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PREFACE

On behalf of the University of Florence, of ETRIA the European TRIZ Association, and APEIRON the Italian Systematic Innovation Association, it is my great pleasure to welcome the participants to the 4th edition of the World TRIZ Future Conference.

In 2004 ETRIA is proposing its fourth annual meeting where a broad spectrum of subjects in various fields will be presented and debated with experts, practitioners and newcomers of TRIZ.

The last two editions of the conference have been focused on scientific, academic and pedagogical aspects of TRIZ development in 2002 and best practices in systematic innovation through industry in 2003.

The aims of the 2004 edition are the integration of TRIZ with other methodologies/tools and the dissemination of systematic innovation practices even through Small and Medium Enterprises.

According with this objective, the first day of the conference has been co-organized with the Italian TRIZ Association APEIRON. The participants to the conference will be able to follow the presentations and gain the maximum value independently from their TRIZ knowledge since the sessions will follow an increasing expertise order.

This book consists of the collection of articles and extended abstracts submitted to the TRIZ Future Conference by academic and industrial TRIZ experts from everywhere in the world. The final edition was made possible thanks to the effective work and support of the MTI (Methods and Tools for Innovation) Lab of the University of Florence, coordinated by Prof. Paolo Rissone.

Florence, Italy, 4 October 2004.

Gaetano Cascini

INVITED LECTURES

WHY DOES TRIZ FLY BUT NOT SOAR?

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Abstract
TRIZ was virtually unknown in the West until 1991, when Invention Machine Corp. began marketing its software in the U.S. Since then, hundreds of small and large corporations on both sides of the Atlantic, as well as in Japan and Southeast Asia, have been exposed to TRIZ. Today, dozens of individual consultants and consulting firms compete for their share of the fledging global TRIZ market, and the number is growing. Many books and hundreds of online articles on TRIZ are now available in English and other major languages, and googling the acronym returns thousands of entries.

All signs point to a steady proliferation of TRIZ, but much work is still required to reach a tipping point. An ideal scenario would have all technology-based companies embrace TRIZ, and all their engineers employ it in their professional pursuits. However, despite the fact that TRIZ has repeatedly proved itself an extremely effective innovation method, today, most leading companies, as well as the majority of technologists, are still unaware of it. Furthermore, just a small fraction of those numerous firms that have attempted TRIZ, use it on a more or less regular basis.

Various obstacles to the corporate deployment of TRIZ have been identified. Among the most often cited ones are the following (in no particular order): lack of corporate innovation culture, shortage of good text-books, relative complexity of TRIZ, its incompatibility with traditional project management approaches, insufficient integration with other productivity enhancement tools, "not invented here" syndrome, and the "latest fad" fatigue." While these factors and their obvious implications are certainly valid, none of them individually or even collectively, can fully account for the slothful implementation of TRIZ.

In this article, I argue that the implementation problem is much more fundamental, and that it can hardly be fully resolved. The primary reasons are: 1) There is no *perceived* tangible need in TRIZ (one can survive and even prosper without it), and 2) TRIZ, as any scientific discipline, is undemocratic (not everyone can and should use it). Thus, in the foreseeable future, one can expect that TRIZ will be deployed via three main channels: 1) basic training to develop a general awareness of the method, 2) development of small in-house TRIZ consulting groups, and 3) professional consulting firms that will participate in most stages of the client's product development process.

