TRIZ IN THE WORLD: HISTORY, CURRENT STATUS, AND ISSUES OF CONCERN

Valeri Souchkov, ICG Training & Consulting, The Netherlands

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INTRODUCTION

The year of 2016 was celebrated as first, the 60th anniversary of foundation of TRIZ since the first paper on TRIZ "*About Psychology of Inventive Thinking*" was published by Genrich Altshuller [Altshuller 1956]. Second, 25 years ago TRIZ started its journey beyond the countries of former USSR where it was created.

In this paper, I attempted to summarize key factors which produced impact on the of evolution of TRIZ during these 25 years of worldwide expansion as well as its consequences which brought TRIZ and its global community to where they are now. On the one hand, it is quite a long period of time, and a lot of things have been achieved. On the other hand, TRIZ is a complicated knowledge- and information-intensive discipline that requires significant time and effort to be developed, understood, and implemented.

Note that this paper does not discuss internal details of TRIZ, it focuses on how TRIZ has been interacting with its supersystem.

In the first part of this article, I tried to give an overview of this 25-year period through the lens of personal experience. The limited format of the paper does not allow one to mention and describe all the important facts and list all the names. Therefore, I focused mostly on main issues and critical aspects that created today's situation.

The second part of this paper focuses on the analysis of the current status of integrating TRIZ into business, science, and education. It also summarizes relevant issues related to TRIZ development, distribution and adoption that were identified during multiple talks and discussions with my colleagues, business partners, and customers about further improvement and development of TRIZ. Some ideas on how to overcome current challenges are mentioned.

1. HISTORY OF TRIZ DISTRIBUTION BEYOND COUNTRIES OF FORMER USSR

1.1. STAGES OF TRIZ EXPANSION

Today, we can distinguish four conventional stages that contributed to international spread of TRIZ from 1991 to 2016. Each of the four stages is described in more details below.

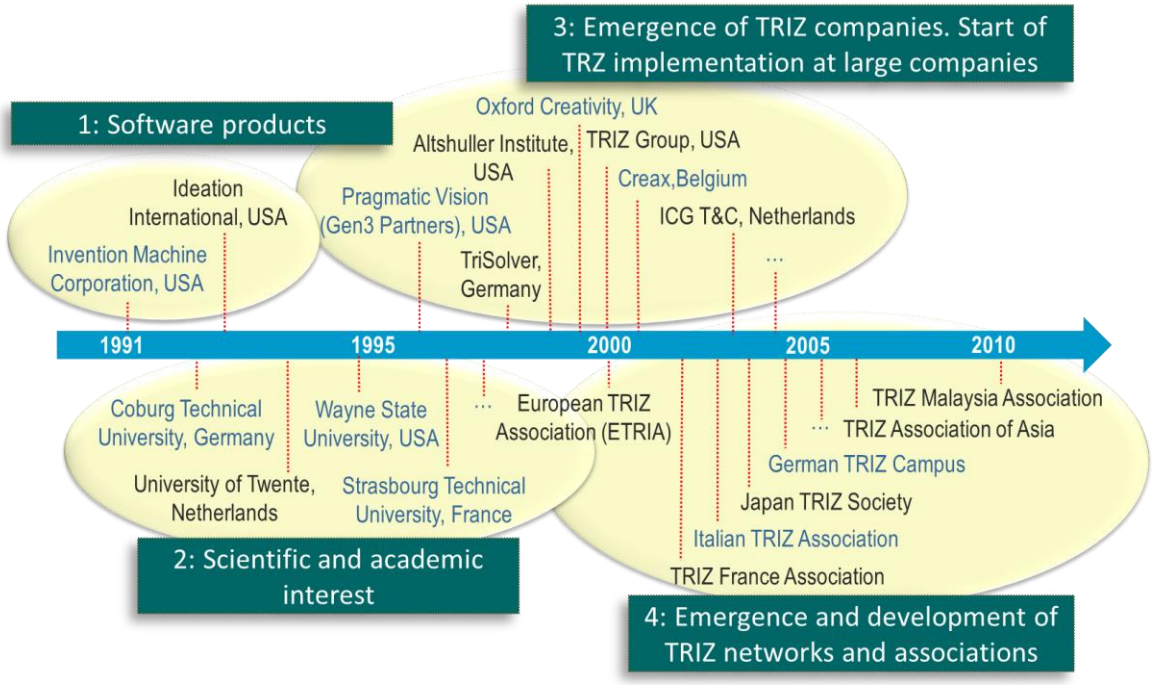

Fig 1. Four stages of TRIZ distribution in the world, including examples of key companies and organizations, participating in the process.

1.1.1. First Stage: Software Products

TRIZ was presented outside the USSR in 1980s for the first time in several books by Genrich Altshuller, published in the English and German languages. Though they didn't spread widely back then, in some countries people became interested in works of Genrich Altshuller, mostly, in the academic environment.

A pioneer in delivering a message about TRIZ was, undoubtedly, Invention Machine Corporation that was founded by a company called Invention Machines Lab from Minsk, Belarus, in 1991. The Minsk-based company released *Invention Machine*™ software, which had been developed by joint efforts of software developers team, Minsk-based TRIZ School headed by Nikolai Khomenko, and a number of TRIZ experts from St. Petersburg, Kishinev, Krasnoyarsk. The company actively attracted the whole Russian-speaking TRIZ community to its activity. The founder of the company was Dr. Valery Tsourikov; I was one of its co-founders.

The opening of the company abroad was driven not so much by an attempt to expand sales as by historical (or economic) circumstances: after the dissolution of the USSR, the economy of the CIS countries began to fall into decay rapidly, investments to industry were drastically curtailed, sales of Invention Machine decreased, and the company had to survive. In 1993, the headquarters of Invention Machine Lab moved to Boston, Massachusetts, the USA.

The sales of Invention Machine in the USA left much to be desired for a while. As a matter of fact, the software was a good supportive instrument of problem solving with the help of classical TRIZ tools, but it worked efficiently only in the hands of those users who had already familiarized themselves with TRIZ well enough. One of the problems was that TRIZ training was not brought to a satisfactory level. The duration of the training on how to use Invention Machine software package was only two days, which was enough only to gain some insight into the product and understand which buttons to press and when. We could not propose longer training, as American companies were not used to invest too much time for software product training.

Simultaneously with the development of Invention Machine, the company offered consulting services. In charge of such services was a department created by attracting resources of St. Petersburg TRIZ School headed by Dr. Simon Litvin.

Nevertheless, despite all the difficulties of a starting period, Invention Machine Corporation acquired quite famous clients in the first years of its activity: it suffice to name such companies as Caterpillar, Eastman Kodak, Ford Motor Company, Motorola, Procter & Gamble, Xerox. In 1997, Invention Machine signed 13 million US dollars contract with Mitsubishi Research Institute in Japan to provide its software to 100 leading Japanese companies. Matsushita, Ricoh, Tokyo Electric, Toyota and others joined the consortium. In 1998, a high-profile business magazine *Fortune* included Invention Machine Corporation in the list of 12 most innovative companies of the USA [Fortune 1998].

Adapting to the market requirements, Invention Machine has been constantly developing throughout its history, and the titles of the product changed as well: first, *Invention Machine*™ evolved to *TechOptimizer*™, then *CoBrain*™, then *Goldfire™ Innovator*. After 2012, when Invention Machine Corporation was acquired by American company IHS Markit, one of the world leaders in technical information analysis. Currently the software is known as *IHS Goldfire*™ designed primarily for the market of large corporate clients. Though *IHS Goldfire*™ still supports classical TRIZ tools, it focuses mostly on the development of semantic search engine which finds relevant solution concepts and ideas in various technical fields [IHS 2016].

