Directed Evolution
Philosophy, theory and practice

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Remarks
- Founder of the Kishinev School, the highest TRIZ school in the former Soviet Union
- Founder of "Progress," the first private engineering company in the former Soviet Union
- Co-author of U.S. Patent Number 5,581,663 "Problem Formulator and Solver"
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Content

Abstract

Directed Evolution, a recent application of TRIZ, has been in development since the mid-1980s (at that time under the name *TRIZ Forecasting*). In 1994 the name Directed Evolution (DE)™ was introduced to refer to the complex of works related to the management and control of technological evolution. The most comprehensive theoretical results of the research that has been conducted in DE were reported at TRIZCON99 (held March 7-9, 1999, in Novi, Michigan), followed by a set of articles[1].

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

Also discussed in this paper is the vital role that DE has in the global processes of managing evolution – that is, for controlling the future. The step-by-step DE process is presented, and selected (and simplified) tools suitable for conducting DE on systems of medium complexity are described. A list of frequently asked questions and a bibliography are also included.

[1] See the proceedings of TRIZCON99: The First Symposium on TRIZ Methodology and Application (Worcester, Mass,: The Altshuller Institute for TRIZ Studies, 1999). Also see *TRIZ in Progress* 1 (Southfield, Mich.: Ideation International, 1999). Regarding the evolution of organizations, see Boris Zlotin, et al., "TRIZ Beyond Technology," presented at TRIZCon2000, and also published in *The TRIZ Journal* (www.triz-journal.com), January 2001. For other related information, see the bibliography.

[2] Nine full-scale and several Express DE projects have been completed; several others are currently underway.

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Part 1. Directed Evolution (DE) as a Thinking Method for an Informational Civilization

Introduction

In April 2000 a significant though almost unrecognized anniversary took place: twenty years ago, Alvin Toffler, the well-known American sociologist and futurist, published his acclaimed book *The Third Wave*[3]. We became acquainted with the book's main ideas back in Russia, primarily through the extremely negative references made by communist philosophers (usually an excellent indication that a book is worthwhile). We were unable to explore the depth of Toffler's ideas until we came to the United States, however, and it didn't take us long to recognize the strong connections between the picture drawn by Toffler, and TRIZ.

Characteristics of the First, Second, and Third Waves

Alvin Toffler assumes the existence of three so-called "waves" of human civilization: *agricultural*, *industrial*, and *informational*. The main features of each are outlined below.

Agricultural wave

The First Wave, called the Agricultural Wave, began about 10,000 years ago, and is characterized by these features:

- Individual production using, for the most part, simple mechanical technologies.
- Utilization of renewable natural resources.
- Life lived in harmony with nature, consuming the resources "willingly" offered by nature.
- Self-provision of food and first-need products.
- Main driving forces are the slow, incremental accumulation of knowledge and skills, increasing wealth, growing population, etc.
- Main conflicts are centered around resources (primarily for 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 minds.
- Low population density, with most people living in small communities; lack of cross-influence of remote groups; existence of the large "traditional" family, which at the same time represents a production unit.
- Children are educated through the process of participating in adult life.
- Individual management or rule exists, where most people-related decisions are made by individuals (like the judgment of King Solomon).[4]

[3] Alvin Toffler, *The Third Wave* (Bantam Books, 1981).
[4] Certain traditions, customs and rules exist, however, there is much room left for individual decisions.

- Life is relatively simple, requiring a limited number of political or other decisions that must be made to manage life, as well as a limited number of traditional hierarchical power systems capable of handling these decisions.

Industrial wave

The Second (Industrial) Wave began approximately 300 year ago, having been established through numerous bloody conflicts with First Wave civilization. The Second Wave, which continues today, is characterized by the following features:

- Mass production of consumer products and services. Complex technologies that integrate 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, lifestyles, etc. Increasing dimensions of machines, equipment, buildings, organizational growth, etc.
- Rapid growth in the utilization of non-renewable resources.
- People seek to dominate nature. Society, particular organizations, and even individuals become powerful enough to endanger humanity and/or the whole biosphere.
- Self-provision is practically impossible, creating a high dependence on the market.
- The main driving force for evolution at this stage is the constantly increasing division of labor and specialization of people, organizations, regions, etc.
- The main conflict is between producer and consumer, which are separated by the market.
- Existence of a "mechanistic" mentality. Attempts to interpret the complexity of the world through simplistic and superficial logic-based models.
- Information becomes a source of evolution and serves as a structure for integrating and standardizing society. Development of a means for the independent accumulation of information; emergence of a 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 and highly mobile family, increased difference in functions performed by men and women at home and in industry, producing an increased difference in mentalities.
- Removal of children from adult life; standard education in public schools (industrial way of education).
- Management of people occurs on a mass (versus individual) basis – that is, based on the principle of equal responsibility before the law, and strongly regulated by laws. This allows for the standardization of most situations, and the ability to apply standard solutions.
- Centralization of political institutions; emergence of large parties, corporations, etc. Development of a governing elite in every facet of human life.
- Increased complexity of society; dramatic increase in the number of decisions that must be made by various management entities; emergence of complex bureaucratic structures.

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

Informational wave

The Third (Informational) Wave began during the 1950s and 60s and continues to grow, clashing more and more with the Second Wave as it does so. Some Third Wave parameters are close to those of the First Wave, while as a whole the Third Wave maintains most of the features of the Industrial Wave, in particular:

- Combination of mass and individual production. Existence of a complex technological sphere based on biochemical, electronics, nuclear, and genetic engineering, special materials, utilization of resources in the ocean, space, etc.
- Reduction in the size of industrial machines, buildings, and organizations, with the utilization of new technologies.
- Emergence and enhancement of "smart" equipment[6] (that is, systems that are capable of collecting and processing information, and making certain decisions to target optimum performance).
- Enormous diversification of products, services, and market sectors; adaptation of products to meet requirements of relatively small groups of consumers.
- Reduction of standardization, unification and synchronization of private life and the industrial environment.
- Reduction in the utilization of non-renewable resources.
- Quest for harmony between human civilization and nature (rather than for dominating it); however, the non-stop increase in the power of society, certain organizations and individuals increases the danger to human civilization and the biosphere.
- People become more self-sufficient, less dependent on the market.
- The main driving force of evolution is the continuously increasing quantity of information and the links between different activities.
- Main conflicts are between various groups of people.
- Mentality based on a systemic approach and characterized by environmentally sensitive behavior, non-mechanistic understanding of reasoning, acceptance of non-linear evolution, system equilibrium, disturbances (haphazard events), feedback, snowball effects, etc.
- Further increase in the role of information, development of the means to allow 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 the one hand, and global organizations (corporations) on the other. Weakening of the nuclear family; emergence of multiple models for the family.
- De-urbanization (reduced concentration of people in large cities), migration to suburbs, conversion of the "electronic house" into a small production unit.

[6] Examples are "smart" automobiles, houses, security systems, etc. The Industrial Wave has provided people with numerous able "servants," which have saved people time and physical energy and thus allowed them to devote more time toward education, cultural and social activities, etc. The Informational Wave is making these servants smart, reducing the intellectual energy required for managing them. One must wonder: How might this energy be spent? Perhaps for creativity?

- Individualization of education as education moves closer to "real life," while at the same time education extends through the entire lifetime of an individual.
- Management (rule) of people based on a combination of mass and individual influence and judgment (especially the informational influence of the individual). Utilization of marketing approaches directed toward achieving a win-win situation via negotiations and other feedback-based techniques.
- Further increase in the complexity of life and the number of decisions that must be made by various management entities, making Second Wave bureaucratic structures ineffective, and creating the need for new methods of managing a society where more people are becoming involved in the decision-making process.

Transition

It is important to note that the transition from one wave to another is an incremental process that consists of three main stages:

- Accumulation of new elements and approaches within the framework of the previous wave; preparation for transition.
- Actual transition in the most developed countries. This transition is usually accompanied with a total structural crisis connected with the destruction of existing social structures. Historically, humanity has witnessed only one such transition – from the First Wave to the Second Wave – and it was very painful.
- Those countries left behind eventually catch up to the new wave. This stage was also associated with an enormous number of casualties (with rare exceptions).

Today, humanity is on the verge of transitioning to a Third Wave civilization, and there is good reason to fear that the transition will be as painful as the previous one. There is hope, however, that things can be done in a much smarter way. We believe that the new science of TRIZ can make significant contributions to the critical task of providing for a smooth transition.

To better understand the role of TRIZ in a Third Wave civilization, we will examine more closely some of the aspects of evolution addressed (in part) by Toffler – that is, methods of managing/controlling the process of evolution to achieve particular goals. In other words, we are talking about *methods of managing the future*.

Historical overview and main assumptions

Managing/controlling the future: a need and possibility

One of the most important needs of an individual is the need to foresee and control his/her future – indeed, this has been reflected in various myths and religions throughout time, and has spawned a variety of fortune telling "techniques." People desire to know what the future holds, not just out of curiosity but rather for the purpose of being able to make necessary adjustments and control their lives.

In general, people would like to be able to control the future of their lives in three areas: *personal life*, *business*, and *humanity as a whole*.

Control of personal life

Psychologists define two types of stress:

- Active stress, where an individual is in control of the situation at hand. Active stress is stimulating and actually healthy.
- Passive stress, where an individual cannot influence the situation. Passive stress is destructive and unhealthy.

Hundreds of years ago the future was much more predictable[7] for an individual. Today, however, the unexpected is almost certain, given the fact that the average person during his/her life goes through several stages of education and numerous changes of jobs, location, friends, etc. Not to mention the unpredictable technological progress that has brought into our lives such things as electricity, automobiles, computers, the Internet, and so on . . .

At the same time, there have always been people who somehow managed to control their destinies, adjusting the future to their own visions: Alexander the Great, Julius Caesar, Benjamin Franklin, Albert Einstein, Thomas Edison, Bill Gates . . . These people are regarded as geniuses, but would it have been possible for an "average" person to do what they did? The following examples prompt the answer:

> *Can a person extract the cube root of 9834752345624563476? A thousand years ago nobody could do it. Five hundred years ago only a genius could do it. Fifty years ago it was a long and difficult calculation. Today, all one need do is enter the number in a calculator and push a button!*
>
> One hundred years ago, to reach a speed of 75mph might require diving into a deep canyon. Today, this speed can be easily reached in a car moving down the highway.

<u>Assumption</u>

Whatever a genius can do as the result of talent, luck, intuition, etc., an average human can do even better with effective, convenient tools. In other words, *the ability to control our own lives depends on having the appropriate tools*.

[7] For example, 500 years ago the son of a farmer knew that he would one day be a farmer, too; a shoemaker's son prepared to become shoemaker; and a knight's son would become a knight – all this, of course, was barring any unexpected course-altering events. Actually, even the unexpected was predictable enough, whether it be illness, war, etc. Location was also predictable, as an individual was unlikely to venture more than seven miles from his/her birthplace.

Control of business

Every day, millions of new businesses emerge in the United States. But less than 50,000 survive the first three years, and of those, only hundreds become giants. At the end of the 1970s, Chrysler was on the verge of collapse, while one of the world's largest airlines, Pan Am, went out of business. . . . On the other hand, McDonalds and Kentucky Fried Chicken went global. Today, and in spite of recent troubles, Microsoft is still powerful; numerous Internet companies continue to grow; IBM and Hewlett Packard have been stable for decades.

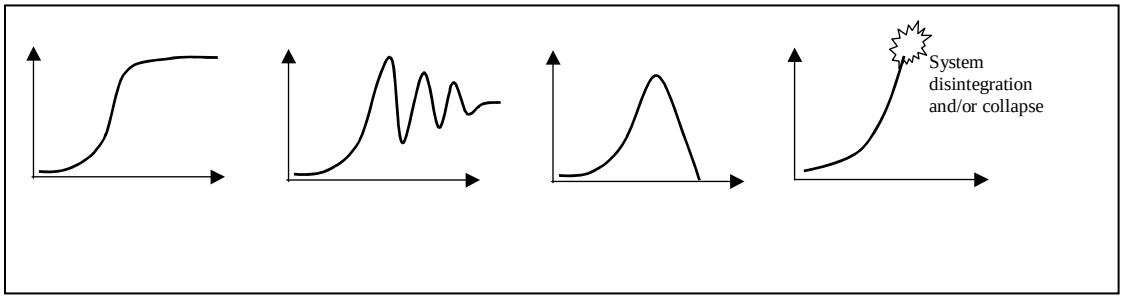
Why is the percentage of survivors so small? There are numerous books on economics, management, marketing, etc., containing valuable recommendations for how to establish and grow a business, how to ensure high efficiency, and how to beat the competition. But not everyone who followed these recommendations succeeded. Why? Typical answers are: lack of talent, luck, opportunity . . .

Assumption

Whatever one group of people can achieve with a combination of knowledge, talent, and effort, another can outdo if they have effective and convenient tools. *The ability to control the future of a business depends on having the appropriate tools*.

Control of humanity's future

Since the 17th century, humanity has been growing exponentially. The earth's population, available sources of power, and the rate at which these resources are utilized have also increased at a rapid rate. But exponential growth of any kind can be dangerous, as the end of the process is unknown. In fact, there are four theoretical "ends," as seen in the figure below. Clearly, only the first of these is acceptable. So the question becomes: How can this outcome be assured?



Let us consider the following analogy. The evolution of humanity can be thought of as a train that moves with ever-increasing speed while also growing in size. In the past, this train struggled with pot holes and canyons – geological catastrophes, extinction, the demise of ancient civilizations, and depopulation due to epidemics, crusades, witch-hunts, world wars, economic crises, etc.

Nobody knows where the train is headed or what lies ahead because there are no windows in any of the cars or even the locomotive. Through a gap here and there we can catch glimpses of the track, but the view is fleeting. What's more, we can't be certain it is the actual track we see and not a distorted reflection . . . In the locomotive compartment are many levers, steering wheels, switches, buttons, etc., but their purpose is unknown. A seemingly innocuous button might initiate an explosion that liquidates the entire human race.

There are many drivers in the compartment, each trying to carry out his/her function. These individuals are, for the most part, intelligent and honest, but they cannot communicate effectively and are mistrustful of one another. Another difficulty: there are many monkeys in the compartment, who look like drivers but are playing their own games and care nothing about the fate of the train.

If humanity is to survive, the most important objectives are these:

- Create windows and reveal all possible forward paths and potential obstacles, for hundreds of years to come.
- Ascertain the purpose of each lever, button, switch, etc.
- Learn how to select the safest, most effective path(s), and learn to quickly solve zillions of problems that emerge en route.
- Reveal the monkeys and get rid of them.

It is quite possible that to ensure a safe and smooth journey the direction of the train should be slightly altered, or the train should be rebuilt, or it should gradually slow down, etc. And although such actions might displease some, it could be critical for survival.

There are additional dangers associated with the informational nature of the Third Wave. The course of humanity has passed through four informational revolutions, and each one was associated with a serious social crisis.

First informational revolution: hundreds of thousand of yeas ago

The first informational revolution happened when Homo Sapiens acquired the ability to communicate through language. Articulated speech allowed people to coordinate group action as well as acquire and transfer information among individuals (and to future generations) in a verbal rather than genetic way. This advantage determined the evolutionary "victory" of those who succeeded in acquiring the skill of speech, and led to the diminishment of others. Indeed, this might very well be one reason Cro-Magnon man survived and Neanderthal man did not.

Second informational revolution: 5,000 - 6,000 years ago

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

- Accurate posting of information (an absolute necessity for developing commercial relationships)
- Centralized political power over society
- Reliable links between generations, accumulation of accurate information; precise formulas for laws and religious dogmas.

Altogether, these advantages ensured the establishment of stable countries and commerce. Other nations and/or tribes that had not created or acquired a written language were conquered or assimilated within more "literate" ones.

Third informational revolution: 550 year ago

The third informational evolution is associated with the invention of printing, which provided for the rapid dissemination of information throughout the masses and, in turn, saw that information played a central role in social changes. The invention and wide implementation of printing (together with other social, economical and demographic events) increased the social role of "information producers" (the religious reformers of the time). The Reformation spread like wildfire, resulting in numerous bloody wars that killed millions of people and displaced untold amounts property. For example, during the Thirty Years War (1618-1648) the population of Germany was reduced from 18 million to 4 million.

