Skills and Tools to Support Productivity in Creative Work

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Introduction

The 20th century was an age of scientific and technological progress. New technologies and scientific discoveries have reshaped the world and changed our standards of living. And most of the changes happened due to innovations which penetrated all areas of human activities.

Efficiency of innovation strongly depends on our capabilities of producing successful ideas that can be realized in form of viable products and technologies. Thus we deal with the issue of productivity: once we are willing to stay competitive, we must be capable of permanently raising and maintaining our innovative productivity.

During past 20 years I had a chance to observe how innovative processes are organized and performed at numerous enterprises worldwide. There was no single and unique approach to innovation, and in most cases the enterprises relied on "luck" when there was a need to produce new ideas. Among the most obvious reasons of low efficiency to generate high-quality innovative ideas were the following:

- Lack of transparent overall methodology: innovation is often confused with purely economic methods for new product development and marketing.
- Lack of innovative culture across entire organization: new products/technology creation is often addressed to R&D only instead of being a part of the overall culture.
- Lack of a process/workflow model: despite the number of existing methods supporting innovation, there is no clear pathway of how to realize and manage innovation.
- Lack of proper idea management: Still, trials & errors are used as a main mechanism to produce new ideas.
- Lack of knowledge management: 70-80% of knowledge generated during innovation sessions are forgotten and lost.

- Lack of measuring results: Often, an effect from the use of innovation methodologies is neglected.
- Lack of overall innovation management: Responsibilities are shared in most cases.

This paper addresses several key issues which should be solved to overcome these obstacles and related to the question: how to increase innovative productivity? It is possible, and if yes, then how? Can our innovative and creative skills be evolved? And how should an enterprise of the future provide infrastructure for innovation?

Automation of Innovation?

Today, any enterprise involved to the development of new products and technologies increases its productivity by raising the degree of automation. Implementation of computer-aided design, manufacturing and engineering systems (CAD/CAM/CAE), Rapid Prototyping, Enterprise Resource Planning (ERP) and other types of Information Technology (IT) systems lead to changes in the infrastructure of the organization. But despite the growing influence of Information Technology, we still have little IT support for innovative activities. Much effort has been invested recently to develop software that would help (like *Goldfire Innovator*™), but we do not have "automatic inventors", or Computer-Aided Invention systems that would allow us to create new products and technologies similarly Lego™ design set, or CAD systems. Today the problem seems to be a lot more complex that it appeared 10 years ago.
In the recent past, I was as well involved to a quite extent to the activities devoted to Artificial Intelligence and later, Knowledge Management. Significant parts of both disciplines were targeted at developing IT systems that would be capable of gathering, extracting, representing and coding knowledge to enable at least, semi-automated reasoning in order to solve problems and generate innovative solutions. A basic assumption was that once we could describe and program a logical system which could reason with a large number of facts and rules (knowledge base), we would be able to build a kind of "artificial intelligence", or something that could really simulate work of human brain and solve creative problems.
This concept failed [Dreyfus 1998], and the question still remains: what do we need to increase effectiveness of innovation? What should be the role of individual thinking, IT and other elements of infrastructure to build a really innovative enterprise? Below, we discuss several key elements of modern innovation structure and their relationships: methodology, knowledge, IT support, and management.

Formal vs. Informal

Perhaps, the most important cause of the failure of attempts to automate invention (and other areas of creativity) was an assumption that logic could solve every problem. Most of modern IT systems incorporate heavy logical mechanisms or include numerous intelligent agents that can search among huge massive of data, filter it out, transform, and display in a convenient form. No doubt, these systems help a great deal with ordinary, well-defined problems and raise productivity. But they are not capable of innovation. They can only solve "typical" problems, that is, problems that already were solved in the past and we understand exact mechanism of a problem solving method and this method is based on a

certain formal approach. Innovation still requires creativity, and this is where IT faces a barrier. What is quite clear today is that logic can not substitute creativity, but it can help triggering it.

We still do not know exactly what mechanisms help us solving non-typical, inventive problems. There are a number of theories and hypotheses that attempt to explain the phenomenon of creative thinking, but still making these theories formal does not seem to be possible. Thus, the higher degree of formalization of the underlying theory is, the higher degree of automation is achieved (Fig. 1). Take, for instance, the concept of a metaphor: it is a very strong method for producing new ideas, but we only have a vague understanding of how it works at formal level. Metaphorical way of thinking is capable of establishing high-order analogies between seemingly unrelated events or objects. And not only brain finds the link, it also makes interpretation of how we can use this analogy to obtain some positive effect.