Almost at the same time as Invention Machine Corporation was established in the USA, one more company, offering TRIZ-based software products and consulting services, was founded in the USA in 1992: Ideation International, created on the basis of Kishinev TRIZ school, headed by Boris Zlotin and Alla Zusman. Same as it was with Invention Machine, Ideation International had to overcome problems and challenges related to a high barrier to entry the American market, in order to develop the company and promote its products and services. The company released its own framework called *Ideation/TRIZ (I-TRIZ)* and software to support it called *TRIZSoft*™ that included problem solving system *Innovation Workbench*™, forecasting system *Directed Evolution*™, system of preliminary analysis of anticipated failures *Anticipatory Failure Determination*™, and some other software packages. Among the company clients were such companies and organizations as BP Amoco, Boeing, Ford Motor Company, NASA, Xerox. Ideation International still exists and continues to offer and deliver its services and products [Ideation 2016].

At the same time, many TRIZ Masters – co-developers and students of G. Altshuller arrived to the USA, such as Victor Fey, Isaak Bukhman, Gregory Ezersky, and others, who founded their own companies to offer TRIZ-based training and consulting services.

More details on the history of TRIZ development can be found in [Souchkov 2015].

Would TRIZ have successfully expanded beyond the former USSR to the developed and innovation-intensive countries without being promoted as a software product? I believe the chances would be quite low. Especially, in corporate environment, where there is no opportunity to invest much time in personnel training and where it is necessary to assess the results in the shortest time possible based on financial achievements only. Nevertheless, one of the resources back then was that industrial companies allocated considerable budgets to invest to the software tools for productivity increase. It was why a software product had much better chances to penetrate into a company rather than a method or a practice being delivered only in the form of training or consulting services. The competition is very strong at this market, and the interest for any new method or tool may disappear quickly if there are no large investments into its continuous advertisement, promotion and update. Non-software based TRIZ products were absolutely not ready for it. On the other hand, academic community rather than industry could have been a channel of TRIZ distribution, but there were challenges in that area, too. They will be described below.

1.1.2. Second Stage: Interest of Academic Environment

The information that big corporations had purchased TRIZ-based software products and developed some successful cases began to spread at some point, and the second stage of interest to TRIZ started: academic organizations and universities became interested in learning more about TRIZ. Among them, there were the University of Twente (The Netherlands), the Technical University of Strasbourg (France), Ecole Polytechnique of Paris (France), Wayne State University (USA), MIT - Massachusetts Institute of Technology (USA), KTH Royal Institute of Technology in Stockholm (Sweden), Brno University of Technology (Czech Republic), Technical Universities of Bergamo and Florence (Italy), Royal Melbourne Institute of Technology (Australia), and other. As a rule, technical universities actively cooperate with industries, so the information about TRIZ began to spread through academic channels as well.

In 1993, being a coordinator of Invention Machine project, I came to the Netherlands, where a joint project between the University of Twente and Invention Machine Corporation was launched to further develop a fundamental platform with the use of cutting-edge means of Artificial Intelligence. In five years, in 1998, the project ceased to exist due to the changes in the strategy of Invention Machine Corporation, according to which the funding of product sales was strengthened by reducing investments to advanced research related to TRIZ. Nevertheless, during those years, we managed to widely spread the information about TRIZ in the academic environment by having access to international knowledge exchange channels. In 1996, we founded the *TRIZ European Research Network*, which later on partially evolved to the *European TRIZ Association (ETRIA)*.

Another important milestone of that time was the launch of the *TRIZ Online Journal* project [Journal TRIZ 2016] by Dr. Ellen Domb (USA) which remains the main source of TRIZ information spread in the English-speaking community till today. Access to any article published in the journal has always been and remains free and registration is not required. It is not a scientific but a technical journal, and I must admit that the quality of the articles varies, but such “democratic nature” of the journal gives everyone who speaks English an opportunity to have access to free of charge information about TRIZ and to publish own results of research or case studies.

1.1.3. Third Stage: Interest of Professional Community, Foundation of Companies, Offering TRIZ Services

The next stage of TRIZ expansion was related to growing interest in TRIZ among consultants and professionals who dealt with the issues of improving quality of engineering products and processes. They were attracted with an opportunity to use TRIZ for accelerating of finding solutions to quality improvement problems. Moreover, the necessary solutions were not of the highest level from TRIZ point of view, but it was exactly what attracted them – TRIZ helped to find solutions with quite a high degree of ideality, which in real life meant quick implementation. In different countries, businesses emerged that offered TRIZ-based services on their own without attracting Russian-speaking TRIZ professionals.

It shall be noted here that exactly an opportunity to use TRIZ for solving quality-related problems gave driving force to wider spread of TRIZ in the world. Back then this field appeared to be far more interested in TRIZ than other fields which require engineering creativity, for example, new product development. It happened thanks to strong improvement of finding simple but working solutions that could be implemented quickly. Quality management still remains one of the main areas where TRIZ is demanded. Several global corporations such as Samsung, POSCO, General Electric have implemented TRIZ in their quality management processes built on the basis of Six Sigma and Lean methods.

Meanwhile, a problem related to distribution of TRIZ and its mastering, and namely - necessity to invest significant time in the training of theory and tools led to the foundation of dozens of companies, offering simplified TRIZ versions: SIT, ASIT, CreaTRIZ, USIT, DreamTRIZ, and so on. The common strategy of those companies was ordinary: to simplify TRIZ as much as possible, to bring only a single tool to the market, that everyone will understand easily, and promote it quickly, leaving competitors behind. It did not lead to roaring success, because problem solving and innovation-related abilities of such versions remain quite doubtful, especially when it comes to problems, requiring high-level solutions. Nothing is heard of some of them today.

On the other hand, one of the leading companies on the global market which offered consulting services and at the same time continued to develop TRIZ, was GEN3 (Boston, Massachusetts, USA). Though the company also worked with a modified version of TRIZ, its version was not a simplification but an adaptation and further development according to the requirements of businesses and organizations which are engaged to continuous innovation. GEN3 developed and successfully launched such new tools as Function-Oriented Search, Main Parameters of Value Discovery, and so on. Today TRIZ services are offered by the spin-off of GEN3, a company GEN TRIZ headed by Dr. Simon Litvin, a former student and colleague of Altshuller [GEN TRIZ 2016].

In the same period of time, the number of TRIZ publications began to grow rapidly, especially publications of books in English and other languages. Those were translations of books originally written in Russian and published before, for example several books by Genrich Altschuller ("*The Algorithm of Invention*", published in English as "*The Innovation Algorithm*", and *"And Suddenly the Inventor Appeared"*), the book by Dr. Yuri Salamatov ("*How to Learn to Invent*", published in English as *"TRIZ: The Right Solution at the Right Time"*), as well as new books, written both by Russian- and non-Russian-speaking authors. Among Russian-speaking authors of that time, the book by Boris Zlotin and Alla Zusman "*Tools of Classical TRIZ*" and the book by Dr. Dmitry Savransky (US) "*Engineering of Creativity*" are worth mentioning. The book "*Hand-on Systematic Innovation for Technology and Engineering*" by Darrel Mann (UK) published in 2001 had quite a big impact on TRIZ

distribution. Nowadays, the list of books about TRIZ is quite long. In 2012, my list included over 200 titles of the books in 40 different languages about TRIZ. Nowadays, the books in Korean, Japanese, Chinese, and Arabic languages are being actively published.

1.1.4. Fourth Stage: Development of TRIZ Networks and Associations

The next, fourth stage was the development of TRIZ networks and associations at regional, international, and corporate levels. In 1998, the non-profit *Altshuller Institute* was established in the USA. In 2000, the *European TRIZ Association ETRIA* was established, which set the target to develop cooperation between academic and industrial TRIZ communities. Since then, associations began to emerge almost everywhere: TRIZ Association of France, *Apeiron* Italian TRIZ Association, German-Austrian *TRIZ-Kampus*, *Society of Systematic Innovation* in Taiwan, *TRIZ Association* in Thailand, *TRIZ Society of Japan*, *Korean TRIZ Association*, TRIZ associations were launched in India, Mexico, Malaysia, Poland.