Fourth informational revolution: 150 year ago

> Economic and technological progress during the second half of the 19th century (mass production of paper, modernized printing equipment, the introduction of high-volume newspapers and publications, the development of railroads, telegraphy, etc.) provided for mass education and wide access to information by the end of the century. The result was that huge numbers of partially-educated people had developed a taste for "light" intellectual fare, bringing to life inexpensive newspapers, evening classes, public lectures, various associations, groups, social theories, salon parties, etc. For the first time in history, society was overloaded with information, which in turn brought forth various superstitions, theosophies, weird philosophical systems, dangerous social theories (such as fascism and various forms of Marxism), etc. The poorly educated became victims of demagogues, having learned how to absorb information but lacking the ability to analyze, to think things through. The Russian Revolution, Nazism in Germany, and Muslim fundamentalism can be seen (together with other reasons, of course) as having resulted from this informational "explosion."

Upcoming (fifth) informational revolution

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

- Changes in the way we live, work, and do business (eCommerce), resulting in serious (and always painful) social changes.
- Possible emergence and spreading of dangerous social theories, religions and/or superstitions.
- Perfusion of dangerous knowledge
- Possibility of socially dangerous associations (such as terrorist organizations)
- Disruption of privacy
- Damage to countries lacking effective access to information (due to limited or no access to the Internet, or insufficient use of English)
- Degradation of languages (other than English)

Assumption

The uncontrollable (i.e., haphazard) evolution of humanity is becoming the greatest danger in the informational era. Until now, human evolution has been realized through numerous random historical events and the actions of outstanding leaders. *It is time to make evolution manageable*. This can be accomplished only if appropriate, effective tools of control become available, and therefore the survival of humanity depends on the development of these tools.

Creativity and management of the future

The essence of management is the making of numerous decisions. In complex situations (where there is incomplete data, large amounts of interconnected and mutually dependable factors, no methods for producing required influences) there is no single best solution – otherwise the situation would not be considered complex. Therefore, decision making in such ill-defined situations requires the analysis of possible variants, the adaptation of these variants, or the invention of new ones. In other words, *creativity* is required.

Evolution is inseparable from creativity. By "creativity" here we are referring to innovation – i.e., the creation of new concepts and assets in any facet of human life, including tools and products; teaching methods; medical treatments; advertising; military, political or economic strategies; theories and works of art, etc.

The possession of creative capabilities (in politics, technology, arts, business, etc.) along with motivation, desire and enormous hard work have differentiated the geniuses and noted leaders who have shaped the history of humanity. This means that *managing the future depends 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 were created by utilizing ancient methods for the physical exploration of variants (the Trial-and-Error Method, or TEM).

Examples of some of these creations that have been unearthed (Indian canoes, Chinese junks, Polynesian catamarans, ancient Russian sailboats, etc.) are surprisingly perfect, with each line or detail of the finest possible shape. Archeological studies have shown, however, that in the beginning, these items were of much poorer design. By traditionally reiterating the same shapes, builders over time were able to introduce certain changes, some of which were fatal and thus disappeared, while others stuck. This process was very similar to natural evolution.

TEM is what was used to create the first flint knives and bows, guns and mills, buildings and boats, effective agricultural methods, education, etc. However, the acceleration of technological and social evolution made physical TEM less and less suitable: it was impossible to build thousands of variants to create the best steam engine or speedy cruiser. TEM had exhausted its resources and it was necessary to replace it with a more effective method.

First Wave model of managing the future – a cycle

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

- Due to ineffective creativity methods, evolution was very slow; changes were barely noticeable over a person's lifetime.
- The future of an individual primarily depended on his/her situation at birth.[8]

As a result, the main means of managing the future was like the prayer "Give us this day our daily bread." Control was mostly local and oriented toward small tasks: what and/or when to plant for the farmer, with whom and when to fight or cooperate for a ruler, etc. Basically, the main model of controlling the future during the First Wave was a *cycle*, as life repeated itself generation after generations and only small stand-alone events needed to be addressed.

Conditions that stimulated transition to the Second Wave

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

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

- The work of numerous unknown inventors transformed TEM into the experimental method, while helping to accumulate an enormous amount of empirical information in all areas of human activity.
- The work of religious scholiasts and philosophers resulted in the development of a powerful technique of logical analysis and conclusions.

Both these conditions developed independently; their combination – that is, the application of logical (including mathematical) analysis to empirical knowledge – constituted the origin of science of the 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.) were dominant. These methods allowed one to learn about a future system long before it was actually built, and included (but were not limited to) the building of inexpensive rapid prototypes, whose behavior allowed one to make certain assumptions about the behavior of the eventual real system, etc. Science had made it possible to search for the best design, the best method of managing economics, etc. by way of calculations and targeted research, and this played a main role in the unprecedented acceleration of industrial growth.

It is important to understand, however, that science of the Second Wave was effective primarily in the optimization of pre-existing ideas and concepts. When it came to the search for new ideas, a slightly modified TEM was still in use.

When faced with a problem that has no readily-available solution, the innovator struggles, asking himself: "What if I do it this way? . . . No good. Perhaps this way? Or maybe . . . ." Such an exploration of variants usually starts with the apparent and slowly moves toward the wild. After hundreds of variants have been explored without success, a desperate innovator might be saved by chance; for example, a tea kettle might prompt the notion of using steam or boiling water . . .

> The history of innovation demonstrates that the number of trials required to guarantee a solution can vary from dozens for a simple problem to billions for the most difficult. Thousands of professionals might be involved for decades in attempting to solve complex problems, until a genius finally arrives. Almost all of the inventions (including non-technical ones)[9], crucial to Second Wave society were made by a relatively small circle of people[10] possessing exceptional creative capabilities.[11]
>
> The history of technology also demonstrates that solutions to important problems often arrive late, resulting in losses that are nearly incalculable. For example, Alexander Fleming, who discovered penicillin, insisted that his invention could have been made twenty years prior and would have saved no fewer than 20 million lives – and this for a single invention!

Second Wave model of managing the future – railroad

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

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

> Strategic planning, which included decision making and the realization of sequential pre-determined actions targeting certain goals, was effective enough in the mostly linear and relatively slowly-changing environment of the Industrial Era. During this time it was still possible to assess the availability of necessary resources, determine the potentially useful and harmful consequences of a decision, and make timely arrangements for preventing undesired events. Adjustments and corrections of plans as they were being carried out were also common. In line with strategic planning came the development of various long-term programs, laws, rules, constitutions, legal systems, etc., which defined group and individual behavior in pre-determined situations.

This model of management/control can be defined as the "railroad" model. (Analogy: people sitting inside the train cannot influence the route, which has been determined by authorities who know best where the train and its occupants should go.)

Conditions stimulating transition to the Third Wave

Surprisingly, industrial methods of management became increasingly less effective with the growth of industrial era.

Management plans are often destroyed by conflict (wars, for example, always destroy the plans of at least one side, and more often of both). Unforeseen circumstances necessitate correction to the point where a plan can become an exception rather than the rule. Organizations established for the purpose of enforcing the realization of a plan (both on public and private levels) often undergo uncontrollable growth and bureaucratization, while the results become increasingly less than satisfactory. Rules and regulations swell due to numerous addendum, explanations, and interpretations, until their complexity exceeds reason and begets an army of lawyers . . .

The ineffectiveness of the classical innovation process, which is based on the "insights" of a handful of exceptionally talented individuals, had become obvious by the end of 1940s.

> The growth of industry, science, and other areas of human activity demanded more and more ideas within an ever-diminishing time frame. This increasing pressure often resulted in stress and even psychosis in inventors, who clearly required new and more effective creativity methods.

Alex Osborn[12] was one of the first individuals to respond to this demand by inventing *brainstorming* – an effective group method for creative activity. Other methods, similarly based on psychological stimulation, followed.[13] This direction 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 that complicate the management of evolution are the following:

- Significant increase in the complexity of society, including increasing numbers of various groups and organizations with different (often opposite) interests and goals; increasing number and variety of links between groups and individuals, which result in the following consequences:
  - Sharp increase in the number of decisions that must be made in a shorter time span.
  - Decisions are always based on particular solutions. Sometimes possible solutions are not available and must first be generated; in other cases, too many solution variants exist, making the choice very difficult.

[12] Alex F. Osborn, *Applied Imagination* (New York: C. Scribner's Sons, 1963).
[13] Alla Zusman, "Creative Methods Overview," *TRIZ in Progress* 1 (Southfield, Mich.: Ideation International, 1999).
[14] Edward de Bono, *Lateral Thinking* (Harper and Row Publishers, Inc., 1973).

  - An enormous amount of information must be assessed to guarantee the best decision.
  - Decisions and/or actions produce nearly unpredictable side effects, and influence the decisions/actions of other groups or individuals that can have a return effect that causes 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 the amount of energy and other resources controllable by certain organizations and/or individuals, increasing in turn the risk associated with certain decisions.

As mentioned earlier, management (or control) assumes the making of numerous decisions. The deployment of the Third Wave era creates numerous complex and unique situations, rendering all known solutions unacceptable. For this reason one cannot rely on the constantly expanding power of the Internet or the enhancements of search engines to deliver solutions – the most critical ones will not be found there.[15]

In this situation, decisions are made by selecting from among several potential variants (sometimes with only a vague understanding of the selection criteria), or by modifying or adapting typical solutions to a specific situation, or, more often, by inventing the best variant. In any event (including selection under uncertain conditions, adaptation or invention) creative work is required, making the need for creativity an increasingly critical factor in all human activities.

Currently, certain methods based on the combination of well-defined goals and the existence of a substantial freedom for employees to make creative decisions (as well as the required initiative) are accepted and effectively utilized in some cutting-edge organizations. These methods should become the main management tools during the Third Wave era.

The primary model for control in the Third Wave is the "car race on unfamiliar, broken terrain." (Analogy: the destination is defined, however, everybody can select his/her own route and make decisions for how to avoid obstacles, what speed to maintain, levels of risk and safety, when to stop to rest, etc. It is a matter of personal decision whether to participate in the race individually or as part of one or more teams.)

Assumption

Creativity is the most important component in any human activity during the Third Wave era. It becomes necessary for a country, corporation or individual to plan and control its own destiny and ultimate survival. The deficit of creativity will become the main obstacle to progress, and therefore enhanced creative methods should be the main tools for managing evolution.

TRIZ – a knowledge-based approach to creativity

At about the time Osborn was creating his method, Genrich Altshuller was developing the foundation of the Theory of Inventive Problem Solving (TRIZ)[16] – an approach based on research in the history of

[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] "TRIZ" is the translation of a Russian-language acronym. See "Selected TRIZ Bibliography" and "A Brief History of TRIZ," *TRIZ in Progress* 1 (Ideational International, 1999).

technology, the utilization of evolutionary patterns, and other knowledge extracted from statistical studies of past inventions. To date, over 50 years of practical utilization and theoretical research have been conducted, yielding the following conclusions:

- Creativity can be taught to any average individual, allowing him/her to solve complex creative problems quickly and confidently.
- Evolutionary (knowledge-based) and psychological approaches are mutually compatible and even effectively complement one another.

TRIZ is based on the following assumptions:

- The emergence and implementation of innovation is not random or haphazard (as it might appear), but rather are dictated by certain general evolutionary patterns governing the creation of artificial[17] systems.
- These patterns can be revealed through study of the history of innovation in various areas, including technology, the arts, social life, etc.
- The revealed patterns can be purposefully applied to:
  - Predict possible evolutionary "paths," as well as potential dangers associated with these paths.
  - Quickly and effectively resolve creative (inventive) problems.

[17] We refer to an artificial system as any system created by humans, including:
- Technical systems: any machine, device, equipment, manufacturing process or other process 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 mentioned earlier, with TRIZ, everyone can be taught to solve problems. But although effective problem solving is necessary for managing evolution, it is not sufficient. To be a true master of his/her destiny, an individual should be able to perform the following functions:

- Analyze the existing situation and evaluate its advantages, disadvantages, conflicts, and basic evolutionary resources.
- Identify main evolutionary trends and possible scenarios, then select the desirable ones.
- Identify potential dangers and problems that can arise in the process of evolution.
- Formulate and solve creative problems that must be solved 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 in a timely fashion.

Originally created as a technique for technological problem solving, TRIZ, over the ensuing four decades, became the most powerful source of knowledge and tools for controlling technological evolution. Subsequently, TRIZ approaches and methods have been extended to non-technical areas, including the areas of social and organizational evolution.[18] In fact, while maintaining its old name, TRIZ was transformed into the *Theory of Evolution of Artificial Systems (TEAS)*, on which basis it became possible to develop a new methodology for managing/controlling evolution – a process called *Directed Evolution*™ or DE™.

> The roots of Directed Evolution extend to the mid-1950s, when an approach for reckoning the future called *Technological Forecasting* [19]was under development. By the mid-1970s this resulted in the establishment of 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 approach 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. With this approach, one can apply selected TRIZ tools to generate one or more ideas helpful for developing the next generation of a product or process.
>
> Unlike traditional technological forecasting, TRIZ Technological Forecasting (as guided by the Patterns of Evolution) actually "forces" a system into its highly-probable future incarnation, by inventing it before it would otherwise occur naturally.
>
> For example, the pattern of evolution entitled *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

[18] Boris Zlotin, et al., "TRIZ Beyond Technology," proceedings from TRIZCon2000 (Worcester, Mass.: The Altshuller Institute for TRIZ Studies, 2000), p. 135. Also published in The TRIZ Journal (www.triz-journal.com), January 2001.
[19] Joseph Paul Martino, *Technological Forecasting for Decision Making*, 2nd edition (North-Holland, 1983). Jantsch, Erich. *Technological Forecasting in Perspective* (London, 1972).

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 of Evolution" – provide the user with predicting power.

In the mid-1990s, TRIZ Technological Forecasting began transforming into Directed Evolution, which is a systematic approach aimed at identifying a comprehensive set of potential evolutionary scenarios for:

- 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, the three approaches –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 does the future hold for 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 the guesswork of forecasting with a strategic decision-making process, which is based on potential evolutionary scenarios developed by applying proven patterns of evolution, followed by the implementation of one or more of these scenarios in accordance with the decisions made.

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

[20] For more detail, see proceedings of TRIZCON99: The First Symposium on TRIZ Methodology and Application (Worcester, Mass,: The Altshuller Institute for TRIZ Studies, 1999). Also see *TRIZ in Progress* 1 (Southfield, Mich.: Ideation International, 1999).

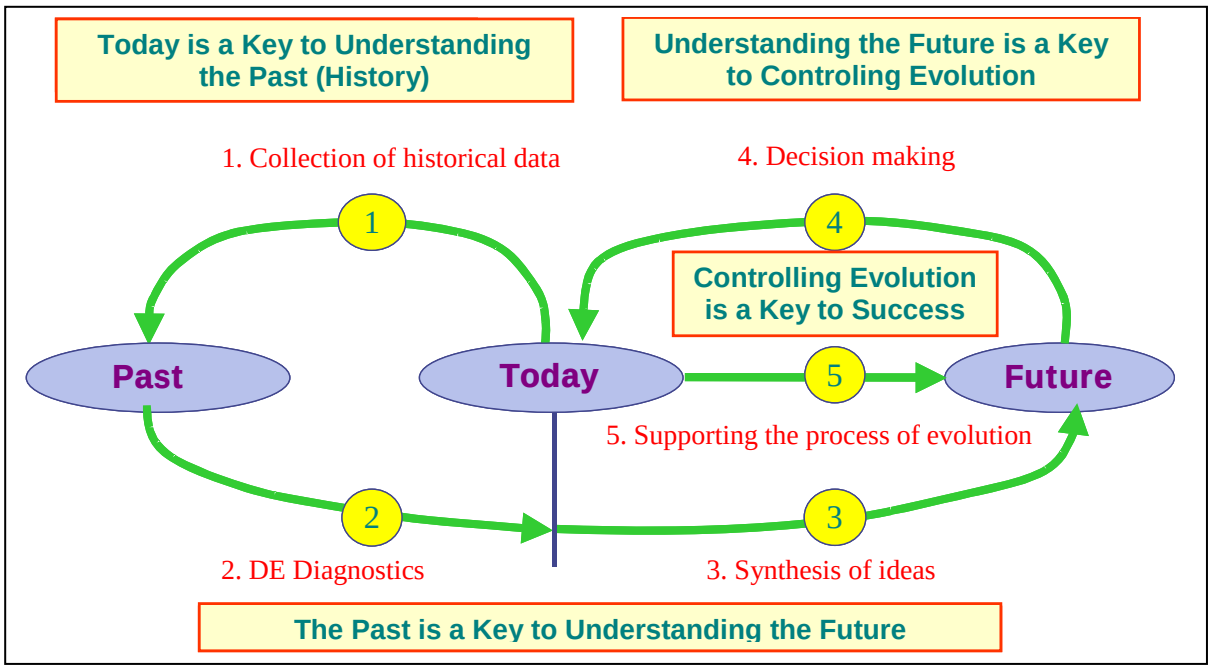
[21] *TRIZ in Progress* 1, Appendix 13 (Ideation International, 1999).