PROFESSIONAL STRATEGIC INNOVATION CONTRA INNOVATION MANAGEMENT - ONLY -

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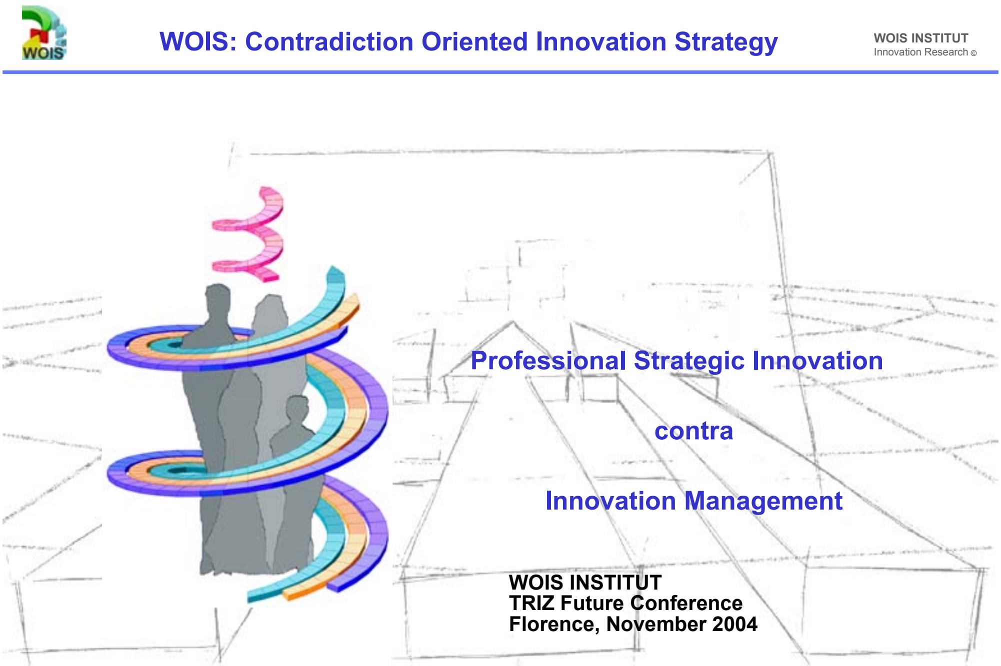


Numerous case studies of companies' developments show, that in particular during critical economic situations, random direct market hits are insufficient for safeguarding company's long-term future.

Consequently innovation processes are necessary that focus on generating sustainable innovations in a more reliable way.

Frequently, specifically the most important early strategic stages of business and development processes can be characterised as a great strategic gap. The importance of finding new directions and initiating corresponding development processes is frequently underestimated, unstructured and unappreciated.

One reason might be that hardly any methodology exists, that supports and stimulates the work of these phases.

For gaining innovative advantages, all departments need to implement processes that aim at repeatable success. New thinking technologies and management models are required that are able to identify and utilise success pattern throughout the company. Beside a high level of expert knowledge it is primarily the corporate culture with an over spanning "innovation competence" that is the key to future competitiveness and differentiation potentials.

With its contradiction oriented attempt the innovation strategy WOIS is a unique mental model for both: deriving challenging development directions and realising successful innovations. WOIS with its new core theory of contradictions can be used as a basis for also integrating known methods of designing value creation chains in an innovative way.

For challenging the limits of the innovation power of companies the integration of a challenging management culture, new thinking technologies as well as the cultural change towards "productive innovation knowledge" needs to be achieved.

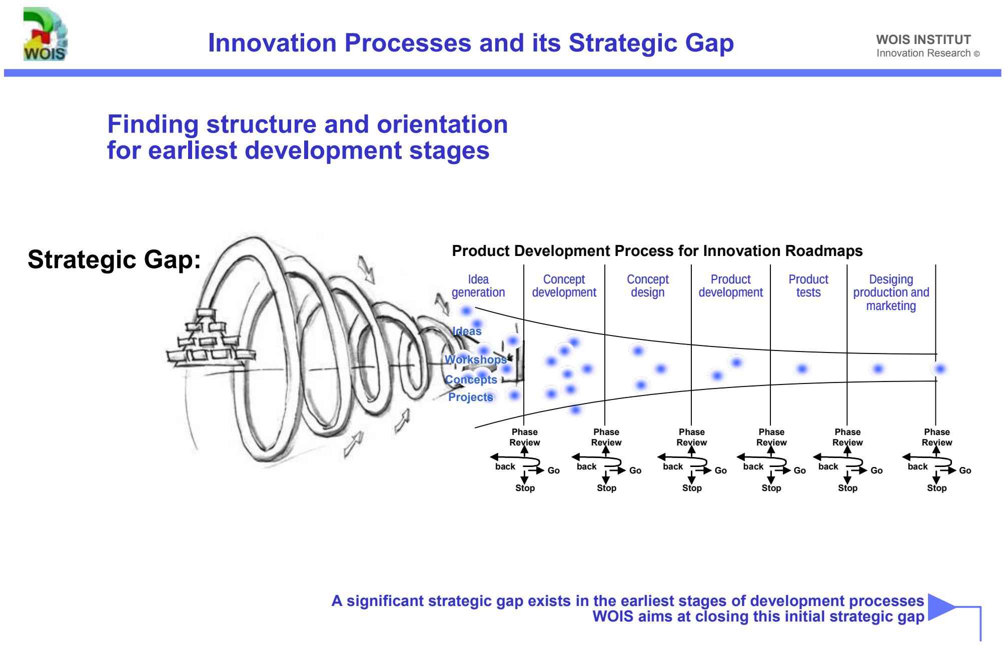
The innovation strategy WOIS provides strategic orientation perspectives for searching for hidden laws of evolution and chances for innovation:

- **Marketing** developments:
  market-, needs- and trend developments
- **Performance** portfolio developments**:**
  Evolution of products, processes, services and organisations
- **Organisation** developments:
  Corporate culture and thinking technologies
  Competence developments of individuals and the entire company
- **Resource** developments:
  Material-, energy-, space-, time- und information resources

This applies to development phases such as direction finding, decision making and innovation development phases within the general business processes - such as the initiation, qualification, management, organisation, creation, development, design, marketing, realisation, management and learning process of companies.

The combination of the innovation strategy WOIS with core knowledge of the company's management throughout the value creation chain offers the chance to develop an extraordinary innovation power.

Throughout the industry detailed process descriptions exist for all kinds of business processes. Often, future perspectives are developed based on ‘roadmaps’ that result from evaluating spontaneous ideas, former project results and preliminary concept proposals.

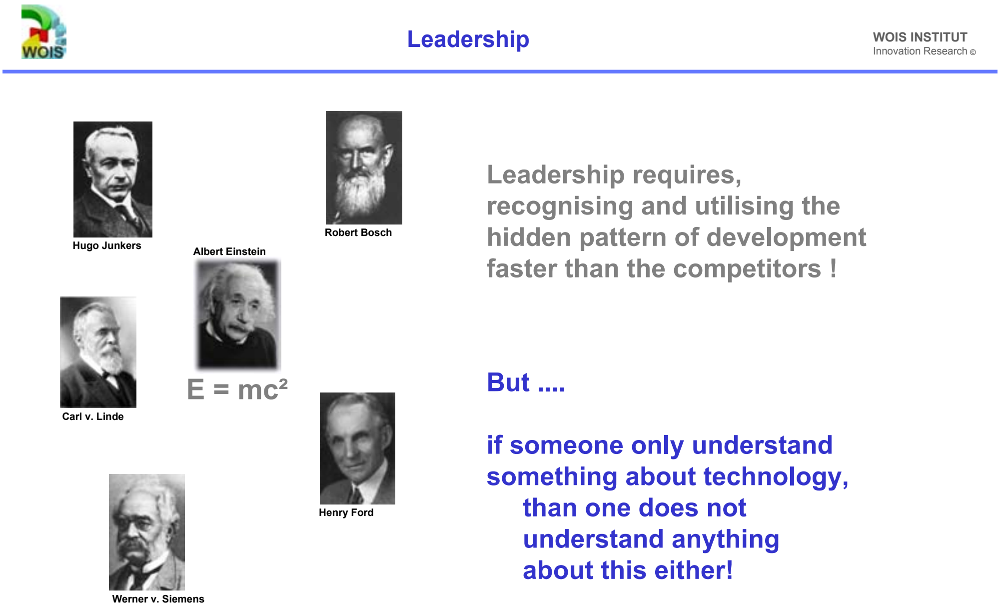


In many companies a threatening gap exists especially at the early, strategic phases of development processes. The importance and impact of defining repeatable and reliable systems for initiating strategic innovations is frequently underestimated.

One might think that companies that fail in defining sustainable strategic approaches will suffer considerable disadvantages - but due to similar behaviours of the competitors this is not the case.

Nevertheless, significant advantages can be gained through implementing systems that permanently allow the flexible adaptation of the development program, without loosing the clear focus for medium and long term targets.

Striving for and maintaining leadership requires a broader view than just being in command of leading edge technological knowledge.

