managing intellectual property, including:
  - Activation and coordination of people creative output (for company, for country, etc.).
  - Patenting new ideas, building patent fences, patent litigation, etc.
  - Patent circumvention
  - Validation of knowledge on compliance with evolution patterns
  - Development of Ideation banks (banks of creative ideas and concepts for different facet of human activity).

DE wide dissemination will be based on series of software products including:

- Personal software *Partner*, *Friend*, *Alter Ego*, etc. which is presented to a new born child and is being updated through the entire life. This software is documenting main

events through games and tests (including simulation games). The software is learning about its user, watching his/her health, helping in studies, solving creative problems, informing about and making available necessary techniques, connecting with sources of information, warning about dangers and serving as a personal assistant (secretary). Practically, all necessary components for this DE software family exist today and one can expect them rather soon.

- Specialized software for supporting DE related to specific areas of industry and other human activities.
- World banks of evolutionary information supporting DE software.

Implementation of the process of controlling human evolution in a worldwide scale cannot be implemented via enforcement. The following measures can help gradually introduce DE philosophy:

- Placing DE information and techniques on Internet and other publicly accessible sources of information
- Establishing commercial organizations and government agencies for conducting DE on the most important issues.
- Establishing associations and clubs promoting DE in various areas. These associations/clubs should integrate people that care about the subject: scientists, businessmen, politicians and others that understand the importance of the subject.

Conclusion

Our humanity is surfing along the waves of civilization. The essence of the First Wave was stability. Life was enough predictable, children were expected to have similar goals and problems, even deviations (successes or failures) could be more or less the same.

The essence of the Second Wave was linear, continuos, sequential and logical evolution. Life was planned – education, work, bringing children, retirement and even funeral arrangements…Of course, deviations were possible, but manageable.

The essence of the Third Wave could be the best described by words of ancient Greek philosopher Heraclitus: “everything is flowing, everything is changing…”, and in unpredictable fashion, too. Today is rather obvious that we cannot live according to rigid plans, that unexpectable events should be expected. An average individual will receive several different types of education, changing several professions, place of habituating, friends, etc. Scientific progress has brought electricity and automobile (industrial era), computers and Internet (informational era); what should we expect tomorrow? Transition to active life and destiny management of becomes inevitable and absolutely necessary to avoid the situation when an individual becomes a toy driven by uncontrollable forces of a stormy sea. Methods of controlling the future will ensure successful and safe evolution for individuals, organizations, government agency, countries and humanity.

Apparently, the book of Alvin Toffler was rather convincing at the moment of publishing (otherwise it wouldn't be a bestseller). From the TRIZ point of view, it is the most powerful futuristic book that has ever been published. Of course, Toffler didn't mention TRIZ or DE, however, it is difficult to ignore the thought that 20 years ago he could foresee something similar to it; that together with TRIZ founder Genrich Altshuller he should be named as DE predecessor.

There is one more predecessor we would like to mention here. Isaac Azimov, in his remarkable series of science fiction novels *Foundation,* has invented and described *psychohistory* – a science that allows prediction and influencing (controlling) the evolution of the human civilization. According to Azimov, psychohistory will emerge in the far future when human civilization expands over the whole Galaxy. However, it is rather obvious that we cannot wait that long, that without the ability to control future the humanity cannot last for more than another century or two. People need Azimov's psychohistory now, and when such demand emerges, it might become real much faster than the most daring fantasy can predict. Emergence of Directed Evolution and its methods allows beginning the era of purposeful control of the future of an individual, organization and humanity as a whole, today.

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Frequently asked questions

DE application

Q1

DE promises too much. It is hard to believe it.

A1

Robert Hooke, an English physicist, a contemporary and competitor to Isaac Newton is known as a founder of several quite different sciences: cytology (science studying cells of life organisms), mineralogy, physical metallurgy, crystallography, etc. How could that happened? The fact is that Hooke became the first scientist who started systematically utilize a newly developed scientific instrument – microscope. The majority of his discoveries have resulted from that. Usually, an introduction of a new tool is followed by with the burst of new ideas, discoveries and opportunities. Similarly, TRIZ and TRIZ based DE are new and powerful tools of addressing creative and futuristic problems, allowing one to expect more and more.

Q2

The technological evolution resembles horse races: everybody strives forward, however, not everybody can be a winner. Can DE help to identify the winning "horse" ahead of time?

A2

Yes and no. It won't help in guessing, but in winning. For example, it can help:

- From the initial 100 candidates, identify 75 that cannot win
- Identify 10 that have more chances to win
- Choose 3 from the 10 and start training, motivating and grooming them utilizing the best professionals in the area
- Identify and eliminate potential obstacles and dangers
- Shortly before the races choose and focus on one horse
- When races started, quickly solve all arising problems and remove obstacles favorite is facing

Q3

Supposedly DE can give an advantage for an individual, organization or country that will start utilizing it permanently. However, what is going to happen if everybody will start doing it? Wouldn't be chaos?

A3

Our life more and more resembles a highway with growing number and speed of automobiles. Everybody has his/her own destinations and is pursuing them in the most convenient ways. However, everyone has to comply with rules and regulations, road particularities, other people and their objectives, otherwise he/she will never arrive to destination. Of course, there are certain individuals that violate rules, that is why we have the police institution to enforce them. Unfortunately, the analogy is not quite complete. Today, we are "driving" along the life highway is mostly in the dark. Only chosen with enormous strong vision can recognize something on the road – they can move with more success than others. DE is like powerful headlights that can help illuminate the way of anybody who would start using it.

So far, nobody is forced to enter the highway or to buy headlights or night vision devices. Do not want to move – stay where you are. However, it is not quite clear what is safer – staying on a shoulder or moving along with the main stream.