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

- Analysis of the historical and current incarnations of a given system, revealing basic patterns of its evolution and comparing them with the general patterns of evolution.
- Strategic planning, including the identification of long-term objectives and subsequent pre-determined steps in accordance with the patterns/lines of evolution. Invention of new features of one or more future generations.
- Revealing of potential obstacles in a system's evolution, including dangers, undesired side effects and other problems that might arise or become more prominent in the process of evolution (Failure Prediction[22]).
- Quick resolution of problems that must be resolved in order to achieve the goals and eliminate problems that emerged in the evolutionary process.
- Selection of innovations to be implemented, based on marketing, technical, social and other trends and patterns of evolution.

Given the above, we believe that DE represents a Third Wave methodology – even a way of thinking – that allows individuals, organizations, nations and humanity as a whole to manage/control its destiny.

General schema of Directed Evolution



The above figure illustrates the general schema of the DE process, which includes the following five stages:

- Collection of historical data

[22] Failure Prediction is another TRIZ application. For more detail see Stan Kaplan, Svetlana Visnepolschi, Boris Zlotin and Alla Zusman, *New Tools for Failure and Risk Analysis* (Ideation International, 1999).

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

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

- Project size (i.e., DE for an individual, organization, specific product or process, etc.)
- Area (industry, market, social system, etc.)
- Age and nature of the system (DE object)
- Marketing and/or technological position and objectives of the customer
- Availability and accessibility of information
- Current marketing situation
- Current situation regarding intellectual property related to the project

Every stage of the DE process consists of sub-steps, each of which is supported by an appropriate means (analytical and/or knowledge-base tools) for analysis and/or conclusion.

The DE process is described in more detail below. All techniques and algorithms mentioned can be utilized for relatively small systems (such as a simple product or an individual). For large-scale projects, more complex computerized processes and tools are appropriate.[23]

Stage 1. Collection of historical data

Main objectives

The main objectives of this stage are to learn about the system, and entail:

- Accumulating data for further work
- Revealing the positive and negative trends in the system's evolution. The revealed trends will be utilized for further comparison with the general patterns/lines of evolution, and for identification of deviations (disturbances).

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 arising in the process of system evolution
- Production problems, contradictions and other obstacles related to the evolution of the production process

[23] TRIZSoft® family of software tools.

- Adjacent and other related systems present in the process of system evolution
- History of the main ideas associated with the system: main discoveries, inventions, improvements, product line evolution and other changes
- Market: sectors, typical user profile, customer expectations and their evolution
- History of related organizations: competitors, vendors, etc. and their evolution
- Resources belonging to the system, changes in resources in the process of evolution, and applicable new resources

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

Tools and techniques utilized

The following tools and techniques are utilized during Stage 1:

- DE Questionnaire
- DE Failure Analysis
- DE Problem Formulation

DE Questionnaire

The DE Questionnaire[24] is based on the TRIZ System Approach/Analysis and consists of a structured set of sequential questions presented 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 the thinking process from the perspective of the patterns of evolution
- Reduce psychological inertia

As mentioned earlier, each step is supported by appropriate analytical and/or knowledge-base tools.

DE Failure Analysis

This step is optional and allows for the revealing of the root causes of various facts and/or phenomena (useful and/or harmful) associated with the system. DE Failure Analysis is a TRIZ application that involves the transformation of an "investigative" problem into an inventive problem.[25]

Problem Formulation

Problem formulation is another analytical technique (and tool) based on the TRIZ System Approach, and is rooted in Genrich Altshuller's multi-screen model of creative thinking.[26] Problem formulation allows one

[24] For more detail, see Appendix 1
[25] See Appendix 2. For more detail see Kaplan, Visnepolschi, Zlotin and Zusman, *New Tools for Failure and Risk Analysis*. (Ideation International, 1999.)

to transform complex and often net-like information about the system (pieces of which usually exist only in the minds of various individuals and thus are rather disconnected) into a well-organized "map" reflecting the cause-and-effect relationships between system elements (as well as the system environment) in the form of "knowledge net." Utilizing this technique allows further transformation of this information into an exhaustive set of specific Directions, which are then analyzed and further developed according to appropriate TRIZ-based recommendations.[27]

Problem Formulation can be completed manually[28] or with the Problem Formulator™ software tool.[29]

Stage 2. DE diagnostics

Main objectives

DE diagnostics is the "heart" of the DE process. The main objective of this stage is to identify possible directions for the evolution of the given system, then formulate all problems and issues that must be addressed for this evolution to be realized. This stage incorporates the following:

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

Work to be completed

DE Diagnostics entails:

- Comparison of historical data with patterns/lines of evolution, including
  - Mapping of historical data along known patterns and lines of evolution
  - Positioning the given system on the patterns and lines of evolutionBuilding lines of evolution for the given system
- Revealing missing and future steps (which are viewed as opportunities for improvement), including
  - Missing steps on general evolutionary lines
  - Future steps on general evolutionary lines
  - Wrong directions, dead ends, and stalemates in evolution
  - Functional deficiencies
  - Unresolved contradictions, secondary problems, etc.
  - Customary inconveniences
  - Psychological inertia, tunnel vision, unreasonable restrictions, etc.

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[26] G. S. Altshuller, *Creativity as an Exact Science* (Gordon and Breach Science Publishers, 1984), 117-123.
[27] For more detail, see Boris Zlotin and Alla Zusman, "Managing Innovation Knowledge," *TRIZ in Progress* 1 (Ideation International, 1999). Also published in The TRIZ Journal (www.triz-journal.com).
[28] See Appendix 3.
[29] The Problem Formulator™ is included in some TRIZSoft® products.

- Extrapolating lines of evolution for the given system into the future, including
  - Prediction of highly probable future steps in the system's evolution
  - Definition of methods and conditions for realizing these steps
  - Definition of limitations for realizing these steps

Tools and techniques utilized

The following tools and techniques are utilized in this stage:

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

Analysis of evolutionary resources

An analysis of evolutionary resources helps to unveil various resources (including hidden resources) that can be utilized to evolve the system into its future incarnation(s).[30]

S-curve analysis

S-curve analysis is based on the extended (i.e., composed of six main stages) S-curve[31], and targets the identification of the system's evolutionary position. By knowing the exact evolutionary position, and by applying a dedicated knowledge base,[32] one can identify the correct directions for development as well as typical mistakes that must be avoided at this stage of evolution.

Typically, S-curve analysis involves the following steps:

Building S-curves for the main system parameters

Building S-curves for influential sub-systems

Evaluating the system's position on the S-curves, based on:

- Number of patents
- Citations
- Organizational features
- Lines of evolution of the applicable market

[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 al. *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.

Revealing the main mistakes typical for the given stage of evolution, and revealing the "correct" directions for development

Revealing "bottlenecks" – i.e., 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 stage allows for the prediction of potential failures and dangers, and is based on TRIZ-based Failure Prediction.[34] This approach involves transforming a "prediction task" into an inventive task.

Stage 3. Synthesis of ideas

Main objectives

The main objective of this stage is generating ideas that will move the given system to the next evolutionary step. The ideas obtained in this stage typically address the following issues:

- New functions, applications and markets for the system
- Various ways and methods related to:
  - Providing the system's function(s)
  - Preventing harmful or undesired effects associated with the system
  - System production, delivery, usage, maintenance etc.
  - Integrating the evolved system into various super-systems

Work to be completed

At this stage, numerous inventive problems that have been formulated in previous stages must be addressed. This entails:

- Analyzing all ideas obtained in previous stages, and formulating related secondary problems
- Structuring, organizing and prioritizing problems formulated earlier
- Problem solving

Tools and techniques utilized

The following tools and techniques are utilized:

[33] See relevant tutorial material for TRIZCON2001.
[34] See Appendix 5. For more detail, see Kaplan, Visnepolschi, Zlotin and Zusman, *New Tools for Failure and Risk Analysis* (Ideation International, 1999).

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

Ideation IPS

The Ideation Process for Inventive Problem Solving (IPS) is a comprehensive, software-based[35] problem-solving process incorporating the Ideation/TRIZ Methodology (I-TRIZ) and its analytical and knowledge-base tools. This process is designed to provide support during the analysis of a problem situation and the development of innovative *solution concepts*, and consists of the following stages:

Innovation Situation Questionnaire

Problem Formulation

Prioritize Directions

Develop Concepts

Evaluate Results

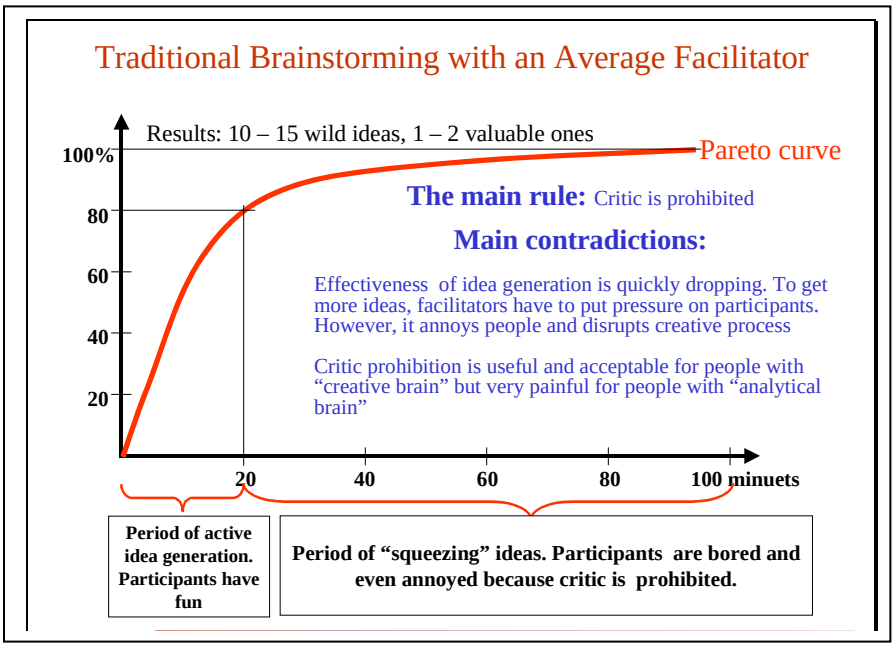
Manual utilization of a related simplified process can be recommended as well.[36]

Ideation Brainstorming

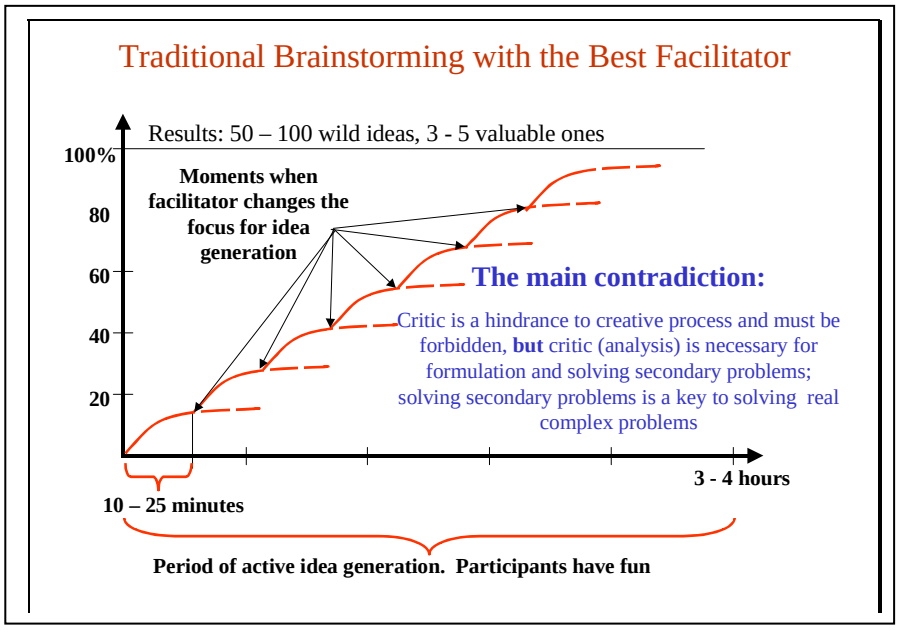
Ideation Brainstorming is a modification of traditional brainstorming and is based on the utilization of Ideation IPS (and optionally TRIZSoft) to support the team facilitation process.[37]

Traditional brainstorming contains substantial deficiencies (see the figure, below), one of which is that participants usually become exhausted with idea-generation rather quickly, then become tired and even annoyed because any criticism of ideas is prohibited.

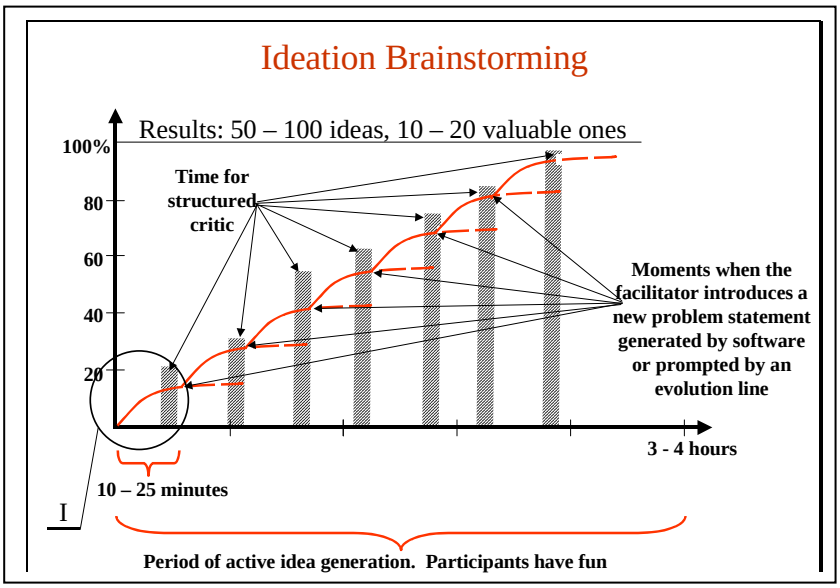
[35] For technical problems, the Innovation WorkBench® software can be used. For other problems, the Knowledge Wizard® Millennium software can be used.
[36] See Appendix 6. Also, the Ideator software can be utilized to support a simplified problem-solving process.
[37] See Appendix 7. Also, see *TRIZ in Progress* 1, p. 246.



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



Ideation Brainstorming allows the team to overcome all problems associated with traditional brainstorming, as it integrates the brainstorming environment with a rigorous problem-solving process (see figure, below).



Stage 4. Decision making

Main objectives

The main objective of this stage is to prepare all necessary material for making decisions regarding the direction(s) of evolution of the given system. If the previous stages have been completed with the participation of Subject Matter Experts in the area of design, production and utilization of the system, this stage should involve personnel in sale, marketing, and finance. It is also very important that the appropriate decision makers are involved – at least during the final part of this stage.