Fig.2. *MyTRIZ* Malaysian TRIZ Association organizes a conference about TRIZ biyearly. More than 800 participants attended the conference.

In addition to regional associations, corporate TRIZ associations were established, for example at General Electric, Intel, Philips, POSCO, Siemens, Samsung. Some of those associations have become and still remain the members of the International TRIZ Association (MATRIZ).

Thanks to the creation and development of national and international TRIZ networks, it became possible to organize large international conferences annually. The most significant of them are:

- *MATRIZ TRIZfest International Conference*, main organizer: The International TRIZ Association (MATRIZ).
- *TRIZ Future Global Conference*, main organizer: The European TRIZ Association (ETRIA).
- *TRIZ Symposium in Japan*, main organizer: TRIZ Society of Japan.
- *Iberoamerican Innovation Congress*, held annually in Latin American Countries and focusing mostly on TRIZ.

- *Systematic Innovation Conference*, main organizer: Society of Systematic Innovation in Taiwan.
- *TRIZCON Conference* in the USA, main organizer: The Altshuller Institute.

In addition to that, annual national conferences and symposiums are organized in Argentina, Germany, China, France, South Korea, and other countries.

Fig. 3. Photographs taken at international TRIZ conferences in 2015

1.2. GEOGRAPHY OF TRIZ EXPANSION

One cannot say that TRIZ has evenly spread around the world. At some point, in some place people would become interested in TRIZ, then their interest would fade away, then it could rise again. In general, the following picture can be observed:

1. **1991:** It is not a surprise that the USA became the "seeding ground", where TRIZ revealed itself abroad. There were several reasons for it and the main one was that it was easier for Russian TRIZ specialists to move to the USA (than, for example, to Western Europe). The second reason was that the USA were the largest and potentially the richest market as far as development and distribution of innovative technologies were concerned. TRIZ was distributed through sales of software products, training and consulting services by Russian-speaking TRIZ professionals, who were supported by local English-speaking management.
2. **1995:** TRIZ expansion starts in Western Europe, primarily through academic environment. There was next to none of Russian TRIZ specialists in Europe back then, however local universities got into TRIZ learning process.
3. **1999:** TRIZ appears in South Korea which becomes the world-leading center of the use of TRIZ for quite a long time, thanks to the policies of such companies as POSCO, Hyundai and Samsung, focused on both vertical and horizontal TRIZ implementation. Some leaders of South Korean businesses saw TRIZ as a chance to catch up and overtake Japanese

competitors. That was one of the reasons why they began to actively implement TRIZ, when they saw TRIZ as an opportunity not only to quickly develop competitive products, but also to take over their permanent rivals. Eventually, it happened so and TRIZ was recognized as one of the key factors of success at Samsung [Forbes 2013]. At some point, there was an impression was that every engineer in South Korea had to know TRIZ to get a job.

4. **2009:** Latin American countries begin to be interested in TRIZ: Brazil, Chile, Columbia. The interest also arises in Middle East: Jordan, Saudi Arabia, Iran. In 2009, thanks to the assistance of Princess Sumaya and Prince El Hassan, I was invited to Jordan to train local specialists in TRIZ for business and management innovation. The project was supported by the Queen Rania Center for Entrepreneurship in Amman. During several years, I taught TRIZ to more than 150 entrepreneurs and specialists. Most active of them moved to the USA and Western European countries either to run their own businesses or to internationally promote innovative startups of Jordan.
5. **2010:** TRIZ comes to China. Entry to China was and still remains difficult because of the language barrier and the issue of copyright attitude. Nevertheless, currently Chinese universities produce the largest number of scientific publications in the world and it also results in the fact that most of academic publications or TRIZ today arrive from China. However, the quality of their publications often leaves much to be desired – but one has to keep in mind that China started to adopt TRIZ very recently.

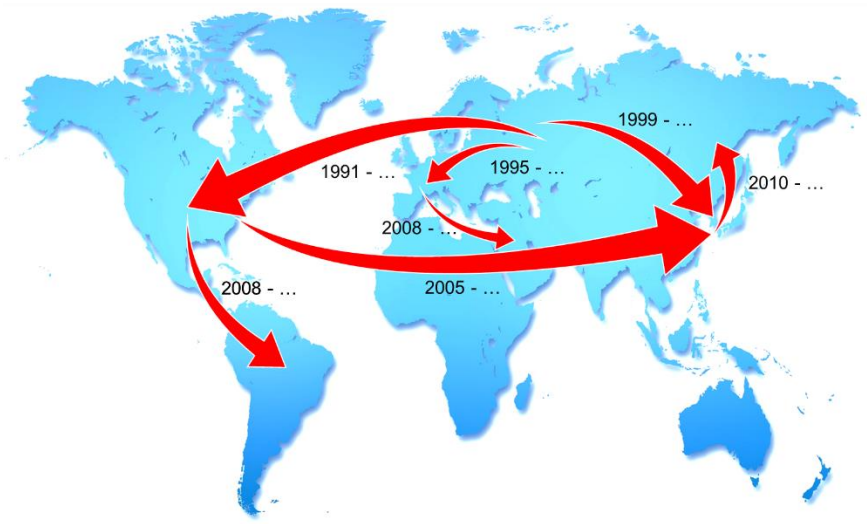

Fig. 4. History of TRIZ distribution in the world over the last 25 years

2. CURRENT STATUS

2.1. TRIZ IN INDUSTRY

As it was mentioned before, Samsung Electronics has been so far the biggest TRIZ user in the world. As of September 2015, 32881 employees of the company received TRIZ training in the company (5581 of them – at the levels higher than basic). Starting with 2012, 6 employees of the company were qualified as Level 5 TRIZ specialists by the International TRIZ Association (MATRIZ) and became TRIZ Masters [MATRIZ 2016]. It is sufficient to say that the total number of people qualified as level 5 TRIZ

specialists since 2012 till 2017 was 23. Some Samsung employees participated in 100 and more innovative projects where TRIZ was used. In due time some other Korean companies took up Samsung's initiative and began to implement TRIZ as well. Among such companies we can name Hyundai, POSCO, LG Group.

Today, we can name several thousands of companies around the world that used or use TRIZ. The list is quite long. Among them, there are both big global companies and companies of medium and small size. Among global companies, we can name such as BMW, Bombardier, Boeing, Continental, Daimler Chrysler, European Space Agency, Ford Motor, Johnson & Johnson, General Electric, Exxon Mobile, Intel, Mars, Medtronic, Philips, Procter & Gamble, Shell, Unilever, Xerox. However, it was by far not in every company that TRIZ was used on an on-going basis or systematically. In the majority of cases, it was used on and off, on an occasional basis. The reason is not so much in TRIZ itself, as in the way innovative projects are organized in the companies. The majority of organizations still do not view innovative activity as a process that shall be on-going or they do not understand how to integrate TRIZ in their activity.

Back in the day, the growing market demand for TRIZ services, especially on the regional markets, led to the growing number of companies offering TRIZ-based services. The list of such companies in the world (excluding the CIS countries), which was prepared in 2013, contained over 100 organizations [Souchkov 2013]. The country with the largest number of companies, offering TRIZ-based services, was the USA (27), then South Korea (18), then Great Britain (8), and Japan (7). However, it should be noted that many of them offer TRIZ-based services as a part of a bigger portfolio of consulting services in quality management, business process innovations, and so on.

It must be noted that TRIZ plays a special role in small and medium enterprises. Global corporations have big budgets and a lot of resources that can be allocated to resolve complicated problems when it is needed, whereas smaller companies usually have no access to such resources. At the same time they still have to solve inventive problems, especially when a company works on implementing a high-level innovative idea. Today, the number of startups, offering breakthrough ideas is constantly growing. But the vast majority of them do not survive. One of the main reasons is lack of available resources to solve numerous problems that should be tackled to ensure the implementation of the main idea and bringing it to market. In such cases TRIZ can be an answer thanks to its capability of providing quick search for most effective and efficient solutions without too much internal and external resource spent.