In some fashion, DE could be compared with literacy and other premises of intelligent life:

- For a long period, literacy was a privilege available for limited number of people and providing them with important advantages. Only in the last century the majority of people in developed countries became literate allowing benefits for everybody and the whole society,
- First students and followers of Dale Carnegy that have learned the best practices of successful communication had got obvious advantages. Today, his recommendations become quite common and have been taught to children. Again, it is for benefit of everybody and the society as a whole.
- For the last 10-15 years, computer literacy has becoming an important part of human culture. It allows for huge benefits, and obviously in the 21-century will become common.
- The technology of managing the future – DE is very young. There are probably fewer people today that can actually conduct it than literate people were 5000 years ago. We believe though that by the middle of the century DE will become a usual element of school education.

Q4

When is the best time for DE?

A4

Below are the typical phrases we heard from our customers in the past:

- You know, several years ago we had serious problems, at that time DE probably could help… Now everything looks OK…

- We are experiencing extremely difficult problems now, it a matter of survival; we have to cut off all consultants…May be later when things are better…
- Right now we are restructuring, nobody knows what new structure is going to be; we have to wait…
- What a pity that you gave these ideas now, when we cannot change that much… It would be so much better if that happened a year ago when everything was changing and we could do something…

The answer is that any period in the life cycle has its own problems requiring cresative solutions; DE can be utilized at any stage (with different results, of course), however, it requires work and there will always be excuses…

DE Reliability

Q5

How can we be assured that DE allowed consider all possibility of evolution and the best set of scenarios is secured? Could we miss something?

A5

One of DE assumptions is as follows:

> A function can be realized in a limited number of distinguishable ways based on the utilization of known resources. New types of resources might arrive as a result of a discovery.
>
> Derivative #1: It is theoretically possible to exhaust (or nearly exhaust) all possible ways of performing a given function.

Utilization of a complete set of available patterns/lines of evolution (over 400) allows practically exhaust possible variants. Of course, there is also a possibility of some gaps because we cannot guarantee that we have revealed all possible patterns/lines. However, practically there is always overlapping resulting in obtaining similar directions/ideas from different lines…

Q6

Supposedly we have conducted a full-scale DE, developed a complete strategy of implementation, and suddenly tomorrow someone invents something absolutely new that makes all work obsolete… How can we justify our expenses?

A6

It is well known that implementation of a new mass technology based on serious discovery takes about the same time (doesn't matter it is a locomotive or a laser) –

approximately 20 years. This period depends on emergence of new generation of professionals rather than on specifics of technology. Usually after a serious discovery is made, new ideas on its practical implementations appear quite fast (5-10 years). Former college students start implementing these ideas after they graduate and earn some power to do it (another 10-15 years).

DE details

Q7

Why is it necessary to waste time for learning the existing system if we are targeting invention of a new generation?

A7

- Often, people are talking about new generation because they do not see how the existing system can be improved. However, it is quite possible that utilization of TRIZ/DE tools and processes will allow for improvement that could be in certain circumstances more beneficial.
- Learning about existing system reveals basic problems, contradictions, resources, etc. that often are consistent with the next generation as well.
- Ideas and discoveries that are the most important for the system evolution are usually obtained in the very beginning, however, the ones that have not find immediate use (sometimes because they did not comply with the current level of technology), were often forgotten. In many cases, their later "reanimation" led to the next step in evolution. Actually, returning to the "roots" allows drawing a line into the future through two points (today and the past).

Q8

Is it possible that patterns/lines show a wrong direction?

A8

Different lines usually reflect different trend in evolution that can contradict one another and offer contradictory directions. On the stage of ideas integration, these ideas may be combined into a powerful new concept.

Directed Evolution Questionnaire

1. Information about the system

1.1. System name

1.2. System structure (sub-system included into the system and how they are connected)

1.3. Super-systems in which the given system is a part of. Other systems the given system interacts with.

- Define hindering forces and limitations exerted upon the given system by various super-systems.
- Define forces driving the evolution of the given system.
- Define basic contradictions in various requirements to the given system.
  - Formulate contradictions using the following template:

An attempt to satisfy the requirement <indicate> to the given system from the super-system <indicate> leads to violation of the requirement(s) <indicate> or limitations <indicate> from the other super-system(s) <indicate>.

1.4. Functioning of the system

- Which useful functions does the system perform for other systems (super-systems)?
- What are the factors of expense, that is, what does it cost (including all undesired effects associated with the system functioning) to provide these functions?
- Formulate functional contradictions associated with system functioning using the following template:

Performing the useful function <indicate> hinders other useful function <indicate>.

Performing the useful function <indicate> leads to emergence of the harmful function <indicate>.

Performing the useful function <indicate> causes the harmful influence <indicate> on the system itself.

1.5. Which functions in the system are performed by humans? Is it possible to automate these functions?

2. Information about existing problems

2.1. Problems that exist in the given system

2.2. Conditions that produce (contribute) the problems

2.3. Mechanisms causing the problems (if the mechanism is not clear, utilize DE Failure Analysis module, Appendix 2).

2.4. Undesired consequences of unresolved problems

3. History of the system evolution

3.1. System predecessors or prototypes (systems performing similar functions)

- Name prototypes' features that the given system has enhanced
- Name new features introduced by the given system
- Name which useful features or functions of the prototypes was not possible to transfer to the given system and why.
- Describe the initial conditions of the given system emergence including:
  - Components that were ready
  - Breakthrough that has originated the given system

3.2. Describe other variants of the system that were considered (built, tested, etc.) in the beginning.

3.3. Indicate the given system generations through its history. Indicate breakthrough that originated the transition to the next generations.