Work to be completed

This stage involves the following:

- Concept development, including:
  - Integration of compatible ideas into concepts, each of which represents a certain variant of system evolution
  - Dividing the developed concepts into groups according to their compatibility:
    - incompatible concepts
    - compatible concepts
    - complementary concepts
  - Dividing the developed concepts into groups according to timeframe:
    - Short term concepts (improvement)
    - Mid-term concepts (next generation)
    - Long term concepts (future generations)

- Building potential evolutionary scenarios (step-by-step), including
  - Formulating the goals of evolution, as well as the strategy and sequence in which these goals will be achieved
  - Developing an action plan
  - Identifying the required resources
  - Protecting intellectual property
- Introducing 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 associated secondary problems
  - Solving of all new problems that are unveiled
  - Introduction of 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 do good intentions so often lead to catastrophe? Every driver knows that when driving along even the straightest of highways, one cannot let go of the steering wheel for more than a few seconds – the microscopic deviations accumulate and the automobile will drive off the road . . .

Similarly, when moving toward certain goals, it is not enough to have good plans and effective control of them – there will always be unexpected deviations. For this reason, the first four DE stages can usually be completed in a relatively short timeframe. Indeed, these are just a preparation for the critical stage of *supporting the evolutionary process*, which involves the continuous monitoring of the process and making appropriate corrections as necessary.

Main objectives

The following issues must be closely monitored during the system's evolution:

- Predicting and looking for possible deviations or 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 might relate to the given system
- Predicting deviations; analyzing planned versus actual results
- Solving inventive problems related to:
  - Utilization of deviations as a resource for achievement of goals
  - Neutralization of deviations, compensation for and protection from their influence
- Correction of scenario(s)

Work to be completed

The following work should be completed during this stage:

- Organizational measures to ensure a continuous Directed Evolution process that includes:
  - Educating personnel in the application of DE
  - Establishing a special infrastructure to support DE implementation
- Controlling the evolutionary process, including
  - Identifying and controlling critical points
  - Timely revealing of deviations, and documentation of new problems (technological, marketing, social, etc.)
  - Promptly solving new problems and integrating new solutions into the scenario(s) of evolution
- Refining the DE recommendations, including
  - Reviewing basic concepts on a regular basis (once or twice per year for a rapidly-growing business; once every 2 to 3 years for a stable, mature business)
  - Introducing corrections, refinement and adjustments to the DE scenario(s) after serious changes (breakthroughs) in social, marketing or technological areas take place.

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 can be continuously utilized in daily activities

The following tools, techniques and other elements can 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 the application of Failure Prediction)
- Revealing the root causes or mechanisms of various phenomena (based on the application of Failure Analysis)
- Inventive (creative) problem solving
- Reduction of psychological inertia

Teaching children

Substantial experience has been gained (mainly in the USSR[38]) in teaching creative techniques to children, as well as how to apply these techniques in daily life. The results have clearly shown increases in self-esteem, better learning capabilities, and positive change overall.[39]

It is beyond doubt that the education of children must become the main method of implementing DE basics on a wide scale. Eventually, children should benefit from the following results:

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

Teaching adults

To date, substantial experience has been acquired in the teaching of various elements of TRIZ – which forms a part of DE – to adults (in the USSR, United States, and elsewhere). It is quite possible to transform these separate courses into an integrated course entitled *Managing the future* if the compatibility of various courses provided by different educators is ensured. (The Altshuller Institute for TRIZ studies is exceptionally well suited for this purpose.)

It is most important that college students learn about the evolution of systems residing in their area of study. The normal academic environment is the most suitable for including special courses on creative problem solving, evolution analysis, etc.[40]

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[38] Recently, two projects are in progress in Iowa and Michigan.
[39] Boris Zlotin, et al., "TRIZ Beyond Technology," presented at TRIZCon2000 and published in The TRIZ Journal (www.triz-journal.com), January 2001.
[40] One project with biomedical engineering graduate students at Vanderbilt University is in progress (see at www.ideationtriz.com).

Teaching professionals

Obviously, with the growth of the informational civilization and the implementation of DE practices, a good number of DE experts will be in demand. Professional DE work requires extensive 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 the DE process

A set of software that supports certain DE stages is currently available.[41]

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

Express DE Process

We have applied the Express DE process to our subject – the application of DE – and have concluded that in the next 25 years DE will become an inherent part of living throughout the world, with the following features.

- DE will become a conventional science with a status similar to that of mathematics. DE research centers, labs, conferences etc. will exist; monographs, dedicated magazines, newspapers, websites and other sources of information are established.
- DE specialists will be engaged to guide the development and evolution of any system, 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.) throughout:
  - Government organizations
  - Enterprises
  - Education centers (schools, universities, continuous education, etc.)

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

  - Medicine, entertainment, recreation,etc.

- Systems to support DE applications within an organization will be established (similar to the 6-Sigma system).
- A DE professional society will be established, with numerous chapters for scientists, teachers, practitioners, forecasters, etc.
- Every individual will have some DE knowledge (similar to mathematics, where the elementary principles are known by most, and a high level of knowledge possessed by DE professionals).
- DE will be taught in:
  - Kindergartens (the simplest elements, such as ideality, resources application, 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 will be applied toward learning other disciplines (elements of creative pedagogy, history of evolution, prevention of psychological inertia, etc.).
- DE will be used in numerous types of software (games, educational and working tools for children, adults and professionals).
- DE will help in the management of intellectual property, including:
  - Activation and coordination of people's creative output (for a company, for country, etc.).
  - Patenting new ideas, building patent fences, patent litigation, etc.
  - Patent circumvention
  - Validation of knowledge in compliance with evolutionary patterns
  - Development of banks of creative ideas and concepts for different facets of human activity.

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

- Personal software with titles such as "*Partner*," "*Friend*," "*Alter Ego*," etc., presented to a newborn child and updated through his/her entire life. This software will document the main events in the user's life via games and tests (including simulation games). The software will learn about its user, watching his/her health, helping in studies, solving creative problems, informing him/her about (and making available) necessary techniques, connecting with sources of information, issue warnings about dangers, and serve as a personal assistant. Practically all necessary components for such a software tool exist today, and we can expect them in the near future.
- Specialized software for supporting DE related to specific areas of industry and other human activity.
- World banks of evolutionary information supporting DE software.

Implementation of the process of controlling human evolution on a worldwide scale cannot be implemented through enforcement. Instead, the following measures can help with the gradual introduction of the DE philosophy:

- Placing DE information and techniques on the 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 that promote DE in various areas. These should integrate people who are interested in DE: scientists, businessmen, politicians and others who understand its importance.

Conclusion

Humanity is merely surfing along the waves of civilization The essence of the First Wave was stability. Life was predictable enough, children were expected to have similar goals and problems, and even deviations (successes or failures) were similar for the most part.

The essence of the Second Wave was linear, continuous, sequential and logical evolution. Life was planned – education, work, child-rearing, retirement and even funeral arrangements . . . Deviations were possible, of course, but were also manageable.

The essence of the Third Wave can best be described by the words of the ancient Greek philosopher Heraclitus: "Everything is flowing, everything is changing . . ." – and in an unpredictable fashion, as well. Today it is fairly obvious that we cannot live according to rigid plans, that unexpected events should be expected. The average individual will receive several different types of education and change his/her profession, location, friends, etc. several times or more. Scientific progress has brought us electricity and the automobile (industrial era), computers and the Internet (informational era) . . . what can we expect tomorrow? The transition to active management of life and destiny is becoming not only inevitable but absolutely necessary in order to avoid situations where an individual is merely a toy at the mercy of the uncontrollable forces of a stormy sea. Methods of controlling the future will ensure the successful and safe evolution for individuals, organizations, government agencies, countries, and humanity.

Alvin Toffler's book was very convincing at the time of publication (hence its bestseller status). And from a TRIZ perspective, it is the most powerful futuristic book that has ever been published. Toffler didn't mention TRIZ or DE, of course, but it is difficult to ignore the thought that 20 years ago he could foresee something similar; that together with TRIZ founder Genrich Altshuller, Toffler would be referred to as a DE forefather.

There is one more forefather we would like to mention here. Isaac Azimov, in his remarkable series of science fiction novels *Foundation*, invented and described *psychohistory* – a science that allows the prediction and influence (control) of the evolution of the human civilization. According to Azimov, psychohistory will emerge in the distant future, when human civilization expands over the entire galaxy. It is rather obvious, however, that we cannot wait that long, that without the ability to control its future humanity cannot last more than another century or two. We need Azimov's psychohistory *now*, and when the demand does finally emerge, psychohistory might become real much faster than even the most daring fantasy would predict. The emergence of Directed Evolution and its sub-methods will issue in an era of purposeful control of the future today – for individuals, organizations, and humanity as a whole.

Part 2. Direct Application of the Patterns of Evolution

Introduction

The following material includes the main recommendations and information on the following Patterns of Evolution:

1. Stages of evolution
2. Evolution toward increased Ideality
3. Evolution toward increased involvement of resources
4. Non-uniform development of system elements
5. Evolution toward increased dynamism and controllability
6. Evolution toward increased complexity followed by simplification (reduction)
7. Evolution with matching and mismatching elements
8. Evolution toward micro-levels
9. Evolution toward increased use of fields
10. Evolution toward decreased human involvement

Basic rules for working with the Patterns of Evolution

- Select a pattern and read the recommendations
- For the given system and its competitors, consider the past evolutionary steps that fall under the selected pattern
- Consider if the recommendation(s) can be applied (or reapplied) to the given system to move it to the next step

Patterns/Lines of Evolution

Stages of evolution

Based on available information about your system and specific information related to the different stages of evolution (see Appendix 1, S-Curve Analysis table), complete the following tasks:

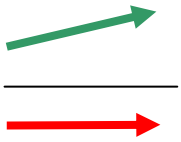
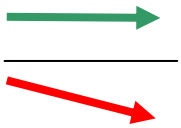
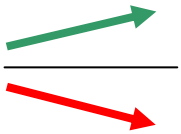
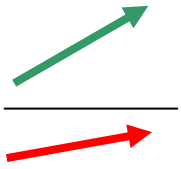
- Identify the stage (or sub-stage) in which your system resides
- Identify the main business objectives for the current and next stage (or sub-stage)
- Identify typical mistakes (“traps”) that should be avoided
- Formulate strategic objectives for the system’s development

Evolution toward increased Ideality

A system's Ideality can be defined as the ratio of *all useful system functions* to *all harmful system functions* associated with the performance of the useful functions:

$$I = \frac{\text{All useful functions}}{\text{All harmful functions}}$$

There are several possible ways to increase Ideality:

Description	Graphical description
1. Increase the number of useful functions, including: - Absorb the useful functions of other systems nearby the given system, or of the environment - Invention of new useful functions 2. Improve the quality (and other parameters) of the useful functions	
3. Reduce the number of harmful functions, including: - Eliminate/prevent harmful functions - Divert harmful functions to other systems or parts where the harmful influence is less critical - Find useful applications for harmful functions 4. Reduce the magnitude of harmful parameters	
5. Combine the above actions to ensure a higher ratio	 Or: 

Evolution toward increased involvement of resources

1. Consider the available resources according to the list in Appendix 2
2. Consider the following ways to modify available resources for better utilization:
   - Accumulation of resources
   - Concentration of resources
   - Combination of resources
   - Physical or/and chemical transformation of resources

Non-uniform development of system elements

1. Formulate contradictions for the given system using the following templates:

   A useful function <state the function> *should be performed because* <state the reason> *and should not be performed because* <state the reason>.

   A parameter <state the parameter> *should be high because* <state the reason> *and should be low because* <state the reason>.

2. Consider resolving the formulated contradictions by applying the following separation principles:
   - Separate opposite requirements in space
   - Separate opposite requirements in time
   - Optimize characteristics in time
   - Separate opposite requirements between the whole object and its parts
   - Separate opposite requirements on the basis of changing conditions
   - Separate an impeding part from an object
   - Separate (remove) a required part from an object

Evolution toward increased dynamism and controllability

1. Consider increasing the system's dynamism by improving its ability to change and adjust to multiple conditions and/or requirements. Use the following recommendations:
   - Decrease the degree of stability
   - Transition from a stationary to a mobile condition
   - Divide a system into mobile parts
   - Introduce a mobile object
   - Apply different physical and chemical effects

2. Improve the system's controllability using the following recommendations:
   - Introduce a control field
   - Introduce a controllable additive
   - Introduce a controllable anti-process
   - Provide self-control of the system
     - Introduce negative or positive feedback

Evolution toward increased complexity followed by simplification (reduction)

1. Increase the system's complexity by segmenting it into parts and then integrating the parts in a new way. To do this, follow these recommendations:

Segmentation	Integration
Make an object dismountable	Integrate parts into a system
Partition into simple-shaped parts	Add integrating elements to the system (frame)
"Pulverize" an object	Create a hierarchical structure
Provide for the degeneration of links during partitioning	Add an object that possesses the required properties/functions

2. Consider integrating the system into a higher-ranking super-system. This can be accomplished via transformation into a bi-system (the combination of two identical or different systems) and/or transformation into a poly-system (the combination of more than two systems). Use the following recommendations:

Build a bi-system . . .

- from homogeneous elements
- from "compensating" elements (where one element compensates for the drawbacks of the other)
- from systems with shifted characteristics
- from competing systems
- from antagonistic systems (systems that perform opposite functions)
- by combining competing systems that are in different evolutionary stages ("towing bi-system")
- utilizing the binary principle
- creating a dynamic bi-system

Build a poly-system . . .

- from homogeneous elements
- from "compensating" elements (where one element compensates for the drawbacks of the other)
- from systems with shifted characteristics
- from bi-systems
- by creating a dynamic poly-system

Enhance a bi- or poly-system by . . .

- enhancing system links
- increasing the differences between elements

3. Consider simplifying the system using the following recommendations:
    - Apply disposable objects
        - Apply a model or copy

- Make an object dismountable
- Change the principle of operation
- Apply specialization
- Use more highly integrated subsystems
- Exclude auxiliary (correcting, preliminary, protecting, housing, etc.) functions
- Exclude duplicate elements
- Utilize self-service
- Consolidate discrete sub-systems

Evolution with matching and mismatching elements

1. Consider matching various system parameters for the purpose of improving functionality. Make the parameters equal, proportional, or mutually dependable.

2. Consider the intentional mismatching of various parameters for the purpose of:
   - Eliminating harmful effects (make the related parameters different, independent, opposite, etc.)
   - Making the system parameters controllable, that is, changeable depending on condition (match or mismatch when required).

   Note: The following system parameters should be matched or mismatched:

   - System structure
   - Materials
   - Physical state (gas, liquid, solid)
   - Chemical properties
   - Temperature
   - Dimensions
   - Weights
   - Strength
   - Reliability
   - Rhythms of functioning
   - Electric or other resistance
   - Magnetic properties
   - Colors
   - Other

Evolution toward micro-levels

1. Consider utilizing deeper structural levels or combinations of these levels, using:
   - System made of elements with specific shapes
   - Poly-system made of elements with simple shapes
   - Poly-system of small elements (powder, micro-spheres, granules, drops, etc.)
   - Effects associated with substance structure (super-molecular or crystal level)
   - Molecular phenomena
   - Atomic phenomena
   - Field actions instead of substances

2. Consider utilizing different aggregate states or combinations of states, using:
   - Solid-state substances

- Plastic and elastic materials
- Gels
- Liquids
- Liquids in critical or supercritical phases
- Gases
- Plasma
- Voids (areas with low density, vacuum, etc.)
- Various combinations of solid, liquid, gas and plasma states (foam, liquids saturated with gas, suspensions, sprays, dust, ionized gas, etc.)
- Aggregate state transformations (melting, evaporation, condensation, solidification, etc.)