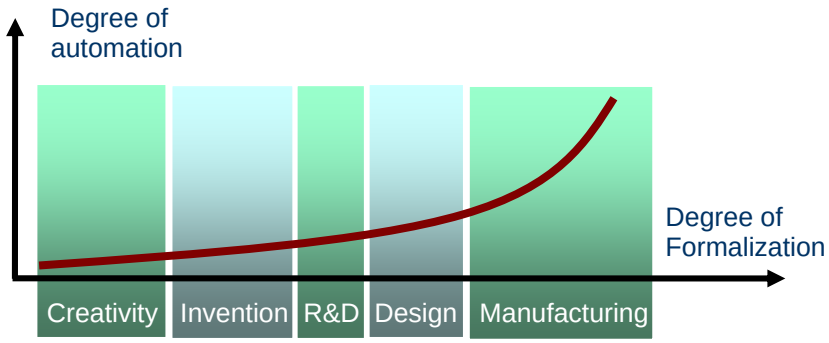

Figure 1. Formalization vs. automation during product development

It is not a coincidence that modern software development efforts are focused on knowledge and information management, as well as search and retrieval capabilities rather than on attempts to formalize different theories of creativity. Various software packages and information technologies can be successfully used to support the entire innovation process focusing on those activities that usually lead to information overload, or require proper communication and management.

Creating New Knowledge

The processes of automating of manufacturing and global outsourcing push European enterprises to seek new ways to sustain and increase their value and increase competitiveness rather than increasing production volumes and implementing cost cutting programs. It becomes clear that the future will be defined by those companies that would be capable of not only product manufacturing, but capitalize on creating and distributing Intellectual Property (IP). With strong historical and cultural traditions in science and technology, Europe still has a chance to become the world-leading "brain centre" which will focus on massive creation of high-quality IP in every branch of business.

However, in contrast to what we used to think, just possessing excellent scientific and technological education will not be enough to reach this goal. Successful innovation

results from the ability to see beyond a narrow field of specialization, ability to predict future changes, ability to find, transfer, and adapt ideas and technologies from other technological areas and businesses. As pointed in [Altshuller 1999], 98% of all inventions in patent collections represent a principle that was known before, they are different in adaptation and implementation of the principle only. Therefore the ideas we need might already exist, but how to find them?

There are two ways to solve this problem. The first way is to develop truly intelligent systems that will allow us to search among the all available information and find what we ask. But the ideas are not readily available by searching, for instance, by keywords. In most cases, they are presented from a specific viewpoint which is relevant to a specific knowledge domain. And if we do not know precisely what to search, a chance that we do not find this idea is quite high. Attempts to create semantic web technologies concentrate on developing mechanisms that will enable search by he meaning, and not by shape of words and phrases.

Another approach to solving this problem is to search for not specific ideas, but abstract and generic principles that form the basis behind different groups of specific ideas. This approach is used in TRIZ-based Systematic Innovation [Mann 2002, 2004], which is based on massive studies of creative output in different areas of science, technology, business, arts, and extraction of basic principles which identify new idea creation strategies.

However, these two approaches are not contradictory but rather complementary. We will not reach the desired degree of efficiency if use them separately. "Strong" thinking capabilities should be enriched with semantic web technologies. Ability to think at abstract level, establish analogies, understand a systemic nature of technology and business systems evolution, as well as decision making on the basis of uncertain information will long remain exclusive skills of a human, and not a machine. At the same time, developing specific technologies on the basis of generic principles is only possible by utilizing specific knowledge.

As a conclusion, a distinguishing feature of an innovator of the 21st century will be a capability to effectively use a combination of generic knowledge with ability to effectively use specific information available in different knowledge sources.

Educational System and Innovators

Our modern system of education does not create innovators. Innovation, by definition, is something new which never existed before. Since amount of knowledge grows over the time exponentially, a higher education focuses on feeding as much as possible specific knowledge and information to students and neglects aspects of developing creativity and thinking – there is simply no time for that. But to be innovative, engineers and R&D professionals should be capable of looking beyond their scope of knowledge, which is almost impossible under the conditions of informational overload. On the other hand, traditional approaches to creativity based on the attempts of chaotic development of creative skills are often ignored by traditional scientific and engineering mainstream school which does not like "inexact", non-systematic methods and thus renders them as useless.

However, it becomes no longer possible to neglect an impact on innovative productivity of people and organizations produced by such inventions as lateral thinking and systematic thinking methods which appeared in the second half of the 20th century. Several

universities already introduced teaching thinking methods to their curricula. This process will expand more and more. While all domain-specific knowledge should not necessarily be kept in the heads of specialists, since it can be easily retrieved from electronic media from everywhere, knowledge and skills with thinking methods will become crucial to provide competitiveness, survival and growth, both personal and, as a result, societal.