2.2. TRIZ AND EDUCATION

Speaking about TRIZ in education, we should differentiate between two education levels, each requiring its own methods and approaches. The first one is teaching in the academic environment: at colleges and universities. The second one is professional education, which is more commonly referred to as "training". The education at the universities focuses on theoretical basis first and only then on methods and tools, whereas in professional education, theoretical basis is usually explained very briefly because of the lack of time and absence of necessity. Modern professional education requires teaching a person how to use a tool in as short a time as possible. That is why, in modern professional education, the ratio between theory and practice constantly moves towards practice, and nowadays it is approximately 20 to 80.

Here comes a contradiction. On the one hand, TRIZ is not only a set of tools. It is also a system of thinking, which is hard to master without understanding of its theoretical basis. On the other hand,

the time given to education does not give an opportunity to learn theory to the fullest extent, which would be enough to use TRIZ tools as efficient as possible. Such contradiction can be eliminated, for example, by separation of conflicting demands: a student can learn theory on his/her own, using books or video-lectures before the workshop, and only then come to a practical training. However, the experience shows that in such case there are sub-tasks: more often than not students come to a workshop and say honestly that they did not have enough time to prepare for it. They say: "Let me practice now, and I will read about it later". Usually, it happens so at professional training. The problem is that by far not everyone actually reads after the training workshop. This contradiction still waits to be eliminated.

2.2.1. Academic Education

The first TRIZ programs in Western European and US universities were introduced in 1994-1995. In some universities, they disappeared; in some – they remained; in some – they develop further.

Many universities implemented TRIZ introductory courses and conduct them. At the end of 2013, we counted over 120 universities on all the continents (except for CIS countries) registered in our database, where TRIZ was included in the curriculum to a certain extent. In the vast majority of cases, it was either an introductory elective course, or TRIZ was a part of a wider course program, such as Innovation Management, New Product Development and so on. Such courses include programs with duration from 8 to 32 hours. Of course, the time is little but at least it gives students an opportunity to learn that TRIZ exists and understand what it is about.

In 1998, I was invited by the University of Twente (The Netherlands) to give an introductory 16-hour course once per year for master students majoring in Industrial Engineering Design and Technology Management. Since then, the situation has changed. Currently, I give several courses annually: introductory courses (8-16 hours) for second-year and master students, as well as an 82-hour course for master students called "TRIZ Basics: Theory and Practice" that can be expanded up to 134 hours [Wits 2010]. Moreover, this course is partially open for professionals. Training is done in the form of "full immersion", which means that students are taught this course for at least eight hours a day, and continue next day during two weeks. Such format allows professional engineers and scientists to participate in the course as well. As approximately 60% of the course is practice, students use TRIZ to solve real-life problems and develop inventive solutions. Such an approach allows bringing together students and professionals in mixed groups. Often students work on real industrial problems, which professionals bring along, and find rather interesting solutions. There were cases when after the graduation from the university, students found jobs in the departments of the companies, with which representatives they had studied together at such course.

2.2.2. Professional Education

As far as the development of professional TRIZ education is concerned, its introduction was a bit slow, too. The entry market barrier was quite high due to the following reasons:

1. Extremely strong competition. In modern world, professional education is developing very actively, which means that a lot of study subjects are being offered on the market. Companies usually plan 20-40 hours for the training of a specialist per year. It is not much, taking into account a huge number of professional courses available. That's why TRIZ education has to compete not even so with trainings in different invention and innovation methods, as with all kinds of training proposals in general, including such course as "*How to Make a Presentation*", for example.

2. Traditional method of training, which was used back in the USSR and was based on the academic schedule «Day: theory; evening: homework», was not efficient in the countries of Western Europe and in the USA. As I have already mentioned above, modern professional education is based primarily on practice. To do so, all the training material should be presented and structured very precisely and clearly: all the tools should be described step by step, processes shall be described with all entries and exits, focus should be made and special attention should be paid to places, where "bottlenecks" might appear in the process. Cases offered for training should be checked and worked through by the teacher. Moreover, it would be highly advisable if these were cases come from his or her own experience. Today, a teacher of professional courses acts more like a coach, than a teacher in the academic environment: his/her task is to teach students how to use processes, methods, and tools at the time when students are studying cases. The goal is to master the skills of working with processes and tools within a short period of time.
3. Lack of understanding how to use the material learned in the future and how to integrate new skills and knowledge in the activity of their organization. This leads to a situation, when a trained specialist comes back to a working place and continues to work in the same old way. So, new knowledge and skills disappear and are never used again. In order to overcome this barrier it is necessary to understand how TRIZ can be integrated in the existing business processes of organizations.
4. Lack of support from top management when it comes to corporate training. If the idea to launch TRIZ training in the company is a grassroots initiative, then the most probable scenario is that after several courses everything freezes, even if trained specialists give high points to a course, its content and a trainer. In order to vertically implement TRIZ in an organization, strong support of top management is required.
5. Lack of highly qualified TRIZ teachers and trainers. Unfortunately, sometimes I have to «retrain» already trained students more than once. As classical TRIZ teaching does not require a license, there appeared a lot of teachers back in the days who developed their programs based on one or two books they had read, and one or two problems they had solved or helped to solve. However, such teachers usually disappear quickly, but sometimes they manage to create a stir.

I tried to list the key reasons only, though there are many other smaller reasons: lack of a unified base for TRIZ teachers and trainers, inconsistencies between different versions of the same TRIZ tools, lack of coordination between TRIZ teachers, lack of a general training program.

One of the problems was that before 2007, trusted international certification of trained TRIZ users was not available. But thanks to the initiative of Dr. Mark Barkan, President of the International TRIZ Association (MATRIZ) at the time, this problem was solved. Introduction of international certification eventually led to a higher demand for professional certification TRIZ training, especially in corporate environment.

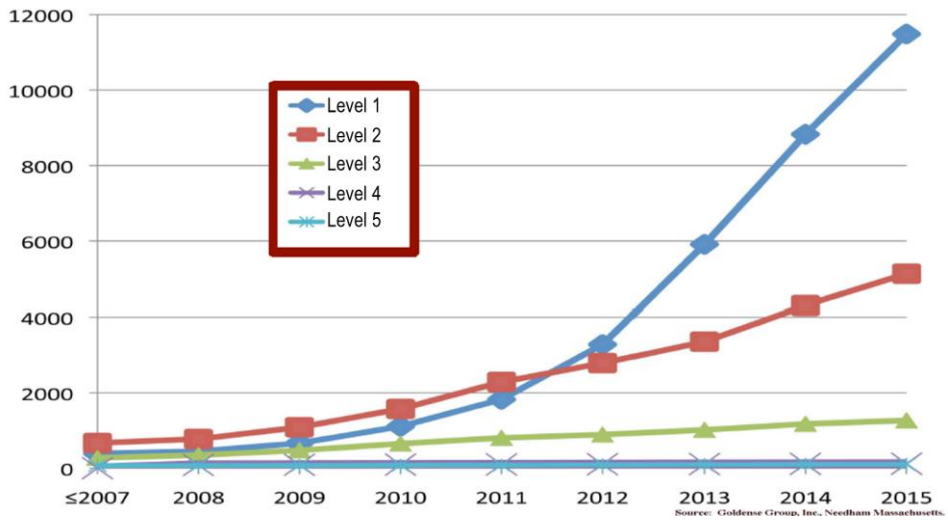

Fig. 5. Growth of certified TRIZ users in the world on the basis of MATRIZ data (with consent of B. Goldense) [Goldense 2015]

Among the most famous companies that trained hundreds and thousands of their employees, there are Boeing, European Space Agency, Ford Motor Company, General Electric, Hyundai, Intel Corp., LG, Procter and Gamble, Siemens.