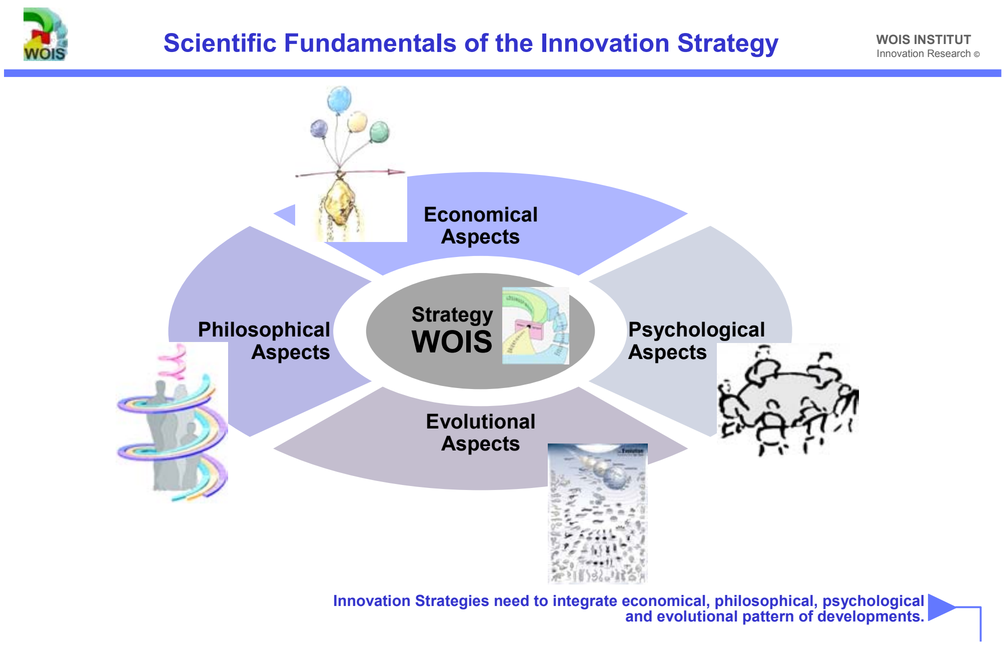


Leadership is all about recognising and utilising the hidden pattern of successful developments faster than the competitors. Consequently, a strategic framework is required that helps gaining a more reliable view. This especially applies to decisions regarding chances for the future orientation and design of value creation chains.

Looking at the bibliography of the great inventors of the industrial revolution it can be observed that none of them focused on exploiting one great idea only but had extraordinary wide spread interests. Their inspiration by social issues, historical and natural phenomena opened their view and encouraged necessary change.

In times of multi-criteria problems, company over spanning development networks and ever faster development processes, it is essential for companies to ground significant decisions on a reliable sustainable decision basis.

Especially 'stock market governed' company's belief in 'management by financial target agreements', but fail in implementing the ability for developing future perspectives. They are dead-locked in efficiency programs, unable to develop and implement strategies for future wealth creation.

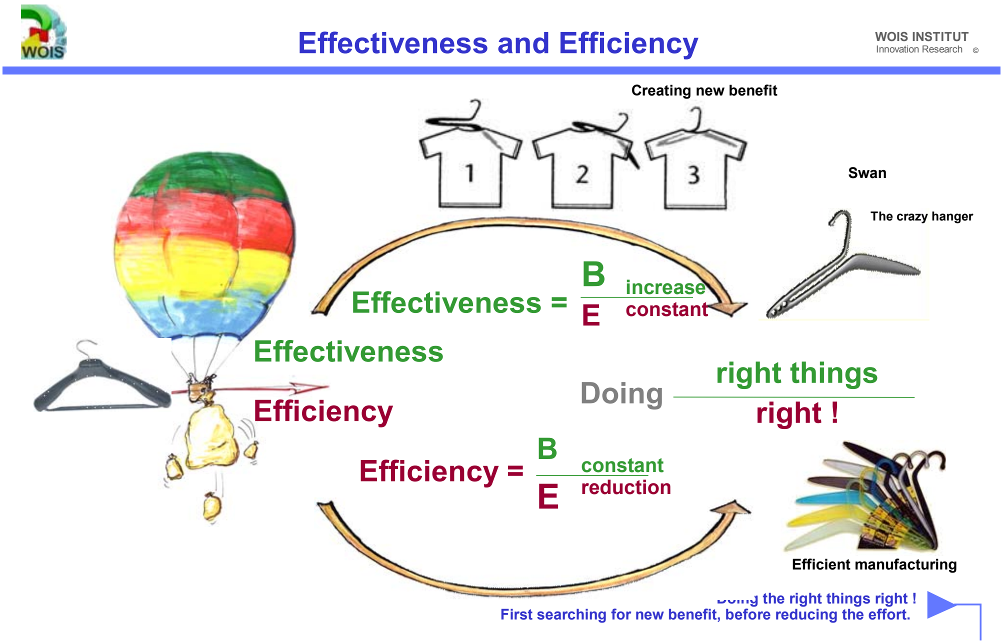


Future orient companies require a system that consists of a

- growth oriented economical model,
- an energy focusing philosophy,
- a culture of a commonly shared understanding concerning future challenges and
- knowledge on the hidden pattern of competition.