Technology only?

When we say the word "innovation", we usually assume that we address the world of technology since the term "innovation" is often regarded as a synonym of technological invention. However, innovation should be understood in a broader sense. Introduction of new business products and services, creative solutions found as a response to business conflicts and needs, novel transformation of businesses can as well be regarded as innovations. Solutions can be innovations with respect to different systems: to the company, to the nation, to the whole society. If a business solution helps to boost business performance within a certain company, it can as well be regarded as innovative. A major implication of this point of view is that despite the popular opinion that innovative skills are needed by engineers and scientists only, we have to reconsider a target audience for innovation teaching. Ability to think creatively and innovatively should become a core skill of every working professional who is in one or another way wants to provide his/her personal growth as well as a growth of a business he or she is involved to.

Divergent and Convergent Ways of Thinking

Now we more and more recognize the importance of generating new knowledge. The way we solve problems, produce and develop new ideas influences competitiveness of both standalone enterprises and national economies. The 20th century was featured not only by appearance of new technological advances, such as semiconductor, nuclear, laser and DNA technologies, but also by evolution of thinking methods. Alex Osborne developed a structured approach to brainstorming, George Prince and William J.J. Gordon created Synetics, and Edward de Bono introduced lateral thinking and his famous "Six Thinking Hats" method.

While all these methods target at enhancing our "divergent" way of thinking, which targets at eliminating mental inertia and expanding a search space for finding new ideas by the trials and errors method, a new group of methods for creating new ideas and concepts emerged: systematic methods, which use another model of thinking, known as "convergent". Convergent thinking is based on using previous experience and information to generate new ideas, as well as heuristics that serve as guidelines to navigate in the search space. These methods were pioneered in 1947 by the Swiss astronomer Fritz Zwicky, who introduced a morphological box approach to generate new types of rocket engines. And in 1956, a Russian inventor Genrich Altshuller published the first paper on the systematic nature of creativity, where he presented his discovery: creativity is a systematic process which is governed by general laws. By today, his work has been greatly expanded by extensive research efforts and is known as TRIZ, which is the Russian abbreviation standing for a *Theory of Inventive Problem Solving*.

TRIZ and Systematic Innovation

TRIZ was originated by Russian inventor Genrich Altshuller in the middle of the 20th century, who discovered that a process of invention has a systematic nature. Later, together with many followers and associates, Altshuller evolved his original approach and created a science of innovation, which today becomes rapidly known outside the countries of the former Soviet Union.
Modern TRIZ is a methodology and a set of tools for solving problems and generating new innovative ideas and concepts, which is based on the following philosophy:

- Evolution of all artificial systems is a systematic process and is governed by certain laws and trends. Knowledge of these laws and trends is essential to correctly forecast future evolution of any system and make proper decisions.
- Systems evolve via elimination of contradictions. A contradiction arises when any attempt to improve a system causes negative effects which are not acceptable. A standard way to reach the needed improvement is to compromise between positive improvements and negative effects. TRIZ states, that in order to generate a breakthrough solution, the contradiction should be resolved: all positive improvements must be achieved while no negative effects should arise.
- There are a limited number of patterns of creative solutions, which can be studied and described. All specific solutions can be covered by these patterns.
- To solve a difficult problem, it is necessary to formulate the problem properly by decomposing and structuring a problem space.
- Every system tends to reach the highest degree of ideality: to provide maximum benefits at lowest possible costs.
- In order to be successful in inventive problem solving, an individual should possess both generic knowledge of strategies of solving contradictions and specific knowledge of the domain in which the improvement are going to be made.

Certainly, there is no need to create breakthrough solutions in every case. For instance, for a relatively small improvement we do not need to change the basic operating principle behind a product or a technology. In this case we have to deal with "incremental" innovation. But still, as long as a problem can be represented as a contradiction, the best way to solve the problem is to find how to eliminate the contradiction with as minimal as possible changes in a system.
TRIZ suggests recommendations on solving new problems accordingly the guidelines drawn from previous experience of tackling similar problems in different areas of technology. Well-known psychological methods for activation of thinking (brainstorm, for instance) or traditional design methods aim at finding a specific solution to a specific problem. It is difficult: too much information has to be browsed and there is no guarantee that we move in a right direction. TRIZ organizes translation of a specific problem into abstract problem and then proposes to use a generic inventive principle or a solution pattern, which is relevant to the type of the problem. As clear, by operating at the conceptual level, the search space is significantly reduced that makes it much easier to find the needed solution concept among the patterns TRIZ offers.