3.4. Indicate the given system modifications created for different market sectors.

3.5. Describe the problem solving history including:

- Basic problems that have been resolved during the previous system evolution
- Conditions and mechanisms responsible for the problems' emergence
- Methods that have been utilized for problem solving

4. Information about similar systems

4.1. Indicate other systems that perform similar functions in the same area (close analogs) and their positive differences

4.2. Name other systems that perform similar functions in different areas (remote analogs).

4.3. Name systems that perform opposite functions (anti-analogs).

DE Failure Analysis

Step 1. Invert the problem

Instead of guessing about the possible causes of the drawback, "invert" the problem by formulating it in a pro-active way. To do this, apply the following template:

It is necessary to produce the phenomenon *[describe the drawback]* **under the conditions** *[describe conditions that initiate and/or accompany the drawback]*.

Step 2. Find a way to produce the phenomenon

Find a method by which the required phenomenon can be intentionally produced. For this purpose review those areas of everyday life, science or engineering, where the phenomenon represented by the drawback is utilized for some useful purpose.

Step 3. Verify the hypotheses

After you have discovered the method(s) by which the drawback is intentionally produced, think of them as hypotheses for the possible root cause(s) of the drawback. The next step is to **verify each hypothesis** by determining if all the components necessary for this method to be realized in your system are present as available resources.

(Note that for this drawback to occur spontaneously via the method you are attempting to verify, all the necessary components must be present within the system or its nearby environment.)

Problem Formulation

Problem formulation consists of two procedures:

- Building the diagram
- Formulating problem statements

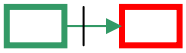
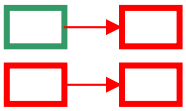
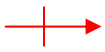
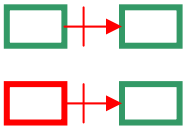
Building the diagram

By building a diagram, you are systematically transforming your knowledge about the situation at hand into a graphical "cause and effect" model. This is done using the *Function-Link-Function Method* presented below.

Main definitions

Function – a function, an action, a parameter, or any factor (statement) related to your situation that can be considered useful or harmful.

Link – an arrow connecting two functions and reflecting cause-effect relationship between them. The following types of link are utilized:

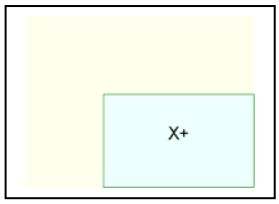
Image	Type	Name	Verbal example of utilization	Graphical example of utilization
	Useful	Produce	Useful function produces another useful function	
	Useful	Counteract	Useful function counteracts harmful function	
	Harmful	Produce	Useful function (or harmful function) produces harmful function	
	Harmful	Counteract	Useful function (or harmful function) counteracts useful function	

Building diagram procedure

- Create a box and enter a function[42] name.
- Define for yourself if the introduced function is useful or harmful.

[42] You may enter a function, a parameter, or any factor (statement) that can be considered as useful or harmful.

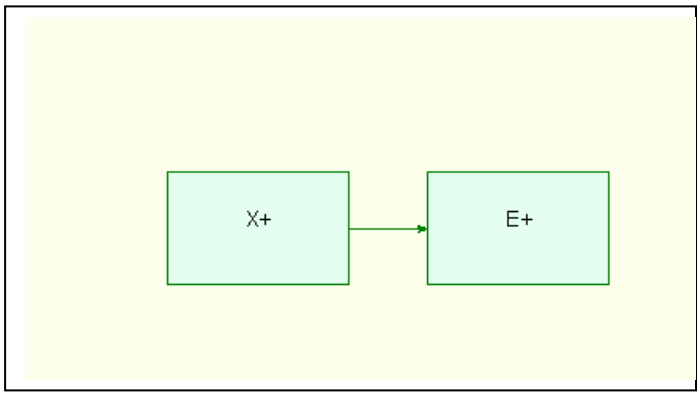
- If the function is useful, name it X+ mark the box with the green color (see below).



Answer the following questions:

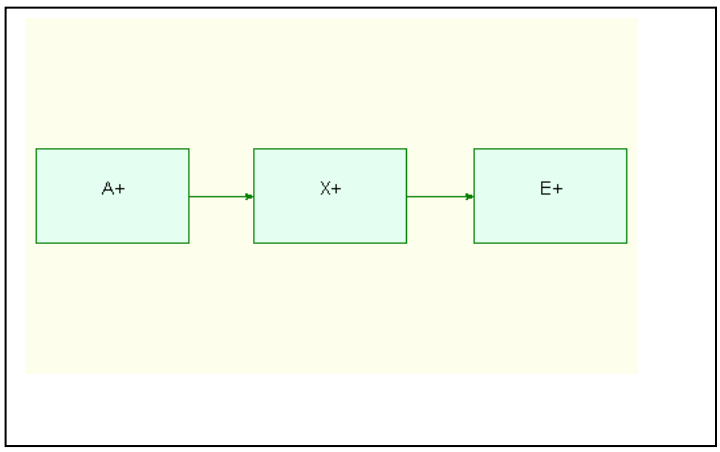
Q1: Does this function X+ produce another useful function E+, that is, what is the purpose to perform the function X+?