Evolution toward increased use of fields

1. Consider utilizing the following fields and/or combinations of fields:

Basic field	Specific fields	Special corresponding substance(s)
Mechanical	Gravity	
	Pressure	
	Shocks, vibration	
	Explosion	Explosives
	Acoustic waves	
Thermal	Heating / cooling Aggregate state transformation	Water-ice-vapor Bi-metals Shape-memory effect materials
Chemical		Catalysts, inhibitors
Electrical	Electrical charges	Dielectric materials
	Electrical current	Conductive materials
Magnetic	Electrical current	Conductive materials
	Permanent magnetic field	Magnetic materials, magnets, ferromagnetic particles

2. Consider transforming an existing but unusable field into another, more useful one.

3. Consider changing field parameters from one to another of the following:

- Permanent, one-dimensional field
- Permanent, multi-dimensional field
    - Gradient and/or asymmetrical field

- Alternating field, rotating field, traveling field, etc.
- Alternating resonance field
- Non-sine field (rectangular, trapezoid, etc.)
- Pulsed field
- Combination of fields with different parameters

Evolution toward decreased human involvement

1. Try to replace a human with a machine, device or other equipment using the following recommendations:
   - Make the operations simple (reduce the level of intelligence required to realize the process)
   - Aid humans in easily-automated operations that require power, accuracy, speed or some other characteristic prone to human error
   - Substitute a human without changing the principle of operation
   - Change the principle of operation to suit a "mechanized" operation (i.e., pay attention to power, accuracy, speed, etc., rather than intelligence)

2. Consider the following ways of substituting humans in various kinds of activities:

In operations:

- Use simple mechanical tools instead of hands, teeth, etc.
- Use mechanical energy transformers and accumulators for human power, such as levers, gears, jacks, bow, springs, sling, etc.
- Use non-human energy sources (animals, wind, water, steam, chemical power, electrical power, nuclear power, etc.)

In control:

- Use tools to control system functioning, such as rudders, steering wheels, airfoils, guides, etc.
- Use special devices to transform control commands, such as amplifiers, reducers, filters, rectifiers, stabilizers, modulators/demodulators, etc.
- Use devices to produce control commands, such as cams, gyroscopes, punched cards, etc.

In decision making:

- Use various sensors (mechanical, thermal, chemical, electrical, magnet, etc.) instead of human senses as information tools
- Use devices for processing information – i.e., analyzing, summarizing, measuring, verifying, etc.
- Use devices to make decisions based on information analysis

Summary

1. Summarize all generated ideas and group according to:

- Ideas that you know how to realize
- Ideas that you like but do not know how to realize. (Use problem-solving tools to further develop these ideas.)

2. Try to foresee problems that might arise during implementation. Use the Failure Prediction module (Appendix 3) for this purpose.
3. Formulate secondary problems and utilize problem-solving tools to resolve them.

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Appendices

Appendix 1. Frequently asked questions about Directed Evolution (DE)

Applying DE

Q1: DE promises too much. It is difficult to believe.

A: The English physicist Robert Hooke, a contemporary and competitor of Isaac Newton, is known as the founder of several quite different sciences: cytology (the study of cells of living organisms), mineralogy, physical metallurgy, crystallography, etc. How did this happen? The fact is, Hooke became the first scientist to systematically utilize a newly developed scientific instrument – the microscope. The majority of his discoveries resulted from this utilization. Usually, the introduction of a new tool is followed by a burst of new ideas, discoveries and opportunities. Similarly, TRIZ and TRIZ-based DE are new and powerful tools to address creative and futuristic problems, allowing one to expect more and more.

Q2: Technological evolution resembles a horse race: everybody strives to move forward, but not everybody can be a winner. Can DE help to identify the winning "horse" ahead of time?

A: Yes and no. It won't help with guessing, but with *winning*. For example, it can help (for example):

- Identify, from an initial 100 candidates, the 75 that cannot win.
- Identify 10 that have the greatest chance of winning.
- To select 3 from among the 10, who can then be trained, motivated and groomed by the best professionals in the applicable areas.
- Identify and eliminate potential obstacles and dangers.
- To choose, shortly before the race, a single horse to focus on.
- After the race has started, to quickly solve all arising problems and remove obstacles that face the favorite.

Q3: Supposedly DE can provide an advantage to the individual, organization or country that starts utilizing it continuously and permanently. But what will happen if everybody starts using it? Wouldn't chaos result?

A: More and more our lives resemble a highway with growing numbers and speeds of automobiles. Everybody has his/her own destination, which is pursued in the most convenient ways. However, everyone must comply with the traffic laws, road particularities, and other people and their objectives – otherwise he/she will never arrive at the intended destination. Of course, there are certain individuals that violate these rules, but this is why we have police institutions to enforce them. Unfortunately, the analogy is not quite complete. Today, we are "driving" along life's highway mostly in the dark. Only those with an enormously strong vision can recognize something on the road ahead – these individuals are able to move with more success than everyone else. DE is like a set of powerful headlights that help illuminate the way for anyone who uses it.

So far, nobody is forced to enter the highway or to buy headlights or night vision devices. If you do not wish to move you can stay where you are. However, it is unclear which is safer – staying on the shoulder of the highway or moving along with the flow.

In some fashion, DE can be compared to literacy and other premises of intelligent life:

- For a long time, literacy was a privilege available only to limited numbers of people, for whom it provided important advantages. Only in the last century did the majority of people in developed countries become literate, allowing everyone (even society as a whole) to partake of these benefits.
- Dale Carnegie's earliest followers, who learned the best practices of successful communication, obtained obvious advantages. Today, Carnegie's recommendations have become quite common and are even taught to children. Again, this is to everyone's benefit, and even to society as a whole.
- For the last 10-15 years, computer literacy has become an important part of human culture. It allows for huge benefits, and obviously will become common in the 21st century.
- DE, the technology of managing the future, is very young. There are probably fewer people today who can actually conduct it than there were literate people 5000 years ago. We believe, however, that by the middle of this century DE will become a standard part of education.

Q4: When is the best time for DE?

A: Below are the typical phrases we have heard from past customers:

- You know, several years ago we had serious problems, and at that time DE probably could have helped. But now, everything looks OK.
- We are experiencing extremely difficult problems now, are battling for survival actually, so we must cut off all consultants. Perhaps later, when things are better . . .
- Right now we are restructuring, and nobody knows what the new structure will look like. So, we must wait . . .
- What a pity that you are presenting these ideas now, when we are not in a position to change much. It would have been so much better if this had happened a year ago when everything was changing and we could have done something . . .

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

DE's reliability

Q5: How can we be sure that DE will allow us to consider all evolutionary possibilities, so we can secure the best set of scenarios? Might we miss something?

A: One assumption of DE is the following:

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 discovery.

Derivative #1: It is theoretically possible to exhaust (or nearly exhaust) all possible ways of performing a given function.

The utilization of a complete set of available patterns/lines of evolution (over 400) allows one to practically exhaust all possible variants. Of course, the possibility of gaps exist because we cannot guarantee that we have revealed all possible patterns/lines. There is almost always a certain amount of overlap, which results in similar directions/ideas from different lines . . .

Q6: Suppose we conduct a full-scale DE, develop a complete strategy for implementation, and then suddenly tomorrow someone invents something absolutely new that makes all our work obsolete. How can we justify the expense?

A: It is a well-known fact that implementing of a new mass technology based on an important discovery takes about 20 years – whether the discovery is a locomotive or a laser. This timeframe depends on the emergence of a new generation of professionals rather than on the specifics of the technology. Usually after an important discovery is made, new ideas for its practical implementation appear quickly (within 5-10 years). Former college students start implementing these ideas after they graduate and become influential (in another 10-15 years).

DE details

Q7: Why should we waste time working with the existing system if we are targeting the invention of the next- generation system?

A: Often, people focus on the next generation because they don't see how the existing system can be improved. It is quite possible, however, that the utilization of TRIZ/DE tools and processes will allow for improvements that can, in some circumstances, be more beneficial.

- Learning about an 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's evolution are usually obtained in the very beginning. However, those ideas/discoveries that do not find immediate use (sometimes because they fail to comply with the current level of technology) are often forgotten. In many cases, their later "revival" leads to the next evolutionary step. Actually, returning to the system's "roots" allows one to draw a line into the future through two points (today and the past).

Q8: Is it possible that the patterns/lines will point in the wrong direction?

A: Different lines usually reflect different evolutionary trends that can contradict one another and offer contradictory directions. During the idea integration stage, these ideas can be combined into a powerful new concept.

Appendix 2. 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).

Appendix 3. 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.)

Appendix 4. Problem Formulation

Problem formulation consists of two procedures:

- Building the diagram
- Formulating problem statements

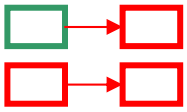
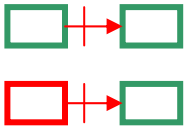
Building the diagram

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

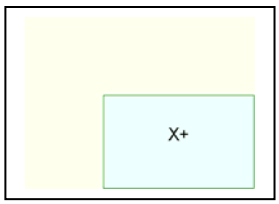
Function – a function, an action, a parameter, or any factor (statement) related to your situation that can be considered useful or harmful.

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	

Procedure for building the diagram

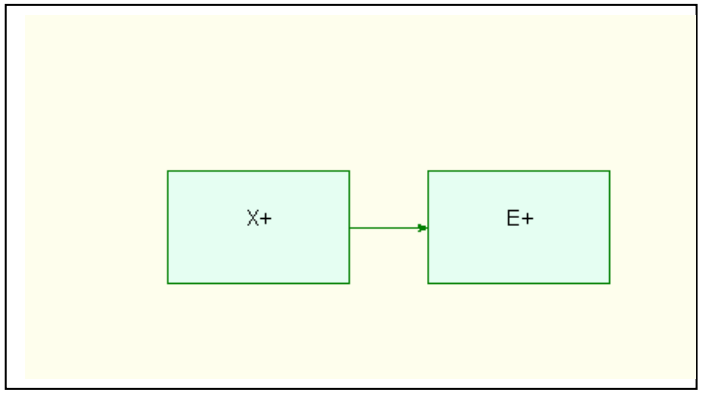
- Create a box and enter a function[42] name.
- Define for yourself if the introduced function is useful or harmful.
- If the function is useful, name it X+ mark the box with the green color (see below).



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+?

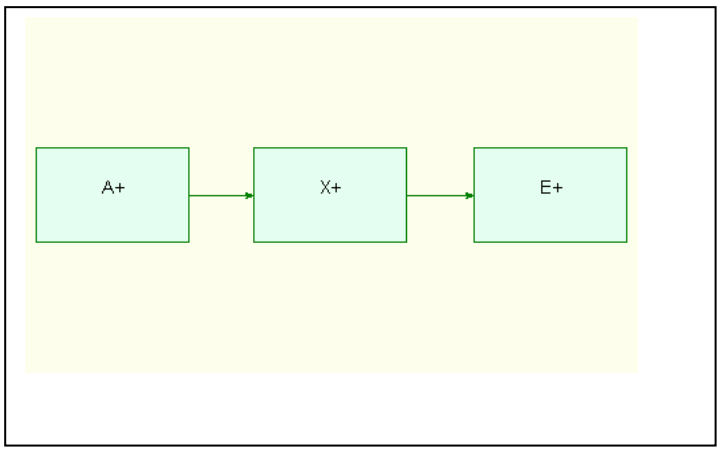
If yes, introduce a new box with the function E+, color it in green and connect with the green arrow as shown below:



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+.

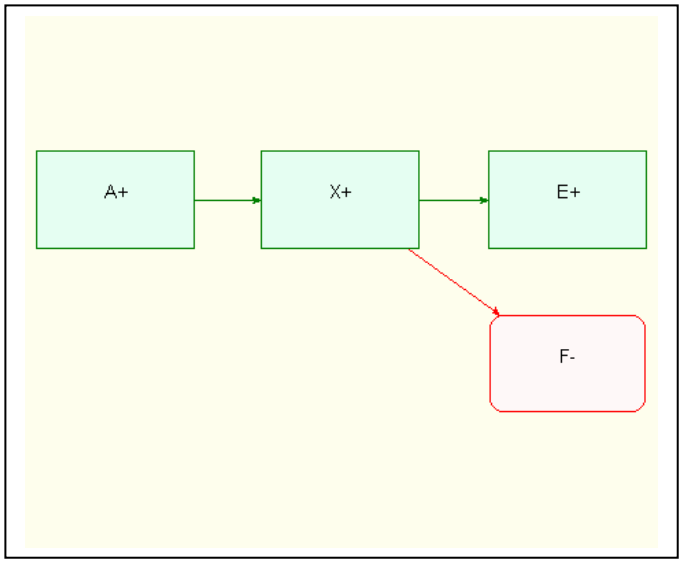
If yes, introduce a new box with the function A+, color it in green and connect with the green arrow as shown below:

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



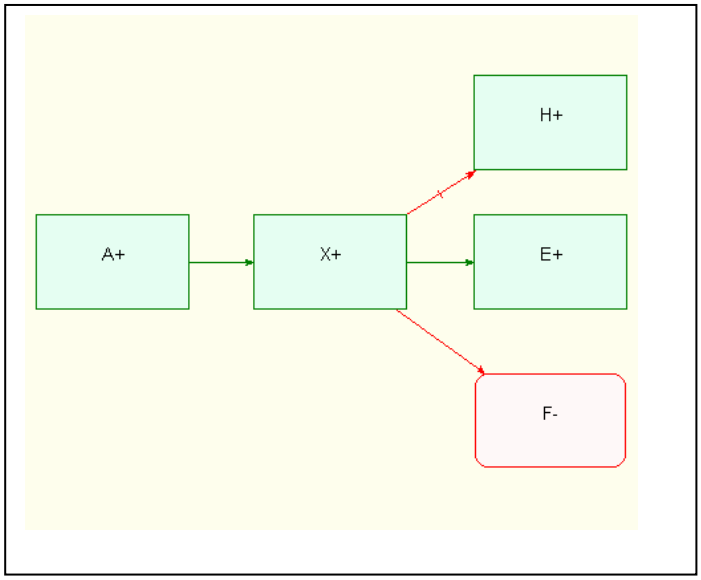
Q3: Does this function X+ produce a harmful function F-?

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



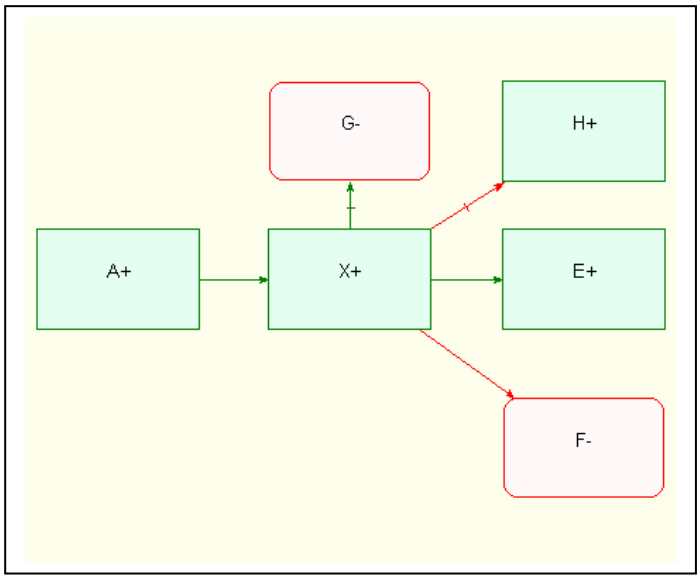
Q4: Does this function X+ counteract another useful function H+?

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



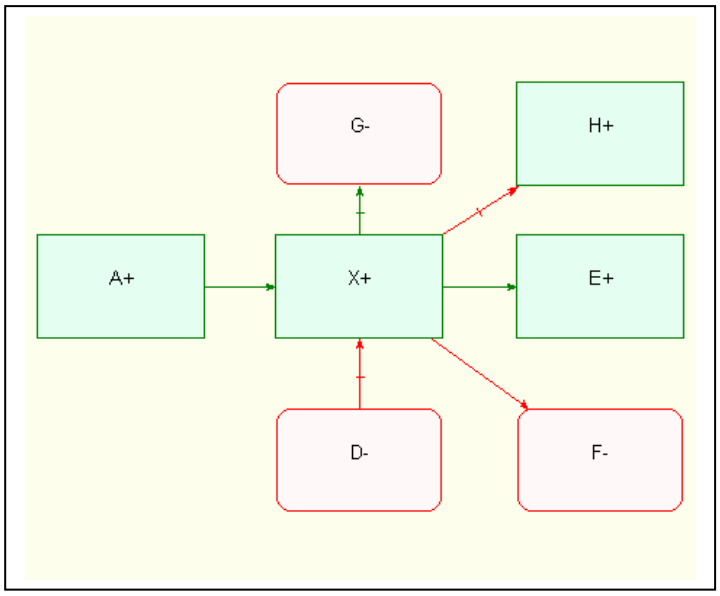
Q5: Does this function X+ counteract another harmful function G-?