The innovation strategy WOIS integrates these aspects into one powerful strategy for business, marketing, product, process, organisation and resource innovations.

During the last years it became a strong tendency throughout Europe that companies as well as government programs became ever more efficiency oriented.
Efficiency measures bear the advantage of being easily measurable. In addition they are useful to demonstrate short term quick wins.



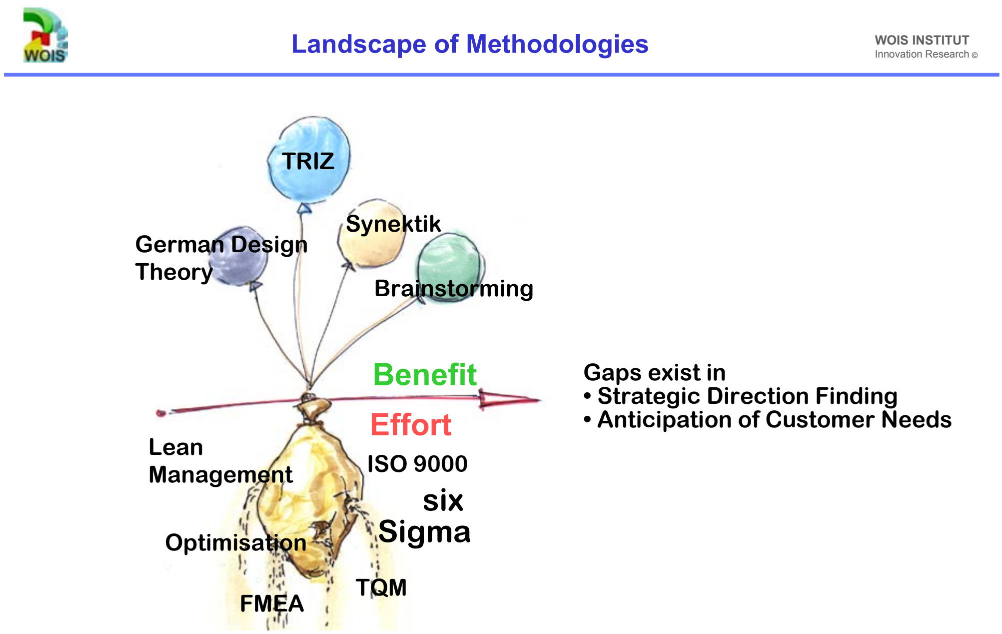
Unfortunately it is the nature of efficiency instruments to work toward a natural limitation. Without creating additional benefit - and thereby increasing the effectiveness - there will be no long term success.

It is a reoccurring pattern of market evolution that competitive systems become more and more optimised and at the same time less differentiated. Unfavourable price competitions are the result of such developments until one of the competitors breaks the barrier of similarity. This usually happens by introducing a significantly changed solution that is characterised by new functionality and therefore also new benefit.

As a consequence future oriented businesses first seek for solutions that offer new benefits for the customers before focusing on efficiency measures.

A wide range of tools and methods exist to assist development processes.

Most popular tools aim at reducing the effort and “ensuring against failure” - in principle following the line of argumentation “It cannot be my mistake I am certified”.