If yes, introduce a new box with the function E+, color it in green and connect with the green arrow as shown below:



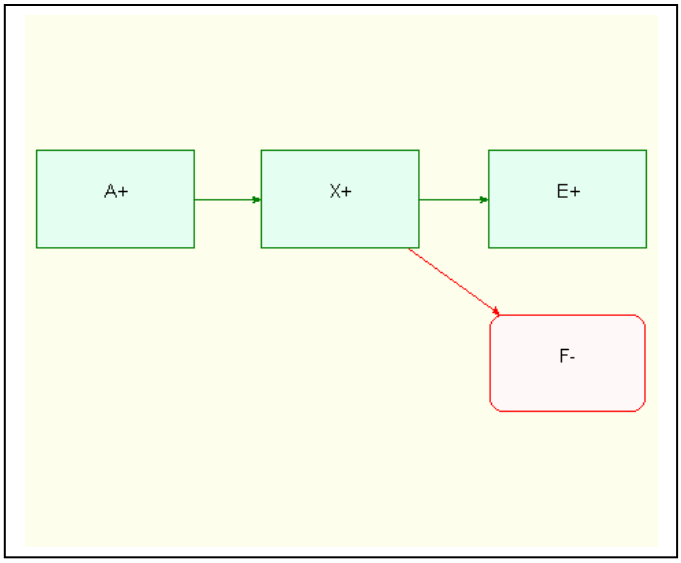
Q2: Is the selected function X+ produced by another useful function A+, or in other words, identify if another function A+ is required to perform the function X+.

If yes, introduce a new box with the function A+, color it in green and connect with the green arrow as shown below:



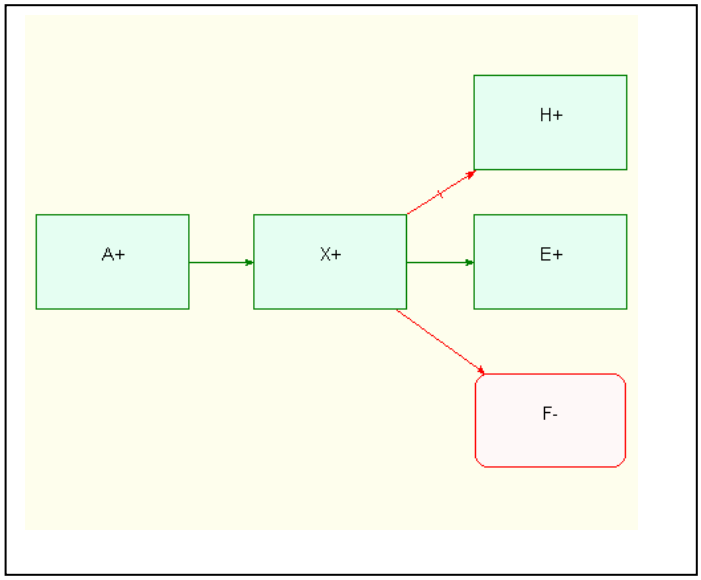
Q3: Does this function X+ produce a harmful function F-?

If yes, introduce a new box with the function F-, color it in red and connect with the red arrow as shown below:



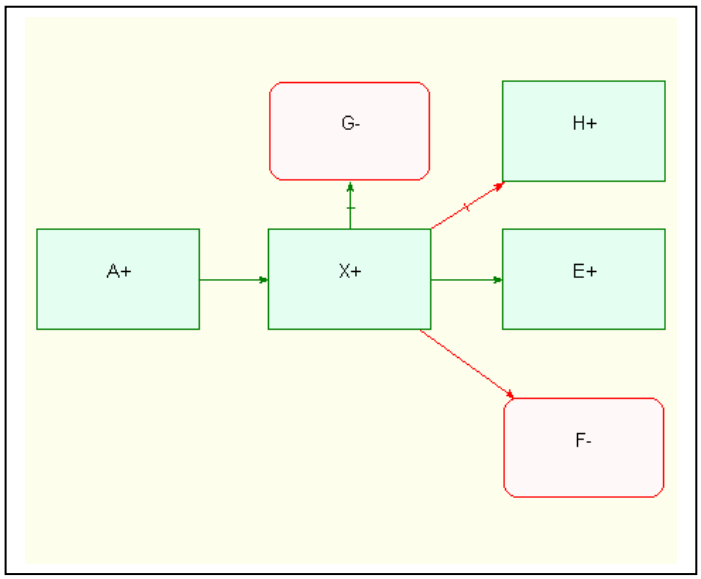
Q4: Does this function X+ counteract another useful function H+?

If yes, introduce a new box with the function H+, color it in green and connect with the red arrow as shown below:



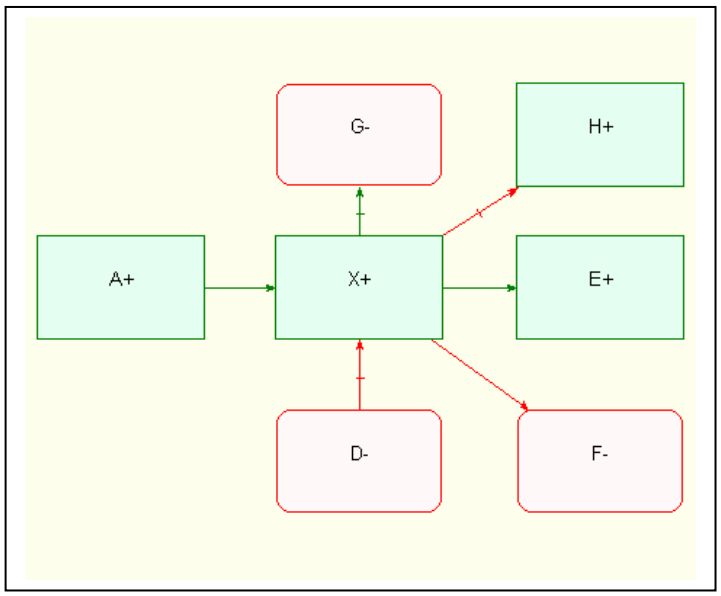
Q5: Does this function X+ counteract another harmful function G-?