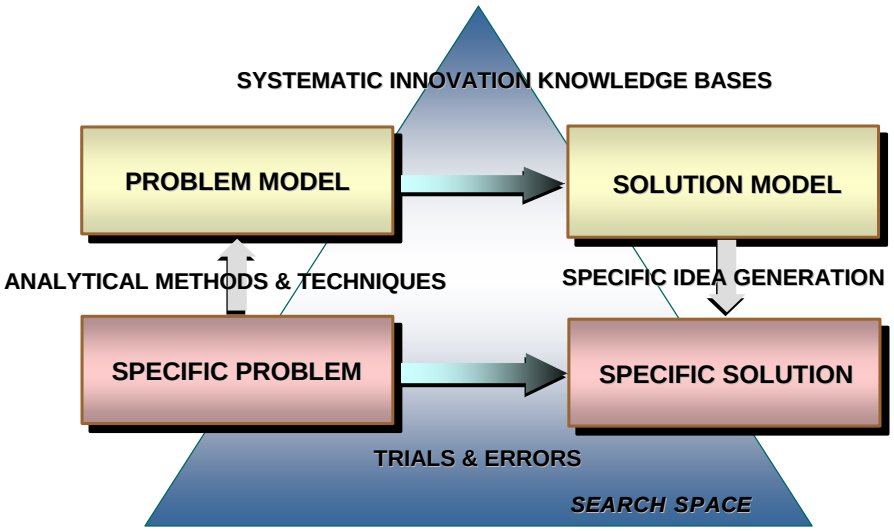

Figure 2. Problem Solving with TRIZ

What is a difference between "strong" and "traditional" thinking? Altshuller has identified that every problem that we find to be difficult is featured by two aspects: a) we do not possess knowledge on how to solve the problem, or b) a problem contains a contradiction: two opposite demands are put on the same system. For instance, a car lights should be bright to well illuminate the area, and at the same time they should not be bright to avoid blinding of a driver of another car. Contradictions are the strongest barriers which prevent us from obtaining breakthrough solutions: traditionally, instead of resolving a contradiction and satisfying both demands (which, in most cases, only seem to be incompatible), our mind tends to find a compromise, and instead of a breakthrough solution we obtain a softened contradiction.

A process of developing skills to recognize, formulate and solve contradictions is twofold: first, it enables us improving our products, services and technologies. Second, it helps us with developing our capability of system thinking. Thinking in terms of contradictions is not a natural way of doing things. To solve a contradiction, we have to break our mental inertia, to go beyond borders of existing technologies, products and systems. But instead, our mind almost always tends to come up with compromises, or trade-offs: because this seems to be safer and easier. To learn how to think and reason in a way that will help us dealing with contradictions, we must force ourselves, which is not an easy process, but inevitable if we aim at breakthrough solutions.

TRIZ offers several methods to solve contradictions. But just having TRIZ principles listed in the book on our desk is not enough: the way of thinking in terms of contradictions and their resolution should become our "habit".

Modern Systematic Innovation

In general, TRIZ and Systematic Innovation provide a range of tools and techniques to help with both analyzing problems and solving them. Among the major TRIZ tools are:

- *Techniques to analyze systems, problems, and situations*: Functional Analysis, Contradiction Analysis, Cause-Effect Analysis. These techniques help to represent

systems and problems from different viewpoints, reveal crucial causes of problems, identify evolutionary potential of systems, find "hidden" problems, reformulate problems.

- *Techniques to solve problems and generate new ideas*: Inventive Principles, Inventive Patterns, Collections of scientific and technological principles. These techniques help with finding relevant problem solving strategies from TRIZ Knowledge Base and contain collections of innovative solutions patterns.
- *Collections of laws and trends of system evolution*, which enable understanding at what stage of evolution a system is, what specific changes a system, either technological or business, will experience in the future, and how to implement these changes.

In 2003, Samsung Corporation awarded TRIZ with the title "The best practice of innovation", after a range of successful projects which resulted in new innovative solutions and costs reduction. One of the TRIZ projects saved the company US$ 1 billion. For Boeing, TRIZ helped to win a project that brings company US 1,5 billion.
Although originally TRIZ was created and developed for solving technological problems, during last 10 years it was discovered that the same basic principles and innovative solution patterns are well applicable to solve business, management, marketing and other types of problems. A number of TRIZ educational centers today introduce teaching TRIZ way of thinking to business professionals and managers who are not related to the technology.