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

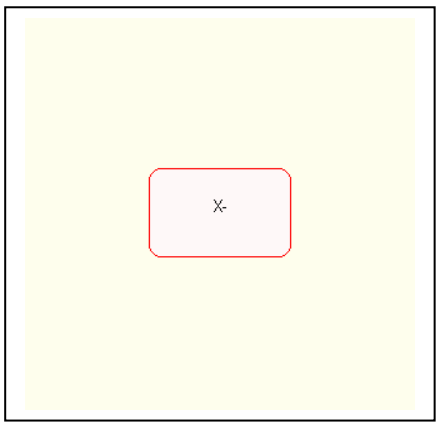


Q6: Is this function X+ influenced by another harmful function D-?

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



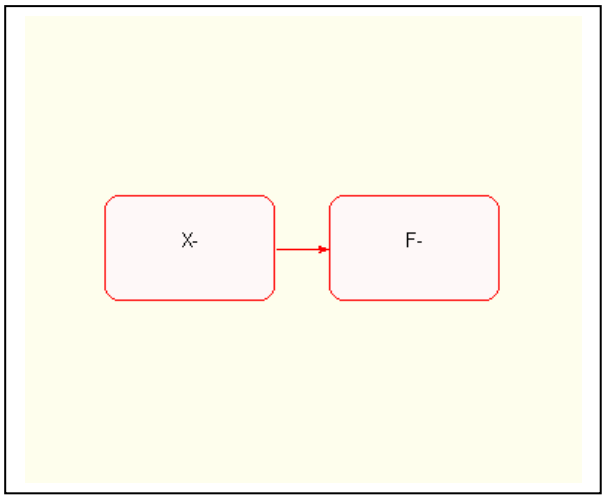
If the first function is harmful, name it X- and mark the box with the red color.



Answer the following questions:

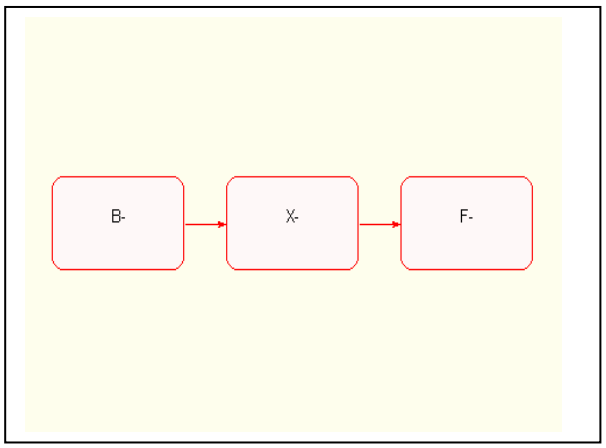
Q1: Does this function X- produce another harmful function F-?

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

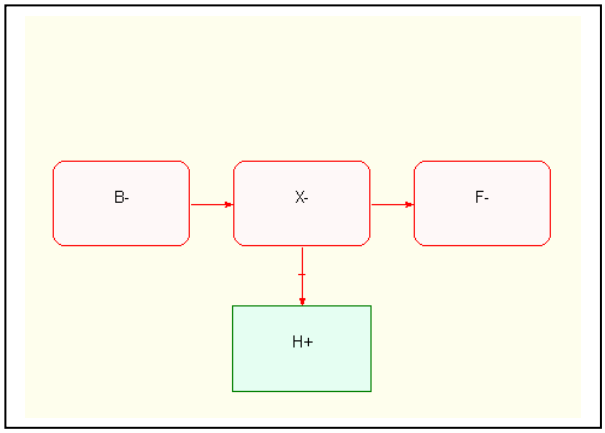


Q2: Is the selected function X- produced by another harmful function B-?

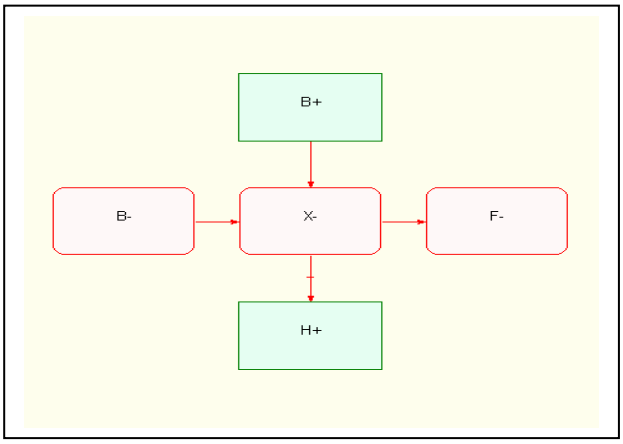
If yes, introduce a new box with the function B-, color it in red and connect with the red arrow as shown below:



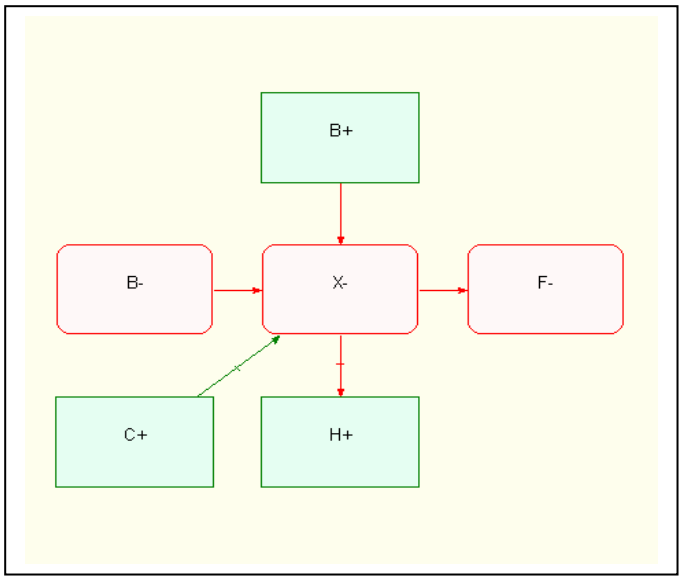
Q3: Does the selected function X- counteracts useful function H+?
If yes, introduce a new box with the function H+, color it in green and connect with the red arrow as shown below:



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:

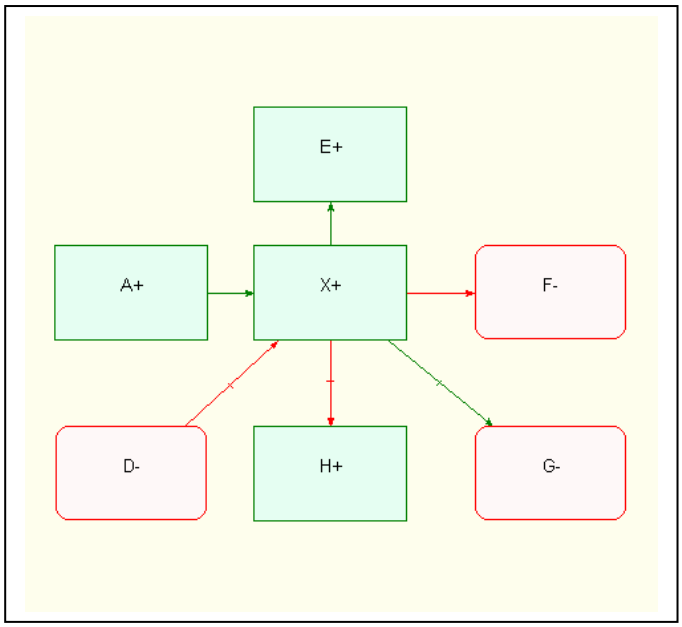


Q5: Is the selected function X- counteracted by a useful function C+?
If yes, introduce a new box with the function C+, color it in green and connect with the green arrow as shown below:



Formulation

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



Basic statements

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

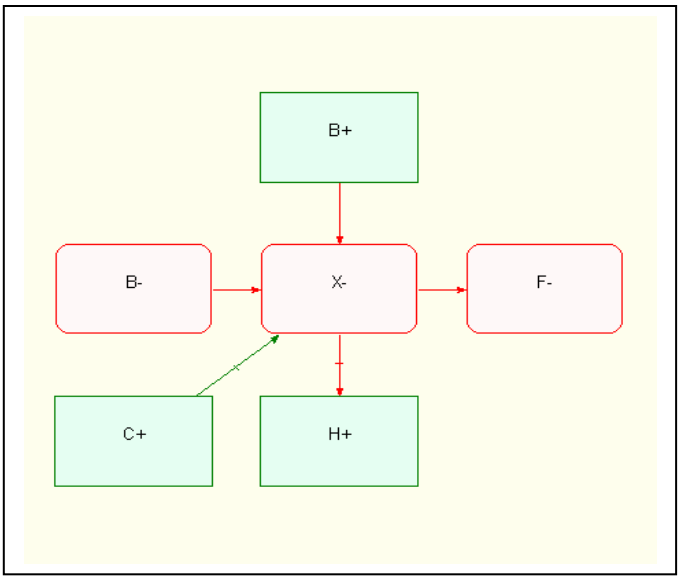
Try to resolve the following contradiction:
- The useful factor [the] (X+) should be in place in order to produce all useful results including
  - providing useful functions (list)
  - eliminating harmful functions (list if any)
- should not exist in order to avoid all harmful results including
  - producing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

Appendix 5. 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

Appendix 6. 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.

Appendix 7. 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.

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

Step 2. Describe the Ideal Solution

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

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.

Appendix 8. 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

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.

[45] Modified for manual application

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.

Appendix 9. S-Curve for Organizations

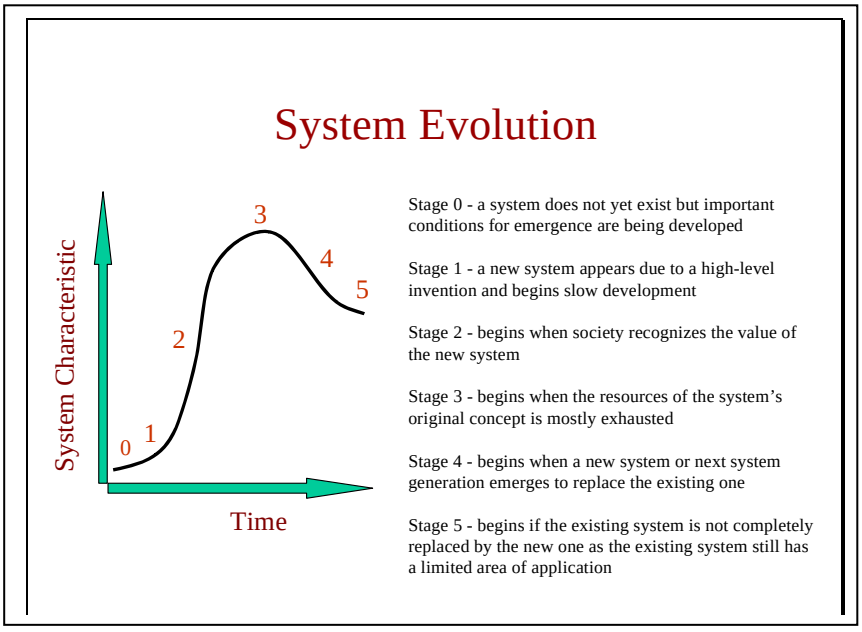
Definitions

The term “organization” refers to any of the following:

- Enterprises
- Government agencies
- Professional associations
- Social institutions
- Educational institutions
- Families
- Countries
- Any other groups established for a specific purpose

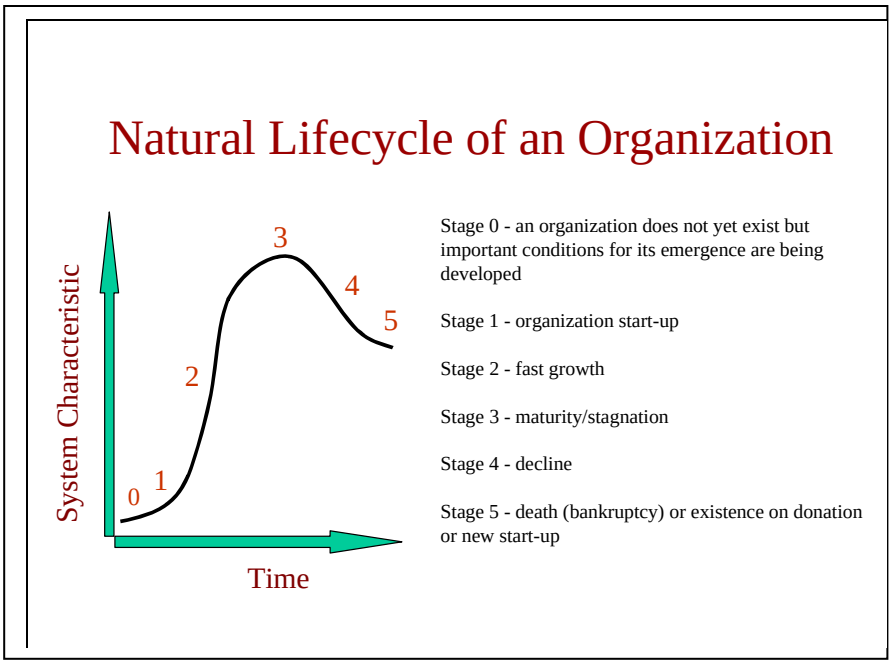
System evolution

The main evolutionary stages of a system are shown below.



Natural lifecycle of an organization

The “natural” (i.e., without interference) lifecycle of an organization is shown below.



General postulates of an organization’s evolution

- Organizations move through the same stages of evolution as other systems
- Usually, the evolutionary stages of an organization are highly dependent on the stage in which its core business lies
- Organizational goals, structure, management system, leadership, behavior, rewards, morale, and overall culture are highly dependent on the current evolutionary stage

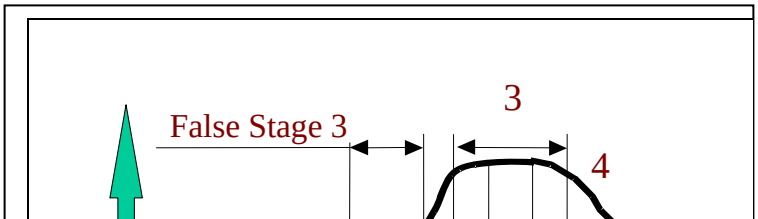
Induced deviations from the natural lifecycle

Premature aging (false third stage)

It was found that, occasionally, a system (organization) resides on the maturity stage, although its evolutionary resources have not yet been exhausted (see the figure below) for the following reasons:

- A serious roadblock has not been overcome
- There is a lack of competitive pressure and thus no need for improvement
- Premature aging has occurred as a result of the wrong management system and a culture which initiates stagnation before the resources of the core technology are exhausted, or other organizational decisions typical for the third stage.

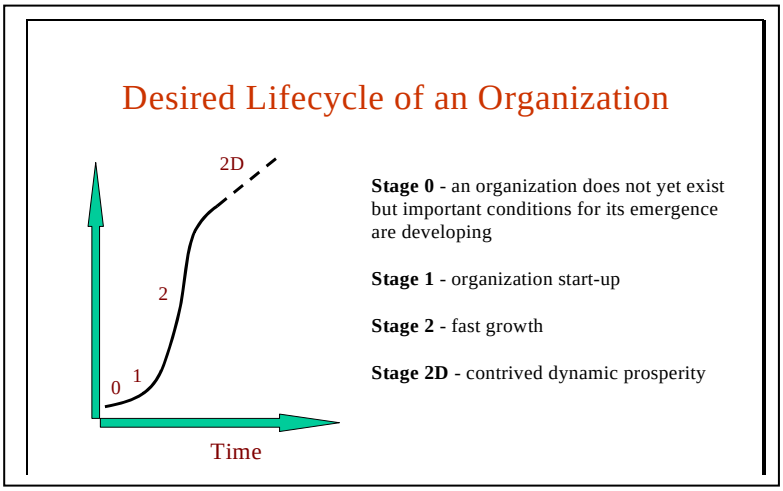
Usually, by lifting one or all of the above limitations, continued growth can occur.



Contrived Dynamic Prosperity

Contrived Dynamic Prosperity is the result of cultural transformation that prevents natural aging and assures achievement of the *desired lifecycle of an organization*.