If yes, introduce a new box with the function G-, color it in red and connect with the green arrow as shown below:

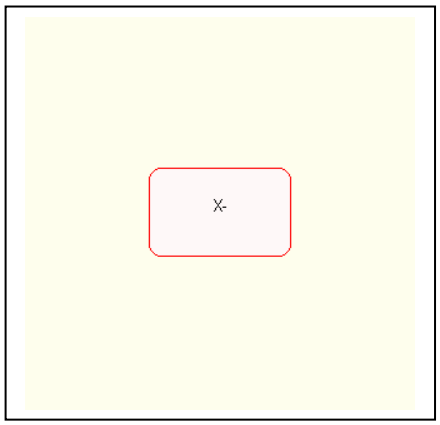


Q6: Is this function X+ influenced by another harmful function D-?

If yes, introduce a new box with the function D-, color it in red and connect with the red arrow as shown below:



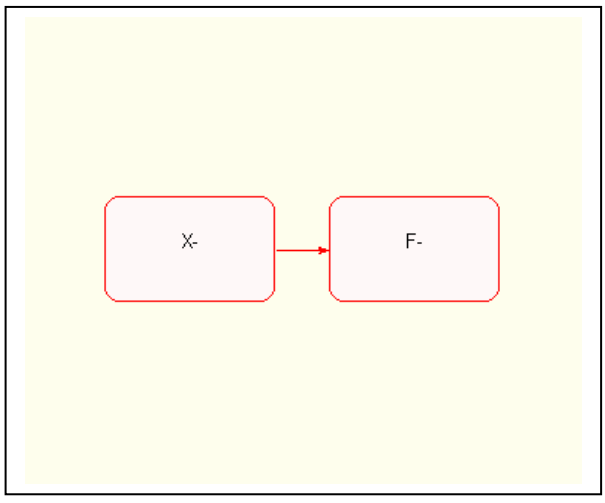
- If the first function is harmful, name it X- and mark the box with the red color.



Answer the following questions:

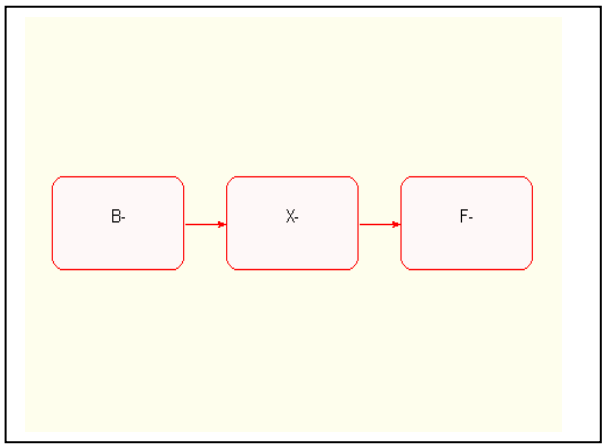
Q1: Does this function X- produce another harmful function F-?

If yes, introduce a new box with the function F-, color it in red and connect with the red arrow as shown below:

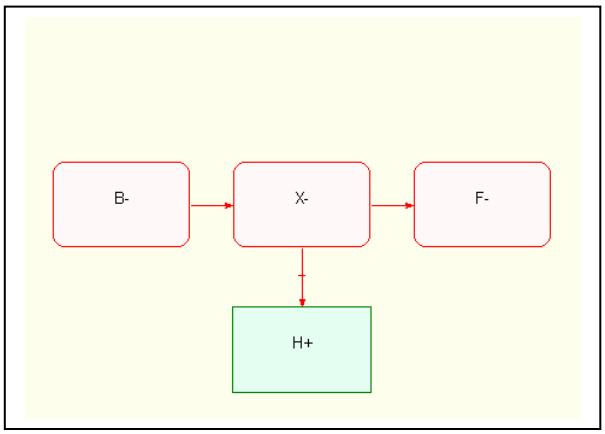


Q2: Is the selected function X- produced by another harmful function B-?

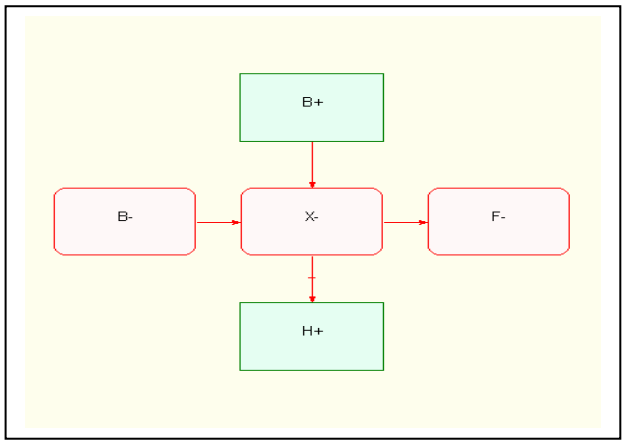
If yes, introduce a new box with the function B-, color it in red and connect with the red arrow as shown below:



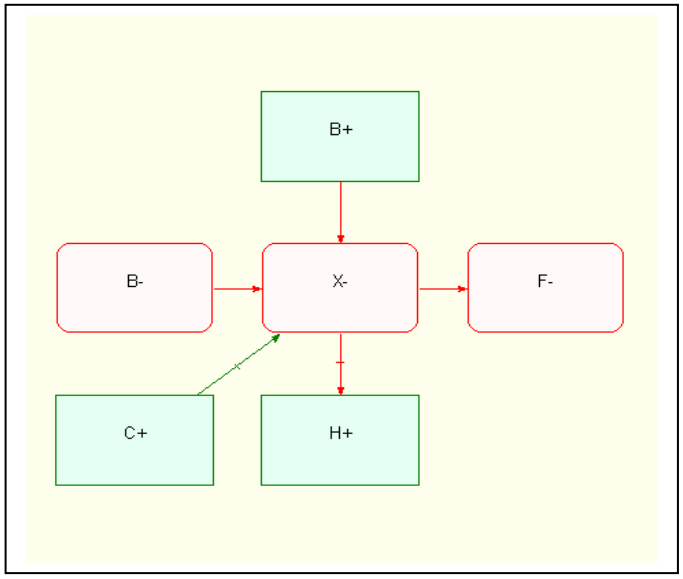
Q3: Does the selected function X- counteracts useful function H+?
If yes, introduce a new box with the function H+, color it in green and connect with the red arrow as shown below:



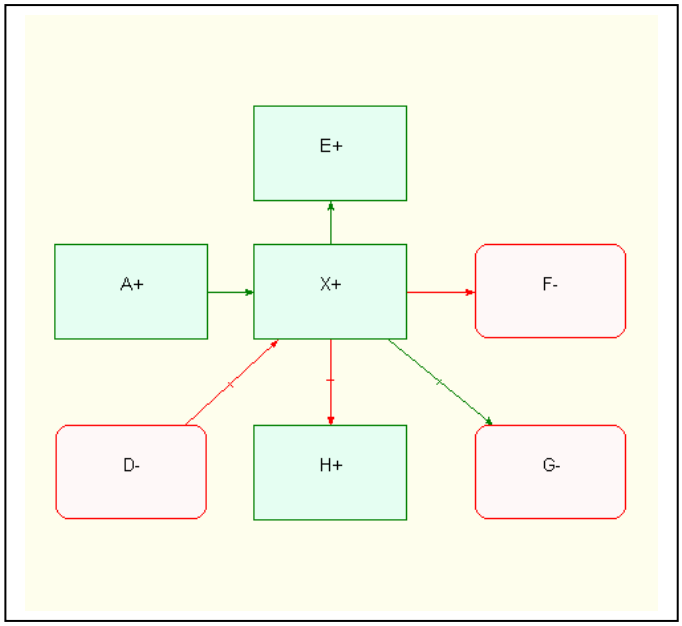
Q4: Is the selected function X- produced by a useful function B+?
If yes, introduce a new box with the function B+, color it in green and connect with the red arrow as shown below:



Q5: Is the selected function X- counteracted by a useful function C+?
If yes, introduce a new box with the function C+, color it in green and connect with the green arrow as shown below:



Formulation
For any useful function X+ (see the basic diagram below)



Find an alternative way to obtain [the] (X+) that offers the following:

- produces all useful results including
  - providing useful functions (list)
  - eliminating harmful functions (list if any)
- does not produce any harmful results including
  - causing harmful functions (list if any)
  - influencing other useful functions (list if any)
- does not require for that useful functions (list if any)
- is not influenced by harmful functions (list if any)

Example:

Find an alternative way to obtain [the] (X+) that offers the following:
- produces all useful results including
  - providing useful functions (E+)
  - eliminating harmful functions (G-)
- does not produce any harmful results including
  - causing harmful functions (F-)
  - influence other useful functions (H+)
- does not require for that useful functions (A+)
- is not influenced by harmful functions (D-)

Additional problem statements

1. Find a way to increase the effectiveness of [the] (X+).

2. Find additional benefits from [the] (X+).

3. Find a way to obtain the useful results ([the] (E+)) without the use of [the] (X+).

For the end useful function only (E+)

Consider transitioning to the next generation of the system that will provide [the] final useful result (E+) in a more effective way and/or will be free of existing problems.

For contradictions

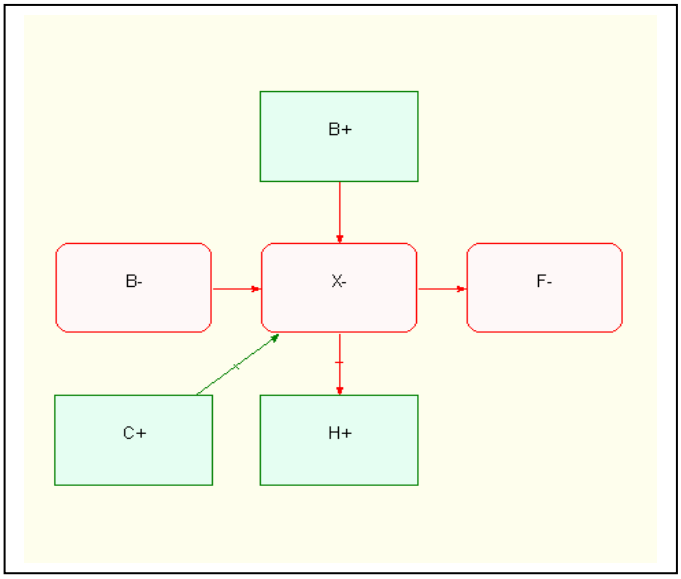
Try to resolve the following contradiction:
- The useful factor [the] (X+) should be in place in order to produce all useful results including
  - providing useful functions (list)
  - eliminating harmful functions (list if any)
- should not exist in order to avoid all harmful results including
  - producing harmful functions (list)
  - hindering useful functions (list if any).

Example

Try to resolve the following contradiction:

- The useful factor [the] (X+) should be in place in order to produce all useful results including
  - providing useful functions (E+)
  - eliminating harmful functions (G-)
- should not exist in order to avoid all harmful results including:
  - producing harmful functions (F-)
  - hindering useful functions (H+).