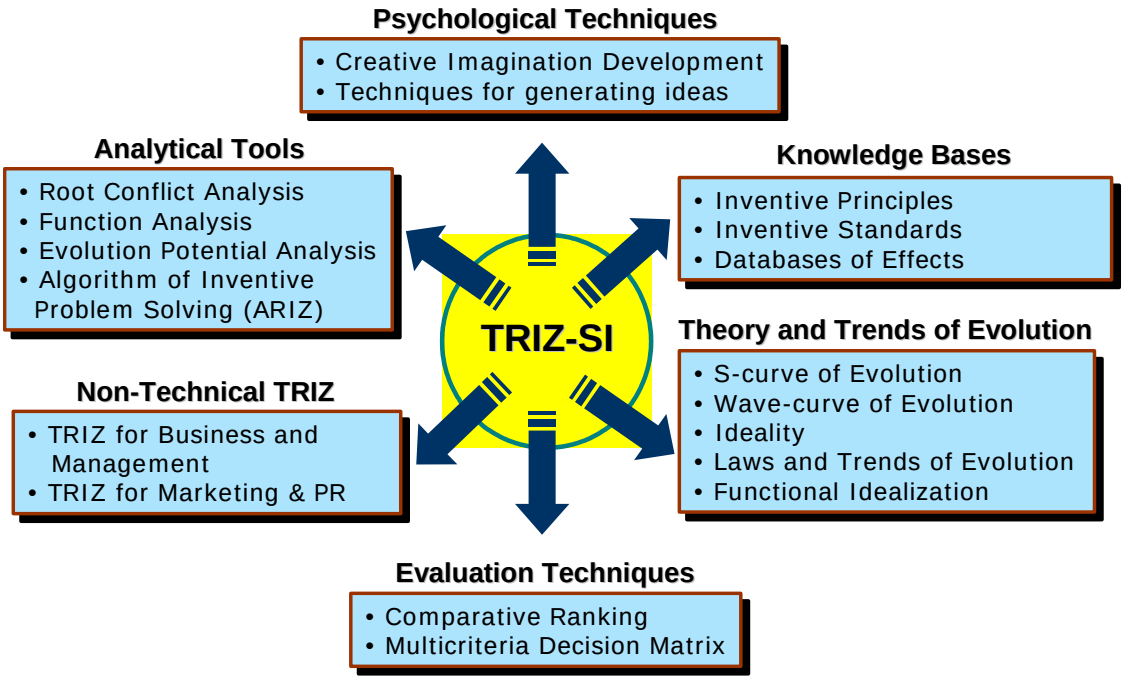

Figure 3: Modern Systematic Innovation

Today, TRIZ and TRIZ software are used in about than 5000 companies and government organizations worldwide. For instance, designers at Eastman Kodak used TRIZ to develop a new solution for a camera's flash. The flash has to move precisely to change the angle of

lightning. A traditional design includes a motor and mechanical transmission. It complicates the whole design and makes it difficult to precisely control the displacement. A newly patented solution uses piezoelectric effect and involves a piezoelectric linear motor, which is more reliable and easier to control.
In general, the use of TRIZ provides the following benefits:

- Considerable increase of productivity in searching for new ideas and concepts to create new products or solve existing problems. As estimated by the European TRIZ Association experts on the basis of industrial case studies, these processes are usually accelerated 5-10 times. In many cases, new solutions became only possible from using TRIZ.
- Increasing the ratio "Useful ideas / useless ideas" during problem solving by providing immediate access to hundreds of unique innovative principles and thousands of scientific and technological principles stored in TRIZ knowledge bases.
- Reducing risk of missing an important solution to a specific problem due to a broad range of generic patterns of inventive solutions offered by TRIZ.
- Using the scientifically-based trends of technology evolution to examine all possible alternatives of future evolution of a specific technology or a design product and select the right direction of the evolution.
- Leveraging intellectual capital of organizations via increasing a number of patented solutions of high quality.
- Raising the degree of personal creativity index by training personnel to approach and solve inventive and innovative problems in a systematic way.

TRIZ is the most powerful and effective practical methodology of creating new ideas available today. However, TRIZ does not replace human creativity – instead, amplifies it and helps to move to the right direction. As proven during long-term studies, everyone can invent and solve non-trivial problems with TRIZ.