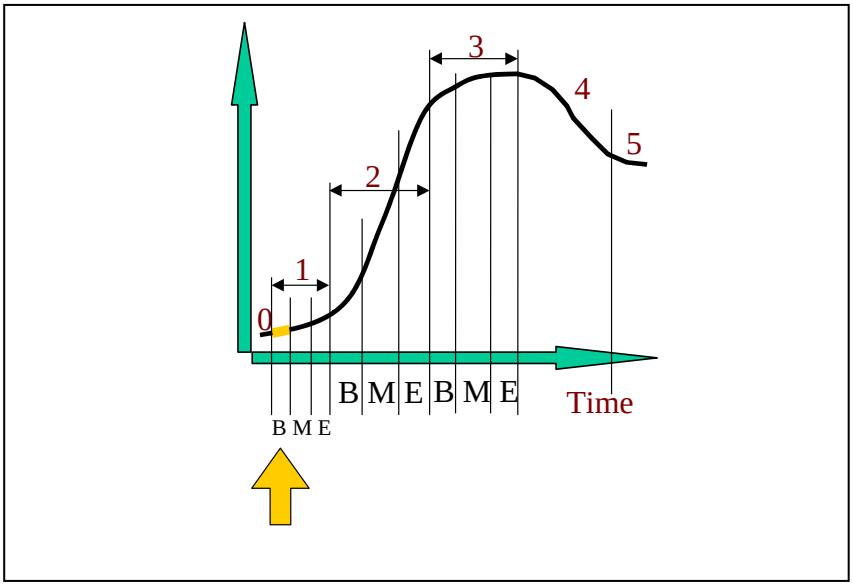
The desired lifecycle of an organization should avoid moving to stages 3-5. Instead, the growth should continue (although the pace might be slower).



Attributes of evolutionary stages
Each stage of evolution is characterized by its own:

- Descriptions
- Objectives
- Mistakes

General view:



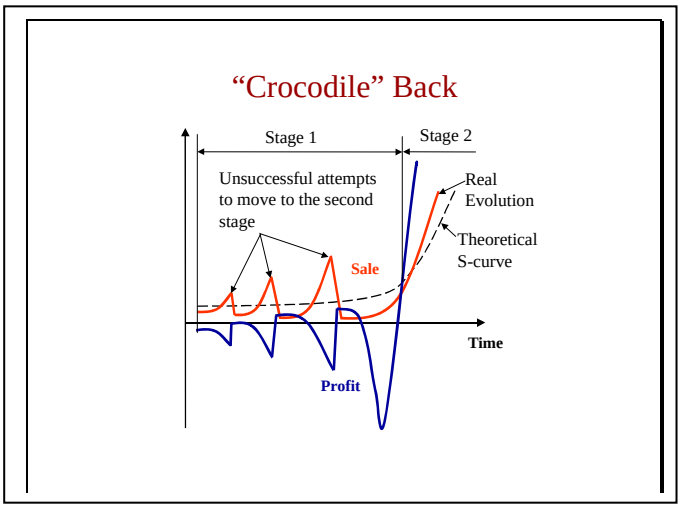
Stage 1

A new business is being created by one or more people and is based on a discovery or significant invention. A small group of enthusiasts gather around this new business. The people who come from outside the business bring with them different habits, customs, and experiences, but at the same time the new culture of the organization is being created. Usually the founder(s) play a large role in the establishment of the organization. The main direction of this culture is to achieve success in the chosen business.

The factors stimulating the evolution of the business and organization at this stage are very personal – a great idea, ambitions, career, wealth, etc. – yet different long-term interests among the participants do not hinder their collective efforts, since the general goal is to establish a successful business. In the best case, the new system does not incite the interests of current business and market leaders and develops in spite of normal resistance to innovation. If the innovation is radical and will eventually replace an existing business or organization, it experiences great resistance from the owners of the old system.

The main contradiction of the first stage is that the new business is required for society, but society is unaware of it and does not support its enthusiasts. The leader of the organization, during this stage, is usually the author of the invention or main creator of the idea. The leader's main characteristic is great conviction for the prospects of the new business. His/her conviction and enthusiasm excites other people. The management system during the first stage is purely ideological, based on satisfaction of the highest needs (thirst for creation, investigation, justice, etc.) and profits, which are expected as a result of the success of the business. The first-stage organization has many attractive features. As a rule, it does not have a formal structure but instead is extraordinarily democratic. There is no subordination, no control structure, and the authority of the organization's members does not depend on rank, position, age or past reputation, but instead is defined only by each individual's contribution to the business.

When the organization is ready, it moves to the next stage. However, this transition might not be a smooth one (see the figure below).



The "crocodile back" is one of the main problems experienced by start-up businesses. In real life, the transition from Stage 1 to Stage 2 is usually not a smooth one. Rather, it is a series of multiple unsuccessful attempts eventually followed by a successful one (see figure). The reasons for these unsuccessful attempts are usually the following:

- The system launched is not ready for commercial use and sale
- The market is not ready to accept the new system

Stage 2

Sooner or later, conditions for widespread recognition of the business appear. The business becomes ready for development, the required resources for growth appear, and general resistance to innovation is reduced. Organization and society are now interested in the development of the business. Positive feedback appears, and a higher level of business develops as a result of increased public demand. However, many new complicated problems related to technology and applications hinder the evolution. The imperfections in problem-solving methods are compensated for by the involvement of more people and money in the development of the business and by extensive increases in development.

Other negative factors at this stage are connected with difficulties in the training of personnel and the mobilization of resources. However, these problems are easily overcome due to the vast amounts of resources available during this stage of development. Recognition by society, the addition of new people, and the transition of the company to a "professional" one significantly change the organization's culture (sometimes painfully). The first-stage elements still exist, however, new elements characteristic of the second stage appear.

The officially recognized organization now has a specific structure, internal relationships, and value system. Gradually the size of the organization is increased through the addition of new people, departments, etc. A staff is established to manage the business, new support services appear, and specialization of staff and services is in progress. All of this sharply increases the effectiveness of the business and promotes its recognition.

The main contradiction of the second stage is that most of the means required for the organization's development improve the business, but these means also create the basis for spoiling the organization during the third stage. In addition to the initial objective of business development, the organization obtains a new objective of self-development and self-preservation. At this stage, the new objective does not replace the main objective but supports it.

As a rule there is a change in leadership. The new leaders are people who entered the organization at the end of the first stage. They are creative people with a taste for organizational work, an understanding of society's interests and of the marketplace, and who have the ability to communicate with business and market leaders. With the expansion of the business the number of issues that must be resolved by the leader also increases. The leader loses the opportunity to work as an inventor or scientist, and instead becomes, step-by-step, the chief of the organization. He/she becomes less available to other employees, and the system hierarchy replaces informal contacts in the organization. In principle, this is the time to make the transition to professional management.

On the surface it looks like the business is booming: the organization is growing, products are being manufactured and sold, advertising and news appear, improvements are being made – but all of this requires more investment. At the same time, the increased investment produces less result and development of the business decreases. The main idea of the business begins to satisfy society less, but the business continues to support the main idea at any cost.

Stage 3

The main contradiction of the third stage is that the interests of society and of the business diverge. Contrary to the first stage, the goals of society are now more progressive than the goals of the business. The business requires continuous development, even at the cost of complete reorganization or bankruptcy. The goals of the business are now reactionary – it tries to stall the dangerous process of reorganization.

An inversion of goals occurs: the main goal of the business is *not* to develop the business in general, because this is not possible. This effort is replaced by the struggle for stability, self-survival, and self-reproduction. At this point business development slows or even stops completely, and can be substituted by the simulation of productive work or pseudo-development.

A new culture forms, now completely free of any first-stage elements (some of the first-stage people left the business or were ousted, others changed). Most of the second-stage culture elements, which are not suited for the new stage, are revised. Instead of the business growing, the staff itself begins to grow, mostly in auxiliary departments, who are working for their self-survival rather than for the business.

During the entire third stage, a "Cold War" between society and the staff is waged. The staff tries to sell products which have less value but are convenient to manufacture, or they launch huge "projects of the century" with the main goal being to secure as much investment as possible from society.

The internal structure of the staff becomes very complicated. Interaction between departments deteriorates and new bureaucratic obstacles appear and grow. Communication takes place only through official documents, and the culture demands the generation of many worthless and time-consuming documents. Initially, documents were required to improve order in the business, but now the increase causes disorder.

As the level of professionalism becomes less important, the hiring of less qualified workers becomes the norm. New ideas and solutions at this stage are only possible in secondary areas, and have a very limited level of innovation. Work becomes completely non-creative. The only types of creativity possible for the third stage are intrigues aimed at personal growth in the hierarchy, acquiring more privileges, etc.

The divergence of personal interests and the interests of society leads to a sharp decline in morale, and cynicism and demagogy blossom. Violators of the order are publicly punished but are morally accepted by the staff, and often admired. The absence of a common business objective and increasing competition for desirable positions in the business destroy communication and create internal tension.

The professional language begins to change. Its primary function becomes preventing others from being "inside" the system, making control from outside more difficult, and hiding the fact that "the emperor has no clothes." New, typically "schizophrenic" language forms are introduced: long speeches, moralizing, a tendency to explain the obvious, to substitute simple concepts with long, complicated "scientific" definitions.

Deterioration of the business can continue for an extended time, although not infinitely. Despite all efforts to the contrary, the evolution cannot be stopped. With the advent of new progressive ideas capable of performing the business more efficiently, another business becomes more powerful. Sooner or later the inevitable happens – the initial system is replaced by a new system with its own s-curve.

Contrived Dynamic Prosperity

Contrived Dynamic Prosperity is possible when two forces are present: one designed to save the "status quo" and the other designed to change it. These two forces are linked in a feedback loop – that is, a change in one force leads to change in the other. In addition to the existing hierarchy, another inverted hierarchy is required to control, cooperate with, and oppose the first one. Cooperation is required to reach the common goal of the well-being of the staff, and competition is required since there are different approaches toward reaching the new goals.

An analysis of the most successful companies has shown that within these businesses, smaller groups exist at different stages of their own evolution, resulting in a state of dynamic equilibrium. The main management mechanism remains economical, but elements of direct management play an increasingly larger role. Sometimes, strong measures are used to prevent the business from progressing to the third stage.

Therefore, besides the three "natural" stages, businesses can exist in a special, artificially created and artificially supported state of Contrived Dynamic Prosperity. This stage is in many ways similar to the second stage, but what was temporary during the second stage becomes a normal, continual condition during Contrived Dynamic Prosperity. There are some differences, however.

As in the second stage, the main motivation is the combination of personal interests and the demands of society as they relate to the development of the business. The near-complete development of the business, as well as the decrease in demand, becomes a main problem during Contrived Dynamic Prosperity. Lower prices, a higher-quality product, advertising, and constant change of the business are usually the most common ways to overcome this problem.

The main goal of the business during Contrived Dynamic Prosperity is to make everybody happy – to create beneficial conditions for each member of the staff, not by demanding more resources from society, but by creating new resources and opportunities. As a result of there being a common goal, there are no major internal conflicts within the staff; relationships between staff members are similar to those in Stage 1. This is one of the most important elements of the business culture, and is intentionally supported by the business leaders. Actions against the staff; laziness, carelessness, greed, etc. are not appreciated by other staff members.

The rules, laws, and customs that regulate the relationships within the group are simple and accessible to all members. These are mostly expressed through the company's folklore and not by formal instructions or orders.

The business leader usually understands and accepts the business culture and does not attempt to replace it with a different culture. In general, Contrived Dynamic Prosperity businesses select their members very carefully, educating them in the company culture and traditions. Since there are few Contrived Dynamic Prosperity businesses, working for one is very prestigious. The respect garnered by each member in the business is determined by his/her contribution to the business, as well as by personal qualities.

General mistakes

Authoritative Approach (political, technical, military, etc.)

- Belief in the possibility of directing and forcing the development of the business by command.

Undirected Development

- Lack of planning and control of development, goal-oriented research and design
- Hope for occasional success or for stability of the situation in the future

"Getting Stuck"

- Implementing minor improvements instead of making significant changes required by the patterns of development evolution.

"Running Ahead"

- Untimely implementation of new elements or solutions when neither is required and change is not matched with other subsystems

Incomplete utilization of creativity and intellect

- Attempts to solve problems requiring creativity by means of quantity, extra financing, redundant complication of a system, etc.

Incomplete utilization of available resources

- Any development or improvement of a system can be done by utilizing one or more types of resources
- In order to utilize resources, it is necessary to know exactly what is needed, where the resources can be obtained, and how they can be utilized.

Lack of understanding of the essence and role of contradictions

- Attempts to intensify one feature of the system while ignoring the deterioration of others
- Improving different parts of the system separately, without considering the effects on the overall system

Lack of understanding of the systematic nature of development; interconnections and inter-dependence of development

- Impossibility of a break-through in one business without development of the supporting areas

Appendix 10. Features of an Enterprise at each Evolutionary Stage

Enterprise Feature	Stage 1: Start-Up	Stage 2: Growth	Stage 3: Maturity / Stagnation	Stage 4: Contrived Dynamic Prosperity
Goals of the organization	Develop the business; create a market.	Develop the business; increase and develop the market and the organization itself.	Survive as an organization. For bureaucratic or monopolistic organizations: continue to develop the organization.	Continue to develop the business; increase and develop the market.
Public relations	Business holds no interest to investors. Customers are unaware of the product/service provided by the organization.	Investors are interested in the business. Customers are interested in the product/service provided by the organization	The public is interested in the business but the organization ignores customer requirements. For bureaucratic or monopolistic organizations: neglect public demands; attempt to force customers to use their products.	Investors are interested in the business. Customers are interested in the product/service provided by the organization.
Factors stimulating business development	Personal motivations of those involved in the business.	Personal motivations of organization personnel; public demand.	Public demand.	Personal motivations of organization personnel; public demand.
Factors impeding business development	Lack of resources; no market in place.	Unable to quickly utilize resources; much time spent searching for new ideas using Trial-and-Error.	Resources of the business are exhausted. The organization is interested in stability rather than change.	The inherent resources in the product/service under development and/or market demand are exhausted.
Main contradiction	Product/service is potentially very useful, but the public fails to recognize this.	Structuring the organization helps to develop the business but moves the organization toward Stage 3.	The public wants a better product for a better price, but the organization is not interested.	The organization must be dynamic to provide long-term prosperity, but this requires great effort and expense.
Organization size	Fewer than fifty people.	50 - 1000 employees and growing.	Practically unlimited.	Practically unlimited.

Enterprise Feature	Stage 1: Start-Up	Stage 2: Growth	Stage 3: Maturity / Stagnation	Stage 4: Contrived Dynamic Prosperity
Management system	***Charismatic***, based on personal enthusiasm.	***Economic*** with some ***charismatic*** and ***administrative*** elements.	***Administrative*** with some ***economic*** elements.	***Economic*** with some ***charismatic*** and ***administrative*** elements.
Organization structure	Informal; concentrated around the leader, or having several centers each with its own leader.	Simple formal, with hierarchical and horizontal links.	Complex, multi-hierarchic. For bureaucratic or monopolistic organizations: with dominance of auxiliary departments.	Complementary simple formal and informal elements; directed toward organizational prosperity. Includes independent departments, horizontal and hierarchical links.
Organization leader	Informal leader, usually the author/inventor of the product or service; creative, highly respected by organization personnel.	Formal leader with professional background, good communication skills, respected by organization personnel.	Formal leader with MBA or financial background. For bureaucratic or monopolistic organizations: a bureaucrat.	Formal leader with professional background, good communication skills, respected by organization personnel.
Organization personnel	Creative and enterprising people looking for a unique opportunity.	People from Stage 1, along with rofess-sionals and auxiliary personnel.	People from Stage 2, along with numerous managers.	People carefully selected, educated and trained to work for the organization.
Main requirements of personnel	Personal reliability, enthusiasm, persistence.	Educated professional; having controlled initiative.	Easily-managed, conforming, lack of initiative.	Professionals who reflect the corporate "culture."
Area of professional knowledge	Not very important; in the process of being established.	Directed, dynamic, in-depth	Narrow and non-dynamic.	Wide in scope, dynamic; in-depth as needed.
Attitude toward personnel initiative	Encouraged in all aspects throughout the business.	Encouraged only within the scope of the assignment	Punished.	Any initiative not harmful for the business is welcome.
Attitude toward mistakes by personnel	Usually not critical; easily corrected; no punishment.	No punishment for mistakes resulting from good intentions. Inaction is not appreciated.	Punished.	No punishment for mistakes resulting from good intentions. Inaction is not appreciated.