For any harmful function X- (see the basic diagram below)



Basic statement

Find a way to eliminate, reduce, or prevent [the] (X-) in order to avoid harmful results including

- producing harmful functions (list)
- hindering useful functions (list if any).

under the conditions of other harmful functions (list if any)

Example

Find a way to eliminate, reduce, or prevent [the] (X-) in order to avoid harmful results including

- producing harmful functions (F-)
- hindering useful functions (H+).

under the conditions of other harmful functions (B-)

Additional statement

Find a way to benefit from [the] (X-).

Analysis of evolutionary resources

The following resources should be considered:

Technical resources

What substance resources are available? Look for:

- Elements of the system and/or its environment
- Raw materials in the system and/or its environment
- Products produced by the system and/or its environment
- Waste materials produced by the system and/or its environment
- Inexpensive substances such as water, air, sand, snow, etc.

What energy resources are available? Look for:

- Mechanical energy (actions, interactions, etc.)
- Sound, oscillations, vibrations
- Thermal actions and interactions
- Chemical reactions
- Electrical energy (actions, interactions, etc.)
- Magnetic fields, actions and interactions
- Electromagnetic fields, actions and interactions
- Light and other types of radiation

What functional resources are available? Look for:

- Additional useful functions which the system and/or its environment can perform
- Harmful actions taking place in the system and/or its environment which can be used toward some benefit

What informational resources are available? Look for:

- Fields emitted from the system and/or its elements
- Substances exiting the system
- Properties of the system and/or its elements (such as temperature, transparency, natural frequency, etc.)
- Variations in energy flows passing through the system an/or its elements

What time resources are available? Look for:

- Time before the process starts
- Time during the process, such as:
    - Pauses
    - Idling motions
- The possibility of performing several operations simultaneously
- Post-process time

What spatial resources are available? Look for:

- Unoccupied space, including:
- Space between elements
- Space inside elements
- Unoccupied surfaces of elements
- Space occupied by unnecessary objects/elements
- Space available in dimension(s) other than those already in use

Human resources

Do you know people who view this situation as a high priority? Are they:

- at the top level?
- at your level?
- at a lower level?
- those on whom implementation will depend?
- other individuals and/or groups inside the company?
- people outside the company?

Do you have allies who would support you if necessary?

Should it be necessary, will you be able to contact all Subject Matter Experts (internal or external) that might be needed to work on the project?

Do you currently have people capable of coming up with creative solutions?

Are people available who can provide necessary testing and implement a solution?

Are there ways to motivate people to improve the situation?

Financial resources and other assets

Are you ready to carry the cost of implementing a solution, taking into consideration that it may constitute 10-15% of the expected gain?

Are you able to use or acquire any of the following?

- Investment
- Cash reserve
- Loans
- Barter
- Other

Can other business assets be used to produce new opportunities? Think about the following:

- Equipment
- Facilities
- Inventory

- Information
- Other

What are your organization's core competencies?

Specific resources for evolution

Specific resources useful for the next system generation, could be as follows:

- New needs that the system could satisfy
- New requirements to the system
- Useful functions provided by other systems that could be transferred to the given system including functions from:
  - Close analogs
  - Remote analogs
  - Anti-analogs
  - Performed by humans
- New functions that could be invented and added to the given system
- New principles that could be invented including
  - Transition to micro-level (including utilization of effects)
  - Transition to utilization of other fields
- Resources of integration, creating bi- and poli-systems

DE Failure Prediction

Instead of brainstorming about what non-obvious failures might occur, in I-TRIZ you "invent" possible failures – then find ways to prevent or eliminate them. For this purpose, formulate the problem of inventing the failure using the following template: **There is a Concept called** [*Concept name and brief description*] **for** [*Purpose of implementing the Concept*]. **It is necessary to produce all possible undesired effects that can occur during the implementation of this Concept.**

Then follow these steps:

1. Describe each stage of Concept implementation.
2. Consider possible failures during each stage using the list of typical potential negative impacts
3. List all obvious ways to "accomplish" each failure.
4. Consider potentially dangerous moments/periods of time during implementation.
5. Consider weak and dangerous zones as resources for potential failures.
6. Consider possible harmful impacts on each stage of implementation.
7. Consider possible failures of devices, objects, etc.
8. Consider measures for preventing the failures you have revealed.

Abbreviated Ideation Problem Solving Process[43]

Step 1. Describe the Problem

1.1. Document your problem situation in free style.

1.2. Consider the possibility to modify the problem statement using the table below:

Point of View	Steps	Modified problem statement
System	Step up to the supersystem	What changes to a supersystem might resolve the situation?
	Step down to the subsystem	What changes to a subsystem might resolve the situation?
Time	Step into the past	What happened in the past to initiate the problem? Is it possible to return and change this critical event?
	Step into the future	Think about the next generation of your system. Will the problem you are facing today continue or will it disappear?
Cause - Effect	Step back	Is it possible to eliminate the cause of the problem?
	Step forward	Is it possible to eliminate (or compensate for) undesired results caused by the problem?
Input - Output	Step back	What are the inputs responsible for the problem? How might they be changed to prevent the problem from occurring?
	Step forward	What are the harmful outputs leaving the system? Is it possible to change the output to block the harmful effect(s)?

1.3. Select which problem statement (original of modified) you would like to work with.

Step 2. Describe the Ideal Solution

2.1. Formulate the ideal situation (or ideal solution) using the appropriate template from the listed below:

[43] This process can be supported by Ideator ™ 2000.

Template 1

An object [describe the object] **acts on itself to achieve a necessary useful result** [describe the result] **An element** [describe the element] **that produces a required useful effect** [describe the useful effect] **is no longer necessary.**

Template 2

An element [describe the element] **that causes a harmful effect** [describe the harmful effect] **is removed from the system.**

Template 3

A harmful effect [describe the harmful effect] **withdraws itself.**

Note. For now, avoid thinking about how the ideal situation might be realized – that will come later. Be aggressive in your "vision " of the ideal. Do not compromise.