Role of Personal Creativity

TRIZ introduces logic behind the inventive process and provides us with a number of high-order patterns of past solutions, which can be used to generate new ideas. A key concept behind TRIZ is that those contradictions that drive technology or product evolution should be resolved in most ideal ways, and this approach meets most crucial needs of any product or technology development enterprise: to reach maximum value at lowest possible costs. The ability to establish high-order analogy by re-using previous experience to solve a new problem belongs to the category of abstract thinking, therefore the use of TRIZ does not provide exact solutions since these solutions simply do not exist yet. But TRIZ-based Systematic Innovation acts as a supporting and organizing method for thinking and helps to define and choose the right solution strategy.
TRIZ software packages available from different vendors do not automate invention: instead, they provide fast and convenient access to TRIZ or customized organization-specific knowledge bases, and can as well be used for learning TRIZ. Today, Systematic Innovation is the most powerful technology for solving innovative problems and producing new ideas, but mastering Systematic Innovation requires considerable time and

effort. This might be considered as an obstacle in a short run but as already proven by some industries, is a winning strategy in the long run.
As a consequence, the role of creating new ideas and concepts still remains and will remain to the great extent the responsibility of human problem solvers. But since the rate of new product development accelerates rapidly, to stay competitive we need to transform innovation to well-planned and predictable activity; and currently it becomes clear that systematic approach to innovation if the best platform to achieve this transformation.
Some companies still resist introducing systematic methods for innovation support though. They believe that breakthrough innovations result from unstructured and chaotic thinking only. This statement is partly correct, but the systematic approach is not a total replacement for unstructured thinking. TRIZ was developed to avoid costly mistakes by the trial and error approach, but not to avoid "free will" creativity. Instead, the best results are produced by a synergy between systematic methods and creativity.
Therefore a winning strategy will be to train such innovators, who will be capable of both convergent and divergent thinking. As clear, to achieve this on a broad scale will not be easy, since it requires a change of the existing educational system.

Managing Innovation

Innovation is not about creativity only. We can think of great ideas, but they will never see the world until implemented. Often, new, seemingly great and bright ideas are rejected since they might not be implemented at all: e.g. they violate physical laws, or too expensive, or market research shows that customers would not be willing to invest to these new products or technologies. If an idea is accepted, there will still be a long way to transform it to a sellable product. Thus, the degree of quality of generated ideas becomes one of the critical factors that determine future competitiveness of a specific business. Wrong investments do not result in the return of investments – and this is why systematic methods for innovation must not be ignored since they increase the probability of producing high-quality ideas and concepts as compared to traditional trials and errors methods.
It becomes clear, that companies need a person responsible for the whole cycle of innovation: from recognition of specific problems and situations that demand for innovation to successful implementation of innovative ideas in form of new or improved products and technologies. Today, this role usually belongs to other types of managers who share other responsibilities as well, like CTOs, CIOs, business development managers, technology managers, or knowledge managers. But innovation itself is a big area, involving different projects, and especially, cross-disciplinary knowledge and communications. As noted in [Roswell et al 2002], innovation management involves 5 categories:

- ***Idea management*:** development of organization-specific methods for managing idea generation processes.
- ***Innovation life-cycle management*:** coordinating the entire innovation life cycle from the envisioning stage through to the rewarding of individual innovators or innovation workgroups.
- ***Product development management*:** realization of ideas in form of commercial products and technologies.

- ***Environmental innovation management*:** constant monitoring and "scanning" of the environment in which an organization operates in order to predict future innovations.
- ***Enterprise-wide "Outside-the-box" innovation management*:** creation of organizational culture that stimulates creative thinking.

We tend to believe that successful innovation life-cycle management involves managing three major components: creativity, knowledge and process:

- ***Creativity*** is needed to break the psychological inertia, to invent a new solution, or to recognize a new application area for the existing technology. Without thinking out of the box, we would be still tied up with old technologies. Systematic and logical methods which enable re-using previous creative experience represented at abstract level helps boosting creative capabilities of inventors and problems solvers.
- ***Specific scientific and technological knowledge*** is required to find new ideas, especially in hi-tech areas. A great deal of technological solutions results from knowledge of technology itself, knowledge of physics, and knowledge of technology in general.
- ***Process management*** is among key elements of successful innovation as well. Although we used to think that management has little to do with creativity (which turns to be a wrong statement, modern world demands creative managers), management is a crucial factor that makes innovation happen.

I observed several times how good ideas were "lost" due to the poor management of the innovation process or problem solving sessions were organized in a chaotic manner without even registering ideas that were born during the sessions. On one occasion, I noticed that the company released a new product, idea of which was developed with my involvement several years ago. When I contacted personnel of that company who were involved to the project, I was surprised to know they even were not aware of this new product. But luckily, in this case the product was brought to the market. In some other cases, ideas were simply forgotten and lost. But sometimes, old ideas are a good source for new innovations, since they were rejected for certain reasons in the past which do not exist any more. But ideas are lost.

Why does this happen? One of the reasons is that, as known, once we solve a "big" problem dozens of "small" problems arise: a new solution has to be verified and in most cases, modified and adapted; a prototype has to be built, costs have to be optimized, a final product has to be developed, and so forth. And not all of these small problems are easy to solve. Sometimes we need to apply innovative thinking again and again to implement the same idea.