Enterprise Feature	Stage 1: Start-Up	Stage 2: Growth	Stage 3: Maturity / Stagnation	Stage 4: Contrived Dynamic Prosperity
Rules and behavior	In the process of being established; informal, based on precedents.	In the process of formalization yet easy to understand and accept; directed toward business and the prosperity of the organization.	Formal and complex, difficult for most personnel to understand. For bureaucratic or monopolistic organizations: used by top "elite" to force people to obey.	Combination of informal and formal, directed toward the prosperity of the organization.
Rewards	Practically no financial reward, only personal satisfaction in knowing that something of value is being developed.	Continued personal satisfaction plus adequate salary or other material reward according to accomplishments.	Salary according to time spent and resources consumed. Additional, non-standard criteria, rather than accomplishments, are usually considered.	Personal satisfaction plus adequate salary or other material reward according to accomplishments
Prestige	According to creative accomplishments in business and in the organization.	According to accomplishments	According to position.	According to accomplishments and to the prosperity of the organization as a whole.
Morale and environment	Good. Benevolent relationships and creative competition.	Normal. Good cooperation and honest competition.	Poor. Conflicts; intrigues.	Good. Fruitful cooperation and honest competition.
Attitude toward organization personnel	Informal communication, friendship, cooperation.	Informal communication. Establishment of seniority system once organization hierarchy is built.	Informal on the same level of hierarchy; formal between levels.	Informal communication together with a system of seniority.

Enterprise Feature	Stage 1: Start-Up	Stage 2: Growth	Stage 3: Maturity / Stagnation	Stage 4: Contrived Dynamic Prosperity
Attitude toward external business environment	Attempting to attract people to the business and to join the organization.	Selection of those best suited for the organization.	Protection from potential competitors and external influences.	Selection of those best suited; cooperation with those who want to contribute.
Discipline	Voluntary; people are dedicated to the business; no enforcement needed.	Combination of dedication and some enforcement.	Mandatory methods employed toward achieving stability.	Combination of dedication and some enforcement.
Reaction to difficulties, stresses	Consolidation and displacement or removal of unsuitable personnel.	Consolidation and active defense; activation of creative approach (as in Stage 1).	Increasing conflicts, destruction, loss of stability.	Consolidation and active defense, activation of creative approach (as in Stage 1).
Flow of information	Free, informal, effective.	Well-organized, effective within the organization, limited with respect to external organizations and competitors.	Information does not flow, is often secret, sometimes misleading.	Well-organized, effective within the organization, limited with respect to external organizations and competitors.
Language	Simple, without special terminology, able to attract people (popular).	Popular plus specific.	Specific. For bureaucratic organizations: completely unintelligible (almost hypocritical) in order to be distracting.	Popular plus specific.
Area where creativity is required	To develop the product/service and the entire business.	To develop the product/service, manufacturing process, other applications.	Small improvements.	Improvement, looking for new applications, diversification.

Enterprise Feature	Stage 1: Start-Up	Stage 2: Growth	Stage 3: Maturity / Stagnation	Stage 4: Contrived Dynamic Prosperity
Ideas, innovations	Many new important ideas; ideas are easy to implement.	Few important ideas; many mediocre ideas; development of important Stage 1 ideas. Implement-ing these ideas is more difficult, but there are more resources to achieve this.	No important ideas, few mediocre ones, many small ideas.	Many mediocre ideas, develop-ment of important ideas from Stage 1. Active search for a new perspective and high-level ideas.

Appendix 11. S-Curve Analysis

Stage (or sub-stage) and description	Business development objectives	Typical mistakes ("traps")
Stage 0 A system does not yet exist but important conditions for its emergence are developing	• Search for the functions required to create a pioneering system • Search for the theoretical possibility of performing the required functions in principle • Search for an entirely new application of the existing system • Collect the necessary informational base • Choose the main trend of research, the main idea, etc. from a set of alternatives	• Day-dreaming; choosing goals based on something other than real needs • Utopist; choosing theoretically unachievable goals – absence of any idea regarding the direction the work should go • Lack of information; choosing the goal without possessing certain knowledge – this leads to wasted time spent rediscovering what has already been discovered; it can also discredit the goal from the very beginning.
Stage 1: Start-Up **A new system appears due to a high-level invention, and slowly begins to develop**	• Develop the technology that can satisfy certain needs of the customer • Find or establish an initial market for the new technology • Attract the financial resources necessary to begin production or services • Establish limited but steady business for the new technology	
Sub-stage 1b: Beginning Begins when the pre-conditions of Stage 0 have been fulfilled. Some specific need is understood, and the possibility of starting the business is proven.	• Creation of a test sample, parts of a new theory to explain something, one of several pieces of art belonging to a new area, etc.	• Single-variant existence of the business; limitation due to the tastes, character traits, interests, mindset, education, etc. of the author of the idea, i.e., the leader of the Stage 1 organization. • Limitation of system abilities due to only one type of application, which is not the most prospective one. • Creation of a new system without collecting enough information; inventing what has already been invented. • Attempts to 'leave time behind' – making the final full-scale product for immediate implementation and recognition without the necessary intermediate steps in development.

Stage (or sub-stage) and description	Business development objectives	Typical mistakes ("traps")
Sub-stage 1m: Middle Begins after the possibility of the business, in principle, has been proven, but the system is not ready for wide implementation. • The useful functions are small, while the expense factors are very high. • The system is rather simple, main engineering solutions are immature; a high level of belief in and imitation of the old systems still exist. • No public recognition has been achieved. The system is regarded as a frivolous toy for eccentric people. • There is a resistance created by experts whose business is impacted by the fact that the new system exists.	• Search for the main design solution that provides sufficient operation of the system. • Search for ways to decrease expense factors related to performing the main functions. • Search for ways to improve the system's useful functions. • Search for ways to increase the number of useful functions. • Reveal new areas in which the recently created system can be applied.	• The system utilizes some subsystems, which perform their functions in the most favorable way but are not designated for operation with the system. • The system utilizes subsystems (materials, structures, technologies, etc.) that are usable and useful at that point in time, but for which there are not enough resources for development. • 'Deficiency of innovation' – lack of courage in using new approaches when creating a new system; this decreases the efficiency of the system. • 'Excess of innovation' – bringing together too many new ideas in the same system, compromising system workability and adjustment, and making it difficult to develop the system's final conditions; this also creates exploitation problems; at the same time, these systems can be useful as a 'bank' of new ideas and as prototypes for the design of long-term products.
Sub-stage 1e: End In general, the business is ready for wide implementation • The principle parts of design, theory, etc. are worked out, but there is no demand for the system and insufficient material invested for advertising, fabrication of the next level of production, building factories for long-term manufacturing, etc. • All tasks are oriented toward accelerating the transition to Stage 2, i.e., for widespread implementation. • This sub-stage smoothly transforms into Stage 2 development when everything is ready for wide implementation and when positive feedback for the development of the business emerges.	• Select the best variants of the system for wide implementation, determining and configuring the necessary level of quality. • Search for auxiliary design solutions that will best satisfy customer needs (convenience, comfort, etc.)and the possibility of introducing the solutions to the environment. • Create the main parts of the full-scale production technology for reasonably replicating the system.	• Attempts to implement the system without providing the proper conditions, such as complementary systems and other systems in conjunction with it. • Attempts to implement unrefined systems with high level of expense factors: low reliability, high cost, complicated maintenance, etc. • Attempts to imitate 'mature' (i.e., Stage 2 and 3) systems; premature complication of the system before it is refined to its simplest variant.

Stage (or sub-stage) and description	Business development objectives	Typical mistakes ("traps")
Stage 2: Rapid Growth Begins when society recognizes the value of the new system.	• Establish a successful business around the core technology. • Establish an effective management/administration system • Enhance the technology to increase its value, based on customer feedback. • Attract sufficient financial resources for rapid growth. • Establish the cultural elements which will ensure continuous Contrived Dynamic Prosperity.	
Sub-stage 2b: Beginning Begins with the existence of all prerequisites for wide implementation of the business. • The business has a high degree of ideality (the ratio between useful functions and expense factors). • Stage 1 organization of the business exists, and experts are able to become the main body of Stage 2 organization. • A concrete, wide or potentially wide demand exists, which can be satisfied by the business. • The super-system is ready to 'adopt' the new business, to allow it to have a certain niche.	• Create the technology for wide-scale development of the business. • Trial exploitation of industrial samples in order to debug the system. • Reduce the expense factors (high cost, material and labor consumption, harmful wastes, danger, etc.) for long production runs. • Actively perform work on the next-generation design by a small group of people and with limited effort.	• Keeping the design and technology solution of Stage 1 during transition to Stage 2 (e.g., solutions related to individual production and exploitation, use of manual labor, on-the-spot adjustments, etc.) • Narrowing the working area, eliminating aspects of the business that cannot be implemented and yield profit in a short period of time.

Stage (or sub-stage) and description	Business development objectives	Typical mistakes ("traps")
Sub-stage 2m: Middle Business development is good, the business receives positive feedback, there are a lot of resources, all involved are happy and convinced that this situation will last forever.	• Active expansion of the business into unoccupied fields or fields previously occupied by obsolete businesses; rapid creation of modifications to the system. • Adaptation of the business, the system acclimates itself to the environment – destructive features require prevention or protection, ousting of competitive systems and stimulation by other systems. • Optimization, 'forcing' of the design and technologies toward the best possible conditions. • Continued work on the next generation.	• Over-intensification of some specific direction of the business that disturbs its rhythmic development. • Monopolization of specific fields of the business by some groups of experts and therefore elimination of competition which lowers the final results.
Sub-stage 2e: End Business development is good enough, there are some difficulties, obstacles, and problems but people are sure this is accidental or temporary and can be easily eliminated	• Timely revealing of the danger of decline of a subsystem that has exhausted its development resources. • Find a way to prevent the natural decline, i.e., substantially improve or replace the exhausted systems. • Contrive and activate a new system to completely replace the declined one; bring the new system to Stage 2.	• Lack of understanding of the facts that the rapid growth of the system's most important features will inevitably stop. • Wrong choice of the system's developmental trend; it is commonly known that the system's development stops when one of its important subsystems has exhausted its resources for growth. • Early rejection of development of a system that has not exhausted its resources, and substitution(s) by a new, more complicated system, typically because it is "fashionable." • Attempts to solve the problems of a declined subsystem "by force," i.e., by increasing power, dimensions, weight, cost, etc.

Stage 3. Maturity Begins when the system's growth stops[46].	• Ensure system development together with evolution of the system's environment. • Ensure the opportunity to move to the next-generation system in the near future. • Facilitate the system's return to Stage 2 by eliminating bottlenecks or transitioning to CDP[47] state (or introduce some of the CDP features in the organization structure). • Ensure stability without harmful effects associated with excessive bureaucracy.	
Sage 3. Maturity: natural limitations Begins when resources for the development within the existing paradigm (concept) are really exhausted	• Reveal the fundamental limitations and obstacles restricting further development; search for a next-generation system, based on other principles of operation, that can remove or bypass the obstacles; force the development of a new system. • Ensure the development of the business by developing a super-system (materials, technologies, utilization tactics, etc.).	
Stage 3. Maturity: artificial (false) limitations Occurs for one or more of the following reasons: • The most effective concepts have not yet been invented, therefore, a lot of available resources have not been used. • The basic system paradigm was stabilized much too early, prior to the emergence of a more or less exhaustive set of solutions. As a result, several generations of experts in this system directed their efforts toward relatively insignificant modifications to the paradigm's framework. Some particularly important problems have not been re-solved. This slowed down the evolution of the whole system • The resources of one or more subsystems have been exhausted, and this is holding the back the system's growth. • Lack of competitive pressure (a special niche product, for example), which produces no incentive for improvement.	• Conduct an exhaustive search for possible concepts to reveal the best ones. Check for available and unutilized resources that will allow for the development of the next generation of the product. • Identify any subsystem(s) that is holding back development, and consider replacing it with a more resourceful subsystem.	

[46] See Appendix 8
[47] Contrived Dynamic Prosperity

Sub-stage 3b: Beginning	• Reveal the time to transition to Stage 3. • Reveal the real causes of the Stage 3 transition, i.e., the subsystem whose resources have been exhausted. Search for new resources to eliminate the transition. • If sufficient limitations have been revealed that cannot be eliminated in the same evolutionary stage, search for the next-generation system (based on different principles) that can avoid or eliminate the revealed transition. • When the transition cannot be eliminated for technological, marketing, or financial reasons, search for possible ways to carry out normal functioning during Stage 3, while saving elements of stage 2 culture and relationships, reducing the power and growth of bureaucracy. • Search for possible ways to move to an artificial CDP.	• 'Self-cheating' – when a person refuses to accept the real causes of the transition to Stage 3. • Attempts to overcome the transition by reorganization, by changing specialists and managers, by increasing discipline, by eliminating self-centered and aggressive individuals. This always produces the opposite result to what was intended, and increases the harmful effects of Stage 3.
Sub-stage 3m: Middle	• Provide system evolution via the general evolution of technology – revealing new materials, technologies, and methods of application. • Search for new applications for the system and new market areas, increasing the level of specialization and providing a set of different specialized systems. • Search for possible ways to create effect-ive bi-systems from competing systems. • Continually fight against increased bureaucracy; save elements of Stages 1 and 2 to fight against the Stage 3 scenario. • Obtain money to create a new generation of the system.	• Imitation of evolution – small improvements of unimportant subsystems, implementation of decorative (cosmetic) solutions. • Instead of moving to a system based on new principles, attempting to return to previous generations of the system, the resources of which are already exhausted. • Acceptance of Stage 3 conditions of existence as the only possible scenario, and increasing the harmful effects of this stage.

Sub-stage 3e: End	• Prepare for implementation of the new system, in particular, prepare to change to the organizational structure required for the implementation. • Search for possible ways to create 'towing' bi-systems. • Search for possible ways to create 'middle-stage' bi-systems, which make transition to the new generation of the system easier for manufacturing and for the end user. • Reduce bureaucracy; reduce resistance on the part of professionals to change, involving them in the creative process to support the new system.	• Fighting against a new system, attempts to stop or decrease its development by political means, intrigue, and financial tricks. • Any attempts to save the old system, instead of creating a new one: – Making compromises instead of resolving contradictions. – Implementing multi-step compensating measures against harmful effects. – Unreasonable increase of system complexity. – Unreasonable increase of system power or dimensions. Note: All of these cause the system's ideality to decrease because they increase cost.
Alternative to Stage 3: Contrived Dynamic Prosperity	• Develop new generations of the core technology. • Diversify and/or adopt the new technology if the existing technology has exhausted its resources. • Enforce a cultural environment directed toward conserving Contrived Dynamic Prosperity.	

Stage 4: Decline Begins when a new system (or the next generation of the current system) emerges to replace the existing one.	• Search for possible ways to improve the system to make it competitive with others (it is possible for the transition to Stage 4 to be artificial and not natural). • Search for possible ways to combine new and old systems, combining the desirable features of other competitors. • Search for new areas of application where the old system can be useful. • Provide planned and smooth termination of the production of the old system and change to the production of a new system. • Provide new training for professionals. • Provide social protection for all workers during reorganization.	• Ignoring changes, not making the required decisions in time. • Panic, unreasonable decisions, looking for a 'magic bullet' that will save the situation all at once. • Attempts to 'save' the managing group by means of downsizing (firings, layoffs, reduced salaries) of the other workers.
Stage 5: Life after Death Begins if the existing system is not completely replaced with the new system and still has some limited application. Or, when the system is completely shifted from its main market but remains in some outside areas, where the new system is not profitable or useful. During Stage 5 the system returns to the first stage of its evolution. All objectives and possible mistakes are the same as in Stage 1. There are two possible evolutionary scenarios: • Quiet existence in some separate sphere • New evolution and sharing of the market with a new system after the appearance of new materials, technology, and market sectors.		