As it was mentioned above, Samsung Company achieved so far the strongest results in corporate TRIZ training. The company founded a corporate TRIZ university and introduced a position of TRIZ Engineer.

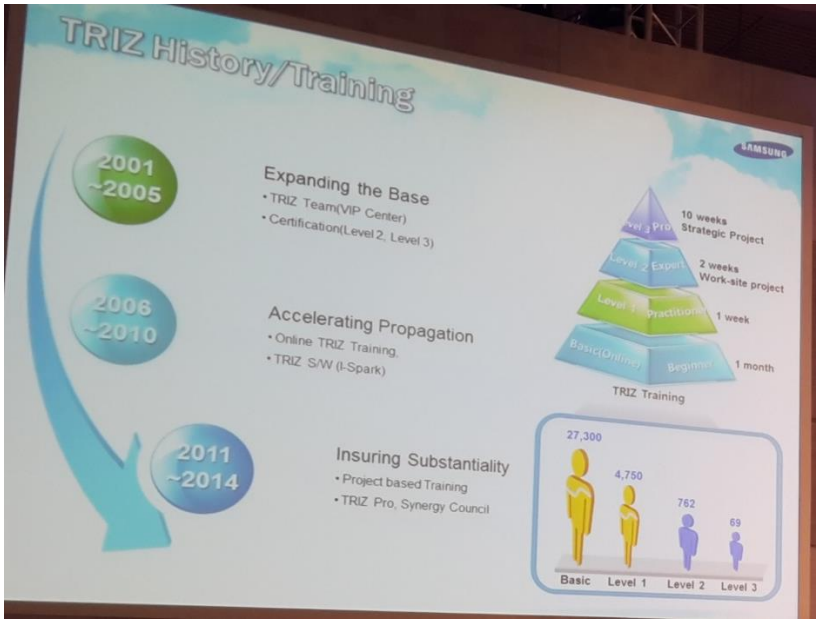

Fig. 6. History of TRIZ training at Samsung Electronics, 2001-2015. The slide is taken from the presentation of Vice-President of Samsung Electronics Dong Seob Jang at TRIZ*fest* 2015.

Public (open) certification training has not yet reached the level of corporate education. The main problem is to gather people in a group for training. The main issues of concern are: lack of sufficient publicly available information about TRIZ itself (mostly in mass media: magazines, TV, websites) and

what TRIZ knowledge and skills give to a professional, as well as narrow market segment. We will discuss it a bit later in the paper.

2.2.3. Distance Learning

In 2011, I started an experiment with online TRIZ learning. It does not seem to be possible to make a fully automated TRIZ learning right now, not because there are no technologies, but because TRIZ is a weakly formalized discipline. Unlike learning math or physics where problems have one or at least several solutions which can be calculated in advance and then the student's solutions can be checked against them, TRIZ deals with open problems and it is not possible to predict a correct (or, "the best") solution in advance. Thus, I decided to choose a blended approach: students have access to all the lectures in the form of video, perform homework, and all discussions and homework assessment is done online individually with a trainer (or in a small group of students). The online training is based on the training programs and curricula approved by the International TRIZ Association (MATRIZ).

One of the main advantages of such method is time flexibility, as time of online sessions is planed dynamically, when a student is going through the course. The efficiency of such training method proved to be quite high, the results were better than during traditional training organized in a classroom. It is obvious: in the classroom, trainers do not have time to talk and work individually to each student. One more advantage is that students analyze their real-life problems or problems of their organizations in course of training, and solutions found are often patented later. In 2015, one of my students from UK made 7 patent applications during the course of training while 5 solutions were later implemented. Summarizing, I can say that the experiment has proved to be quite successful and it still goes on: more than 300 people from 40 countries were trained over the period of four years.

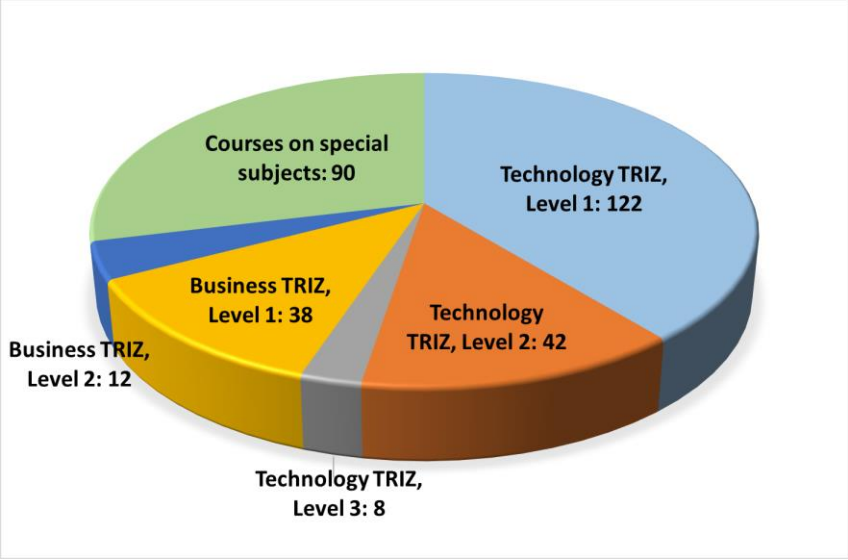

Fig.7. Demand for various courses delivered by distance learning at ICG T&C, 2012-2016 (Technology TRIZ Level 3 course was introduced in 2016).

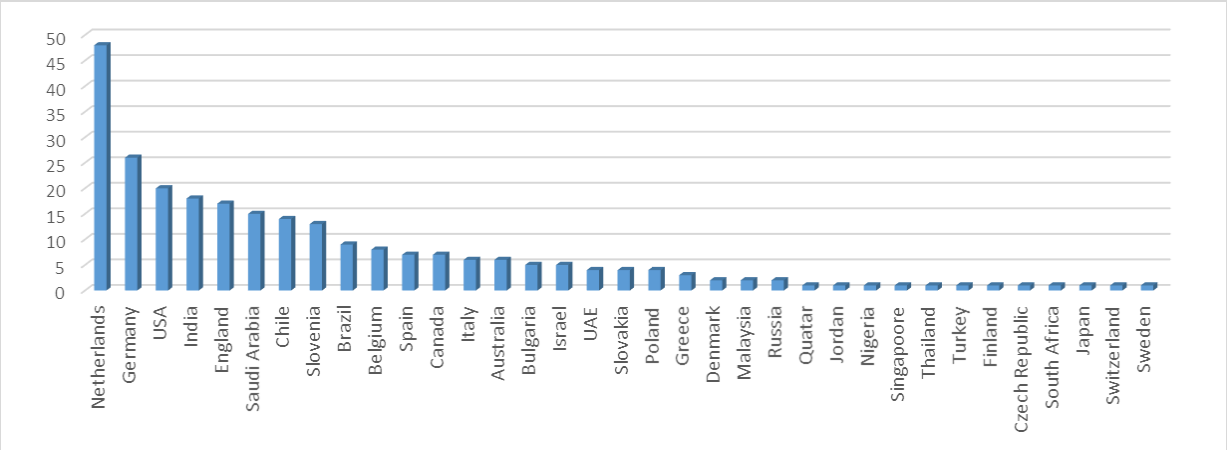

Fig. 8. Number of people from different countries who took distance training from ICG T&C, 2012-2016

2.3. TRIZ AND SCIENCE

As the majority of TRIZ specialists know, G. Altshuller positioned TRIZ as a science of technical creativity. However, if we look at TRIZ from the point of view of modern understanding of science and a broad range of demands and requirements which are used to confirm scientific validity of research, method or theory, we can say that at the moment, TRIZ is a well-developed science only by a stretch of imagination. I personally spent many hours discussing this topic with academic specialists, including professors of the universities who took decision to get to know TRIZ better back in the days. The general outcome of those discussions is that today, TRIZ may not be recognized as a science yet from the Western European point of view (However, a note shall be made: in different cultures and philosophic systems, the notion of science may have its nuances and interpretations: for example, psychology is not everywhere regarded as a science).