In addition, managers face a risk management issue: it is unclear at the beginning of the project if the product will be successful on the market. Thus one more task of the innovation manager is how to solve a contradiction: how to reduce risk as much as possible while the risk should be high; regarding what direction to select to evolve product or technology? This contradiction can be solved by the use of system thinking and understanding the trends of the technology evolution.

IT System Supporting Life-Cycle Innovation Process and Management

Today it is not possible to organize effective work of any business without proper IT support. Since this paper is not intended to address technological details of innovation infrastructure, we only present very briefly general aspects of a possible architecture of IT system that would support life-cycle innovation management. As follows from our experience, a very potential architecture would result of combining two technologies: process management and knowledge management technologies [Marwick 2001]. The first technology defines and identifies all steps and procedures of the innovation process flow and its management, while the second technology defines how to identify, gather, manage and communicate information and knowledge. The resulting IT support system for innovation should be capable of supporting both process management and knowledge management, and providing connections with third-party tools developed to support specific parts of the innovation process, such as, for instance, mind mapping tools, databases of effects and TRIZ principles, evaluation tools, decision making tools, etc.

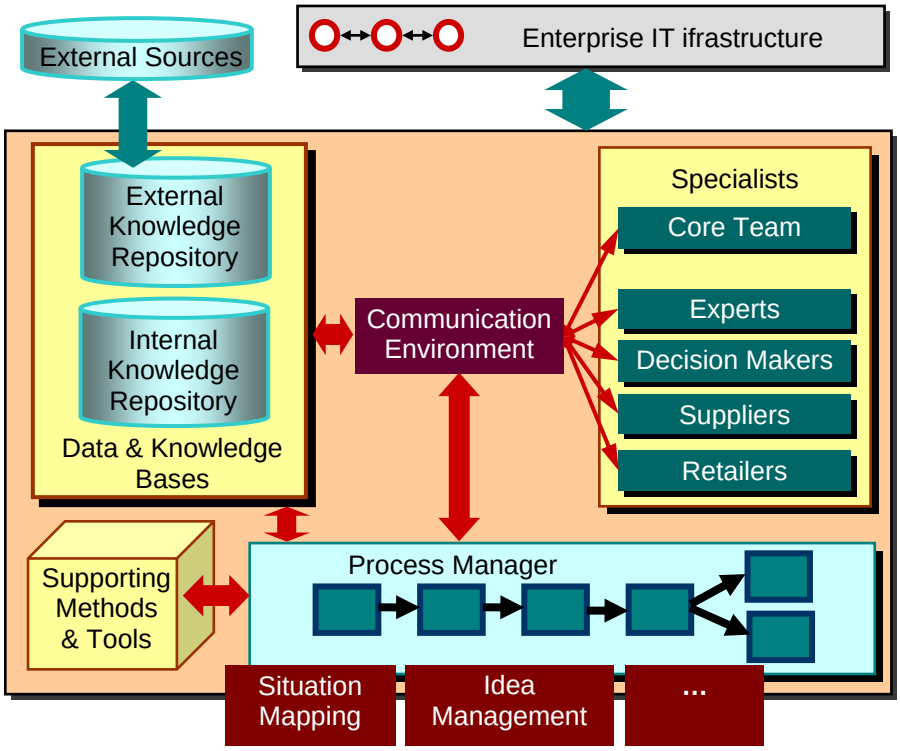

Figure 4: Architecture of IT System to support innovation processes

Core functionality of such system should provide:

- Establishing the process of innovation relevant to a specific organization: from information gathering and mapping best practices to final ideas assessment, evaluation, and decision making, as well as tracking and measuring results.
- Registering all information and knowledge generated and collected during a project: requirements, views, generated ideas, changes, modifications, comments, decisions, explanations, etc.

- Providing access for all project specialists to internal and external data and knowledge bases (with proper access permissions).
- Providing communication among project specialists and management involved to the project.
- Supporting decision making.