2.2. To make your system more ideal, try to apply the following:

- Excluding auxiliary functions from the system
- Excluding certain elements from the system (duplicate elements and elemenmts performing auxillary functions (housing, connectors, etc.)
- Self-service. – consider the possibility for the system serving itself
- Replacement of elements or the total system
- Changing the principle of operation

2.3. If you have found a satisfactory idea, document it. However, we recommend that you continue by going to the Step 3: *Identify and Utilize Resources*.

2.4. If there are one or more drawbacks associated with your idea, you might consider the Step 7. *Work with Secondary Drawbacks*.

Step 3. Identify and Utilize Resources

3.1. Look for available resources that can help you realize the ideal solution (see Appendix 4)

3.2. If you have found a satisfactory idea, document it.

3.3. If you do not know how the ideal solution might be achieved, consider the Step 6 *Synthesize a New System*.

3.4. If there is a drawback associated with your idea, you should move to the next Step 4: *Work with Drawbacks.*

Step 4. Work with Drawbacks

4.1. If realizing the idea might result in a harmful effect, consider the following options for its elimination:

- Isolation
- Counteraction
- Impact on a harmful action
- Reduce sensitivity
- Eliminate the cause of an undesired action
- Reduce the harmful result of an undesired action
- Benefit from a harmful result

4.2. If the idea is not sufficient to provide a required function, consider the following options for increasing efficiency:

- Intensify a field
- Concentrate energy
- Substitute a field with a more effective one
- Introduce an additional field
- Apply multiple actions (operational poly-system)

4.3. If you have found a satisfactory idea, document it.

4.4. To resolve a contradiction associated with the drawback, continue on to the Step 5 *Identify and Resolve contradictions*.

Step 5. Identify and Resolve Contradictions

5.1. Describe the contradictions in your problem using the following template:

The useful factor <describe the useful factor> **should exist in order to provide** <describe the desired result>, **and should not exist in order to avoid** <describe the harmful effect>.

5.2. To resolve a Contradiction, use the following Separation Principles, that is, consider separating opposite requirements:

- In space
- In time
- Within a whole object and its parts
- On the basis of different conditions

5.3. If you have found a satisfactory idea, document it. However, we recommend that you continue (and generate more ideas) by going to the Step 6 *Synthesize a New System*.

5.4. If there are one or more drawbacks associated with your idea, you might consider the Step 7 *Work with Secondary Drawbacks*.

Step 6. Synthesize a new system

If you do not know how to realize the ideal solution or provide a required function, consider synthesizing a new system. Keep in mind, however, that an entirely new system requires substantial effort to implement. For this reason, it is highly recommended that you first explore the following resources that can be helpful in avoiding the need to synthesize a new system:

6.1. Look for a prototype – a system whose purpose is to perform the same (or a similar) function that you need to perform, and try to improve this system to satisfy your requirements.
6.2. Combine known systems to achieve the required results

6.3. If you still wish to find a "new" way to perform a required function, you might consider additional tools[44].

6.4. If you have found a satisfactory idea, document it.

6.5. If there are one or more drawbacks associated with your idea, you should consider the Step 7 *Work with Secondary Drawbacks*.

Step 7. Work with Secondary Drawbacks

With the appearance of a new (secondary) drawback, you should not abandon your idea. A secondary drawback is only another problem, and solving a secondary problem is sometimes easier than solving the initial problem. To resolve the issue, consider the following options:

- Try to resolve contradiction associated with the secondary drawback. For that, return to the Step 5.
- Consider the secondary drawback as a new problem and return to the Step 1 for its resolution.

[44] For example, TRIZSoft® Family.

Ideation brainstorming

Ideation Brainstorming includes the following steps[45]:

Preparation for the teamwork session, including:

- Knowledge-mapping the problem
- Formulation of problem statements and selection of those to be addressed in the teamwork session
- Education of participants how to apply the Ideation brainstorming

The ***team work session***, including the following stages:

- Idea generation stage
- Evaluation stage

The ***idea generation stage***, which includes generating ideas for selected problem statements. The following rules should be in effect:

- The idea generation session around a selected problem statement interrupts if the team stops producing new valuable ideas. In this case, proceed to the evaluation stage. The average time for working on one problem statement should be from 5 to 15 minutes
- The facilitator guides the team through the list of problem statements.
- The facilitator's assistant documents all suggestions and questions so that they are visible to all team members
- All critique is prohibited during this session

The ***evaluation stage*** follows the idea generation stage in order to provide the preliminary evaluation of ideas, and the revealing and documenting of secondary problems. During this stage, try the following:

- Try to find how the idea might fail concluding the following sentences:
  - This idea cannot work because of …
  - This idea is not economical because of…
  - This idea creates a harmful effect(s)….
- Do not spend more than 5 to 10 minutes for the session

[45] Modified for manual application

When the evaluation session is finished begin the Idea generation session for the next problem statement. If an idea is very valuable, the team may proceed to solving secondary problem(s).

When the teamwork session is finished, the facilitator and his/her assistant organize the results of the session, build (if necessary) new knowledge maps, and formulate any secondary problems. All suggestions and problems are presented at the next teamwork session.

Note: Unlike the traditional brainstorming session, where the "pipe dreams" of the team members are quickly exhausted and therefore the productive time extends not more than 1 to 1.5 hours, Ideation brainstorming can last for 3 to 5 hours (with 10 minute breaks occurring every hour). Ten to fifteen serious problems can be considered during this time.