Nevertheless, massive studies of big amount of technical data and information with a goal to discover new, earlier unknown, patterns of invention has been a truly scientific approach. Unfortunately, the authors of such studies did not always publish the information about the quantity or categories of analyzed information, about assessment criteria, they did not compare their conclusions with already existing knowledge and methods, often avoided quotations, did not specify boundary conditions for the use of methods and tools, and so on. And even if we intuitively think that formulated principles and methods are correct, anyway their applicability and workability shall be proved for the results to be regarded as scientific. The fact that these methods are often successfully used in real life is not yet a proof from the point of view of modern western European system of scientific knowledge. At least, as long as their applicability and usefulness are not proved by statistics.

For example, the majority of laws of technical systems evolution formulated by Altshuller are heuristics. TRIZ does not define exactly under which circumstances one or another TRIZ law would exhibit itself or fail to do so. But the notion of a “law” in exact sciences means that it inevitably manifests itself under specific conditions. For example, the TRIZ Law of Increase of the Degree of Dynamics of a technical system’s parts usually manifests itself when a technical system has to meet increased demands but they may not be met by the existing physical and engineering design of the system. If it was defined and described under which exactly conditions the law would inevitably manifest itself, then the notion of using the word “law” would be appropriate. But it has not been done yet except definitions which are too general.

Modern scientific approach requires accurate argumentation based on the statistical analysis of information, if it is hard or impossible to use formal methods. In the majority of works by TRIZ authors there is nothing about it. It was one of the reasons why, though initially the attitude of academic environment towards accepting TRIZ as a science was positive, it was dissolved partly by some degree of skepticism as the academic community is used to modern way of describing and presenting scientific results.

However despite different views on the issue of how far TRIZ is developed as a scientific discipline, TRIZ is present and studied in academia. The first attempt to coordinate TRIZ-related research in European academic environment was made by me in 1996, when the *European TRIZ Research Network* was created with the following institutions becoming its members: the University of Twente (The Netherlands), KTH Royal Institute of Technology in Stockholm (Sweden), Norwegian University of Science and Technology (Trondheim), the University of Strasbourg (France), Technical University of Berlin (Germany). New partners joined it later, but progress was slow because of the lack of financial support. Scientific funds distributing the grants had lukewarm attitude towards TRIZ at the time – mostly because TRIZ was too new, too unknown, and too ambitious.

At the moment, a number of European universities including the Technical University of Strasbourg (France), Coburg University of Applied Sciences (Germany), the University of Bergamo and Polytechnic University of Milan (Italy), Royal Melbourne Institute of Technology (Australia) continue their TRIZ-related research which tends to grow. For example, in 2012-2015, the funds of the European Union were used to finance the «*FORMAT*» project, which was coordinated by the team of Polytechnic University of Milan under the leadership of Prof. Gaetano Cascini. The project set the target to develop methods of forecasting manufacturing technologies and was executed by a consortium which included the Wroclaw University of Science and Technology (Poland), Whirpool and Innovation Engineering (Italy) and PNO (the Netherlands) as well. The amount of project's financing was 1.69 million Euro. Results of the project are publicly available at *www.format-project.eu* . [Format 2015]

Today, in the majority of cases, in academia TRIZ-related research is conducted by postgraduates in course of their thesis preparation. Lately, the number of scientific publications related to TRIZ research in South-East Asia has also increased. Most often the topic of research is not so much the development and improvement TRIZ theoretical background as either automation of inventive process with the use of TRIZ or integration of TRIZ with other methods of engineering design.

The paper by Prof. Leonid Chechurin «*TRIZ and Science: Review of Index-linked Publications*" [Chechurin 2015] presents a good overall picture of modern TRIZ scientific publications.

2.4. TRIZ IN NON-TECHNICAL FIELDS

Since the beginning of 2000s, there have been attempts to use TRIZ in business and management. At the fundamental level, the main paradigms and concepts discovered and presented in "technical" TRIZ are quite applicable and workable for business systems and business processes. When a human brain solves a complicated problem, it uses abstract models, and at the abstract level, the models of technical systems, organizational systems, technical processes, and business processes are almost the same. There are contradictions both here and there, evolution development patterns seem to be very similar due to the common principles of systems organization, and patterns of innovative solutions through innovative system changes seem to be universally applicable.

The problem related to the development of TRIZ for business and management most often manifests itself in blind copying of TRIZ created for engineering. In the many cases, we can observe a situation when a technology TRIZ expert teaches TRIZ tools to business people who do not possess technical background, and he or she uses technical terms and technical inventions as illustrations and cases. In fact, he or she teaches the same 40 Inventive Principles using the same wording as in technical TRIZ. Though the content might be quite clear for the students, such passive knowledge will not transform into active knowledge because of the cognitive gap. As a result, such attempts to teach technical TRIZ to business community often fail. The solution of the problem is to adapt TRIZ to business terminology, re-think and rewrite TRIZ principles, create collections of cases in business and management and so on. This work is ongoing now.

Another future-oriented field where TRIZ can be used is school education. It was a surprise for me to learn about TRIZ distribution in the Middle East countries, especially in Arabic region, where TRIZ is mainly used not in engineering, but in the training of teaching staff of schools and universities to use TRIZ to solve pedagogical issues. There is a number of such courses in Saudi Arabia, UAE, Qatar. Because of the language barrier it is hard to estimate the scale of this activity, which predominantly refers to teaching 40 TRIZ Inventive Principles adapted for pedagogics, and also to such TRIZ concepts turned to tools as Ideal Final Result and System Operator.

In Western Europe, there is also big interest in the use of TRIZ in pedagogics. However, there are some problems. First, there are too few well-qualified and certified TRIZ specialists in the field. Second, it is very hard to introduce something radically new into the local system of school education without support from state institutions. However, state institutions want to see a proof in terms of many examples of success to make their decisions. As clear, such demand creates a vicious cycle.

3. TOP CHALLENGES TODAY

Living behind the “iron curtain“ in Soviet Union, many people, including me had an impression that developed countries of Europe, the USA, Japan and similar countries were starving for new ideas, willing to invest everything into them, to develop, stimulate, motivate with all possible means. However, after the “iron curtain” collapsed and we got the opportunity to travel the world, we soon found out that it was not exactly so.

When creating TRIZ, Altshuller dreamt of creativity democratization, which meant to give everyone an opportunity to invent, regardless of age, degree of creativity, and imagination. That wish was based on a hypothesis that every engineer wishes to invent and create breakthrough ideas. And not only engineer but each person with university background in general.

In fact, in the time of the most active TRIZ development, USSR lived in the atmosphere of technology-related romanticism: technology and science were booming, and almost every boy dreamt of becoming either an astronaut, or a spaceship designer. It was barely possible to buy popular technology-related magazines and science fiction books – they disappeared from the shelves so quickly, often without reaching the shelves at all. However, at the moment when TRIZ came out from the “underground”, it became clear that it was not exactly like that or the world, or more precisely its needs, had changed.

Starting with 2007, I have always taken an opinion poll among students, majoring in technology and engineering, asking them if they are interested to have a job in the future related to inventing. Since then, I have interviewed approximately 2000 students, and every year the number of those who are interested in it, sadly decreases. In 2007, 15% of students said, "Yes", whereas in 2016 – only 6%. Such figures characterize the lack of motivation among young specialists to invent. It means that the majority of people is not interested in technical creativity, so the real market segment is not as big as we thought at the beginning, or as it was, when TRIZ was born and started to develop.

One of the reasons of such attitude may be the fact that many students already know it is easy to invent something, however further promotion and implementation of your invention in tough market conditions will require too many efforts, not related to the main competence of an inventor. But it does not mean that TRIZ and similar methods are not needed.