Establishing Innovation Infrastructure

Summarizing, we can outline four major components of an innovation infrastructure (Fig. 5):

- *Innovation Core Team* which accumulates expertise and experience with methods, techniques and tools of systematic innovation and creativity, as well as with innovation process management. A core innovation team which is literate with these methods and possessing multi-disciplinary background, and equipped with relevant IT tools should be responsible for generating intellectual property and solving most difficult problems. The same team can be responsible for education of staff in new thinking and innovation methods. An important issue is that no matter how these methods are related or not, an organization should establish a process of idea generating which will provide the highest efficiency of work. It is important that formal methods and informal ways of thinking should be well balanced: as known, too much formality kills creativity.
- *Innovation Manager*: a person, who is a strategic thinker, knows innovation process, familiar with methods used along the complete innovation cycle, responsible for innovation, and possesses enough power to implement innovative products and technologies, capable of developing business process of innovation for his/her organization.
- *Knowledge Sources*: Seamless access to scientific and technological expertise relevant to every innovative project, both internal and external must be established via mapping, organizing and structuring various knowledge sources. External expertise plays a significant role for innovation since many breakthrough ideas are based on combination or utilization of technologies that reside outside of the problem solver' expertise. All possible expertise can not be kept within a single enterprise, therefore there is the need to establish and maintain connections with third-party scientific, technological, and consulting organizations. Finding, adding, structuring and permanent monitoring of new knowledge sources should be a necessary activity for innovative teams and individuals involved to innovation processes.
- *IT Support*: Information Technology support for innovation process management is needed to manage large amounts of knowledge and information that might arise when solving specific problem or developing new products. All information flows from idea to product should be maintained, including the abilities of documenting decision making processes, establishing communication means to connect all parties involved to the innovation process, as well as tracking and measuring results. Specifically, communication channels should be established not just among those enterprise specialists who are involved to a project, but with customers and

suppliers who often produce very valuable ideas regarding how to improve products and technologies.

Presence and even evolution of these four components is necessary to turn a traditional company to an innovative company. They form an innovation system of an enterprise. Neglecting any of these components might affect negatively any company survival in the long run.
Another important aspect is formation of innovation culture at an enterprise. In the old economy, innovation at large companies usually was triggered in a bottom-up way, by engineers, employees, etc. One of the pioneers in the field of corporate innovation, 3M allows its employees spending 15% of their working time for their own experiments [Ziegler 2002]. This greatly stimulates innovation at the company. But today the roles are expanding: top management should not only stimulate innovation, but be totally involved to the innovation process.

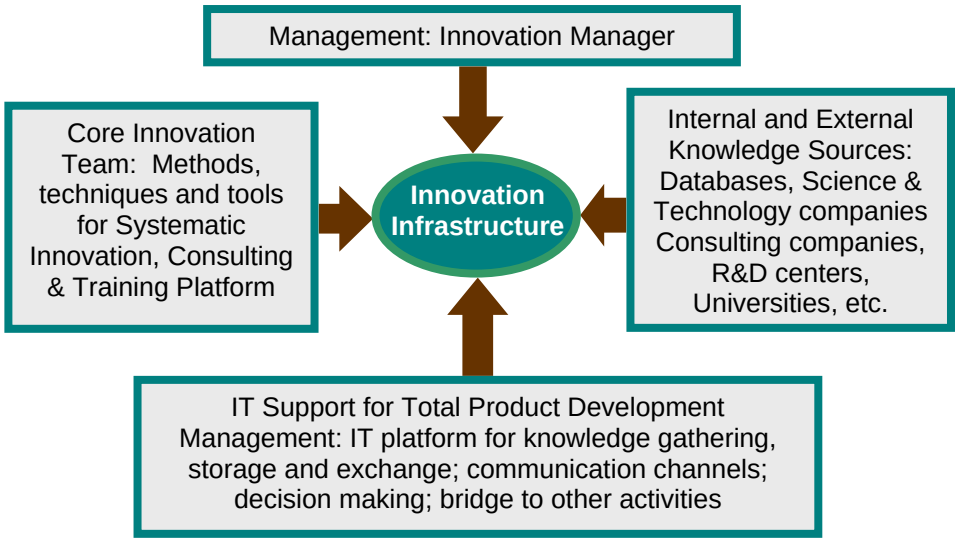

Figure 5: Ingredients of innovation infrastructure

Conclusions

There is a common opinion that innovation is mostly used at the early phases of a new product development process. This widespread opinion is not correct. Innovation should belong to almost every department of a modern enterprise: from R&D unit to sales and maintenance departments. It becomes a task of a company's innovation management to make every business unit or department innovative.
As predicted by Gartner Group in 2002, "By 2005, innovation focused knowledge workers will represent 30-to-35 percent of the employed workforce in developed nations." [Harari 2002]. We are now in 2005, and can judge if this becomes reality. If knowledge becomes widespread goods an economy can rely on, there will be a permanent need to generate new knowledge to stay competitive. And in most cases, new knowledge is a basis for innovation. A task of IT tools becomes to provide most effective communication and knowledge management during innovation process. Thus the role of innovative thinkers

equipped with relevant IT tools supporting innovation will become critical for survival in the knowledge economy.

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