Still, even 6% is quite a big group, but it is more complicated to reach out to them in the field. From my own experience of teaching TRIZ at open public courses over the period of 20 years, I can say that usually people, who come to such courses, strive for the top level of Maslow's Hierarchy of Needs. They are interested in large amount of various knowledge, which among other things leads to significant deficit of time for thorough mastering of new knowledge and skills.

Today, we hear often that TRIZ has reached its saturation point and began to lose its popularity, because it seems to many that it came to the market long time ago and recent TRIZ developments are not too impressive. But it is true only to a certain degree. TRIZ is neither an iPhone nor an iPad that capture the market overnight. TRIZ is a new paradigm of thinking that cannot be fully learned and absorbed over a week. And even the fact that today far from everyone who could use TRIZ actually use it, does not mean that TRIZ is not successful.

However, we can say that it is the way in which TRIZ was brought to market all these years, has probably reached its point of saturation. Oleg Abramov [Abramov 2016] and Len Kaplan [Kaplan 2016] write about it in more details. There is no doubt that there is a number of key reasons which slow down TRIZ distribution, I would like to try to present them in a structured way below.

Reasons, related to TRIZ positioning at the market, TRIZ market and market segments:

1. *Narrow market niche.* Market niche where TRIZ is demanded appeared to be significantly narrower than we thought at the beginning. The majority of engineers do not deal with solving inventive problems. Moreover, invention is not regarded as a part of daily engineering activity. Nevertheless, as it was mentioned above, this niche is not extremely narrow. Having said this, we shall not forget about TRIZ development in non-technical fields, which can significantly expand TRIZ distribution.
2. *Depreciation of interest in search for new ideas due to the stereotyped attitude towards the process of innovation*. Till today, the market understands the word "innovation" as implementation of an idea which has already been produced. It is why very little time is given for finding new ideas. It happens because it seems to be quite easy to generate many ideas with the help of brainstorm. Probably it is correct, but what about value of these ideas? At the beginning of my career, I met with top managers of different companies and often heard a phrase "Ideas? Why should we need new ideas? We already have hundreds of ideas. The question is not how to find new ideas, but what of the existing ideas should we choose and implement?" Usually such statement means that there are no breakthrough ideas but plenty of ideas of low or average value. But the situation changes, when it comes to solving critical

problems, especially if an organization already produced a lot of ideas which do not help. Main attention is paid to value of the ideas rather than to their number.

3. *Not clear or not complete value proposition presented by TRIZ vendors*. Potential clients do not always see how TRIZ may impact their businesses in both short- and long terms. TRIZ is often understood as a quick fix to one or several customer problems. But learning and practicing TRIZ also develops such personal skills as critical thinking, systemic view, and systematic creativity. The point that TRIZ can considerably enhance intellectual capital of an organization often remains invisible.
4. *It is stated imprecisely and incompletely what TRIZ does.* If you ask people a question «What do you need TRIZ for?», you will mostly hear the following answer, «To solve a complicated problem or a problem that seems insolvable». But this is only one part of the right answer. Complicated problems were solved without TRIZ in the past. The main value of TRIZ with respect to practical problem solving is that TRIZ allows to dramatically speed up the process of finding solutions to complicated problems and increase the accuracy of forecast of systems evolution.
5. *TRIZ positioning.* TRIZ is often seen as an instrument to receive large and breakthrough ideas. There is nothing wrong about it, but such positioning also makes potential market niche smaller. These days big corporations with large budgets are not very optimistic about permanent production of breakthrough ideas. As a rule, many of such companies prefer to avoid risky investments into the development of high level ideas; they just wait when the next startup with a breakthrough idea appears on the market and acquire it, if it is proved that the idea can be implemented successfully. Nevertheless, TRIZ works perfectly with low-level inventive tasks that still give quick and significant economic effect. Such tasks are mostly related to improvement of manufacturing and production processes, decrease of process- and product related costs, improving consumer experience and so on. Such inventions can be called “incremental”, but an overwhelming number of companies are in critical need for such solutions particularly. In addition to that, solution of such problems quickly proves economic efficiency of TRIZ.
6. *Results from using TRIZ*. In modern world, consulting services mean not only search for solutions but also implementation of final solutions. However, the majority of TRIZ consultants neither offer this part of the service nor provide customers with follow-up services on solution implementation. Resolving this challenge means finding a business model which would satisfy the requirements and expectations of the client to the greatest possible extent, for example, by establishing partnership with solution implementation service providers.
7. *Incorrect advertisement wording.* You can often hear a phrase «TRIZ will solve your problem» in advertisements, but it is not true. A person solves a problem; while TRIZ ensures process navigation and offers recommendations for the choice of solution search strategy.
8. *Different interpretations of TRIZ as a term.* In advertisement and publications, you can often come across phrases like «TRIZ is science», «TRIZ is a method», «TRIZ is an instrument». In reality, TRIZ is a combination of all three levels today: TRIZ is a theory of inventive problem solving and innovative technical systems development (evolution), a set of methods based on this theory, and a set of practical tools realizing these methods.
9. *TRIZ simplification.* Because a lot of «simplified TRIZ» versions emerged, TRIZ is often perceived as another variant of brainstorm and not taken seriously. On the other hand, simplification is needed to make entry barrier for TRIZ lower. Any simplification is welcome

unless “a baby is not thrown out with a bathwater”. And there are only few proper simplifications today.

10. *Different perception of TRIZ in different cultures.* Different cultures and systems of thinking perceive TRIZ differently. TRIZ is not based on simple following each step of the guidelines, but it is based on the synergy of systematic approach to thinking and creative imagination, which can have different basis in different cultures. Because of that, TRIZ may perfectly fit one culture, but be poorly perceived in another culture at the same time. I have faced this problem many times personally, when teaching TRIZ in different countries. It is a separate big topic for research. There is a wonderful book by Professor of sociology Gert Hofstede “*Cultures and Organizations: Software of the Mind*” about the differences between cultures and their perceptions [Hofstede 2005].

Reasons, directly related to TRIZ:

1. *Not ready to be implemented into business processes, lack of business practices*. Classical TRIZ was not ready to be implemented in the business processes of organizations. It consisted of a set of isolated tools. In that form TRIZ was and sometimes still is being brought to the market. Correspondently, the effectiveness of TRIZ implementation was low. Processes with specific incomes-outcomes were not described clearly. That was why a TRIZ user without long training would quickly get lost among TRIZ tools and could not understand what to use and where.
2. *Lack of analytical instruments*. In classical TRIZ, there were no problem and situation analysis instruments, except for Function Analysis. However, situation decomposition, problem identification, its structuring and statement are the most important parts of modern innovation process. Over the last years, this task has been solved by creating a number of new methods and instruments for problem and situation analysis. For example, my TRIZ training courses include 50% of material, developed within the framework of classical TRIZ, the other 50% is represented by material and instruments, developed over the last 10-15 years.
3. *Weak connection between TRIZ and analysis of market demands*. The majority of TRIZ instruments deal with technical issues only and little attention is paid to market . There is no doubt that the laws of technical systems evolution help “predict” the next great leaps, but invention tasks appear at every stage of system evolution: let it be technical systems or business or social systems. It is why it is crucially important to ensure interaction between marketing research and instruments that ensure quick and proper reaction to changes and new requirements.
4. *Complexity*. Complexity of modern TRIZ tools for analytics and solution finding and necessity to invest quite a lot of time in education also decrease TRIZ availability for wide market segments. Nevertheless, TRIZ needs not so much simplification, as gradual development and implementation. It is already being done today with development of TRIZ educational programs for different competence levels.
5. *Insufficient motivation in the development of thinking skills and creative imagination, absence of structure of applied and psychological TRIZ parts.* It leads to a situation when TRIZ tools are mastered simply mechanically; a user is not willing to think on his/her own in the process of problem solving and expects that if he/she follows the steps of this or that method, the answer will come itself. One can often see that TRIZ teachers do not explain about such TRIZ concepts as Ideal Final Result, Multi-Screen scheme of powerful thinking

(System Operator) or make a passing mention about them without exercises. The result is like a user gets a car without fuel.

6. *Absence of high-quality TRIZ textbooks.* Although many of books about TRIZ were published, in most cases they are just popular descriptions of some parts of TRIZ or author's interpretations of TRIZ. A group of authors has been recently created to write proper textbooks.
7. *Insufficient quality of scientific publications*. Low quality of scientific and research publications about TRIZ, especially written by authors from non-academic environment increases a gap between scientists and practitioners in course of TRIZ development. In the majority of cases, it happens because the authors without scientific experience are not willing or do not have time to get familiar with the rules of writing scientific publications. Such approach leads to the emergence of insufficiently thought-out and poorly tested methods and instruments.

Reasons, related to TRIZ integration into a modern business environment:

1. *Lack of financial assessment methods of results obtained with using TRIZ.* It is especially relevant for the projects where TRIZ is used to develop the concept of a new product, and where TRIZ is used at the very beginning of innovation process. Thus, the results obtained in this phase may become "invisible" in the process of further design and implementation especially if they take longer time. Here is an example: in 1999, I consulted a company producing medical equipment on the forecast of future evolution of their products. The work was going according to a principle "No cure no pay", which meant that the payment should have been done only when the results were accepted. During assessment of the final report, an R&D department manager concluded that the development options proposed were for remote future, and my report looked more like science fiction rather than a document addressing the company near future needs. The payment was not done. In 2006, I found out that the company patented and launched new product line based on those ideas which I offered in my report. I could have tried to "restore the justice" but it would have been a waste of time. In addition to that, it was a good lesson for me to avoid such situations in the future.
2. *Low level of TRIZ integration with other innovation supporting methods*. Today, ways of integration of different but complementary methods are being explored primarily by the academic community. Sometimes, companies introduce teaching TRIZ to personnel and try to find such opportunities of integration on their own; but at the end of the day they just have no time for it. It means that a project «freezes". The problem can be solved if simultaneously with TRIZ training, we find critical points in already existing business processes and company practices, where it is possible to integrate TRIZ for a particular client.
3. *The age of the main category of TRIZ users is high*. Visiting 3-4 large international TRIZ conferences per year, I always pay attention to the absence of young people. TRIZ barely attracts young people, young specialists. It is a pity. Of course, we can continue to ride an old train using a new rail track, but it is unlikely that we go far. We need to create new formats of TRIZ content presentation and its distribution that suit the modern times.
4. *Lack of coordination between the members of global TRIZ community*. Over the last 20 years, so many different TRIZ versions and TRIZ-based tools have been created, that TRIZ beginners often feel lost when trying to make sense of the chaos of the alternatives offered. I constantly come across such situations. Today, The International TRIZ Association (MATRIZ) and the

European TRIZ Association (ETRIA) offer such coordination on global scale, and further development of such coordination is needed.

CONCLUSIONS

Genrich Altshuller was undoubtedly one of the most outstanding thinkers of the 20th century. He not only laid down the basics of a new discipline of technical creativity which has a large potential to become a new field of science, but also created tools that can significantly strengthen thinking potential in the process of finding solutions to complicated practical problems. Numerous cases of successful TRIZ application in diverse industries prove its effectiveness and efficiency to support the tasks of innovation front-end and create new knowledge and new value. Moreover, fundamental basics of TRIZ successfully go beyond technical field, which has been proved more than once. TRIZ methods help efficiently solve open innovative problems in engineering, business and social sphere.

Yet some of the ideas and conclusions discovered and made by Genrich Altshuller have not been fully absorbed and have not found application yet. I am convinced it will happen in the future. He was a person who went ahead of his time. His findings related to understanding patterns and a process of systematic creative thinking can be further developed and implemented at a greater scale. Although modern society invests considerable efforts and resources to the development of physical means of technological innovation, it does not provide enough support for the development of our problem solving and creative thinking skills which are, perhaps, most critical ingredients to create successful innovations. Thinking goes first, and technology follows up. The reasons of such inefficiency is that there are not much methodological and scientific support to teach and develop pragmatic creative thinking. At the same time, the ideas and concepts developed in TRIZ may be a solution to building and teaching a new paradigm of innovative thinking.

At the World Economic Forum in Davos in 2016, a list of skills that will be mostly demanded in 2020 was presented [Davos 2016]. Top three places were taken by:

1. Complex Problem Solving.
2. Critical thinking.
3. Creativity.

TRIZ complies with this list better than anything else, especially because it has overlapping of all the three skills. It is why it would be strange if TRIZ disappeared in the time, when there is such a big demand for the thinking skills that it helps develop. Nevertheless, because of the reasons listed above, the use of TRIZ in its classical version is limited. So, today we can observe how TRIZ moves to a new curve of evolution, which is reflected in new and updated tools, organization and structure of TRIZ processes, a broader use of TRIZ in non-technical fields.

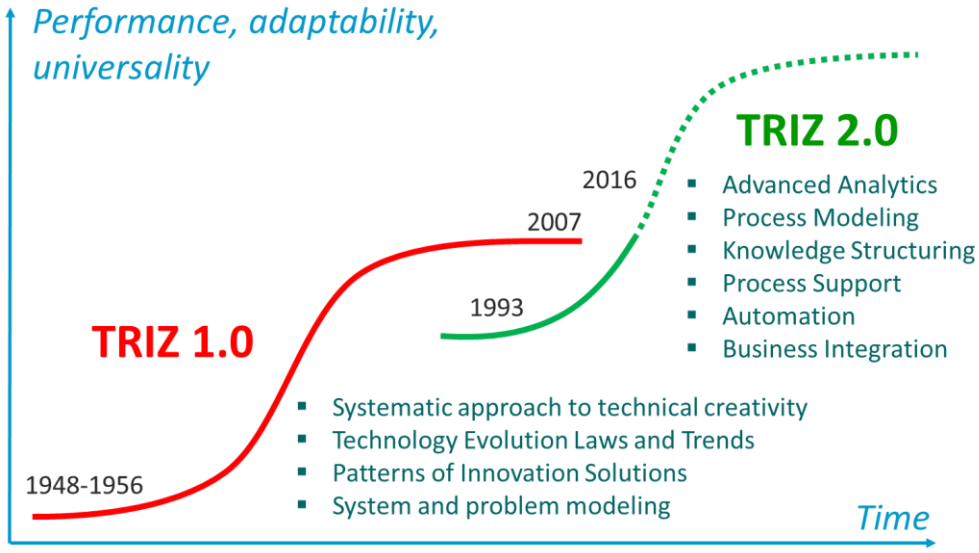

Fig. 9. Transition of TRIZ to a new S-Curve where such important parameters of value play role as performance, universality, adaptability as well as automation and integration with business and social environments.

It is very important to keep in mind that such fundamental disciplines as TRIZ do not develop and are not accepted quickly, because they require long-term studies which lead to gradual improvement. Time is needed for academic community, teachers and businesses to understand and accept the new paradigm and reconsider the existing theories, methods and practices.

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ABOUTH AUTHOR

Valeri Souchkov, TRIZ Master, co-founded Invention Machine Lab (later Invention Machine Corporation) in 1989 and the European TRIZ Association (ETRIA) in 2001. In 2003, he founded ICG Training and Consulting. In total, he trained TRIZ to more than 6000 professionals and students from over 60 countries and participated in more than 100 innovative projects. His customers list consists of more than 300 organizations, including such companies as 3M, ASML, ABB, BASF, Canon, Danone, Fujifilm, LG Electronics, Microsoft, Orange, Philips, PepsiCo, Siemens, Shell, TNT, Unilever. He is author of several modern TRIZ tools and over 100 publications on TRIZ and Systematic Innovation. Currently, he also teaches TRIZ at the University of Twente and TIAS Business School. Valeri is Executive Board Member of the European TRIZ Association and Vice President of the International TRIZ Association (MATRIZ).