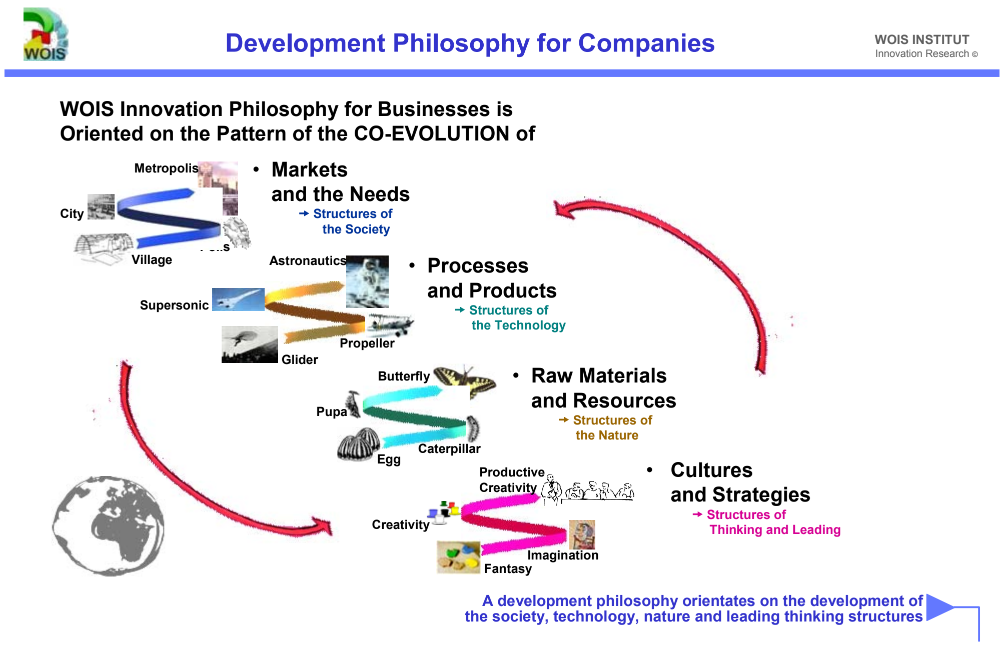


Nevertheless, companies do not gain leadership because they are not responsible and certified against mistakes, but due to people that are responsible for the success.

Therefore, approaches are required that focus on generating new benefit prior to applying tools to minimise the effort.

Modern innovation processes must not rely on random intuitive ideas. They necessitate repeatable processes that increase the likelihood of delivering reliable short, medium and long-term perspectives with powerful corresponding concepts.

Searching for the common ground for modern innovation sciences it became obvious that neither engineering or economical sciences, nor natural sciences are a suitable basis as they do not incorporate all relevant aspects.



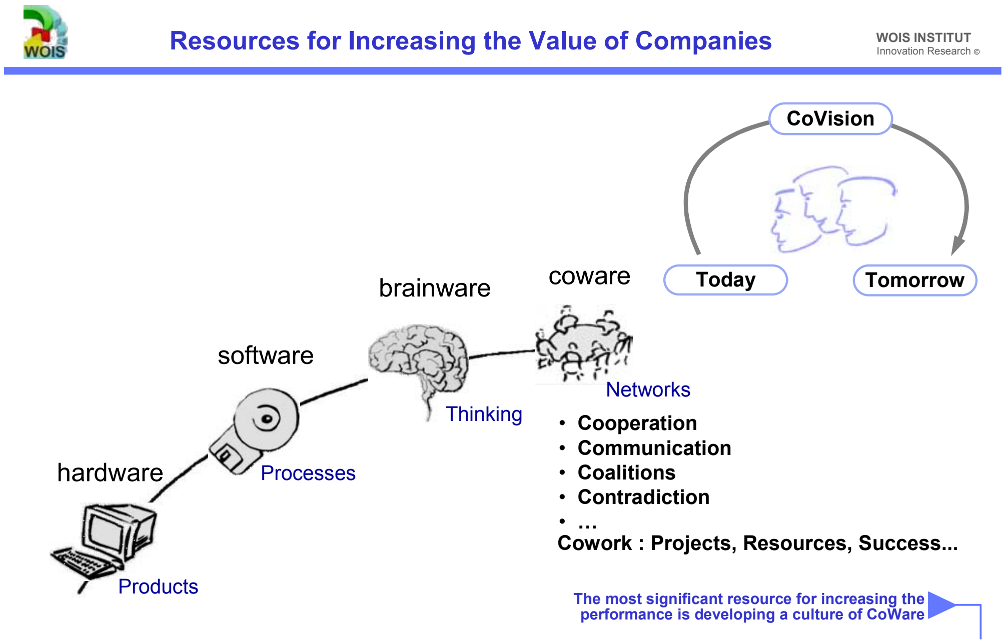
The origin of science is the philosophy. It defines basic interdependencies of the nature, society and thinking.

This broad view combines all relevant aspects of modern challenges, despite of the aspect of technology. Accordingly, a modern innovation philosophy needs to combine the aspects of social, technological, natural and thinking aspects.

Such a definition would be too general to be of any help for modern innovation processes. Nevertheless, specifying this definition shows that successful approaches need to consider the Co-Evolution of the markets and needs, products and processes, raw materials and resources as well as of the culture and strategies.

Beside the innovation philosophy also the resource basis of companies defines its competitiveness.

Modern hardware and software resources are the backbone of every business. Developing businesses additionally requires the people that are able to come up with unique, competitive ideas.



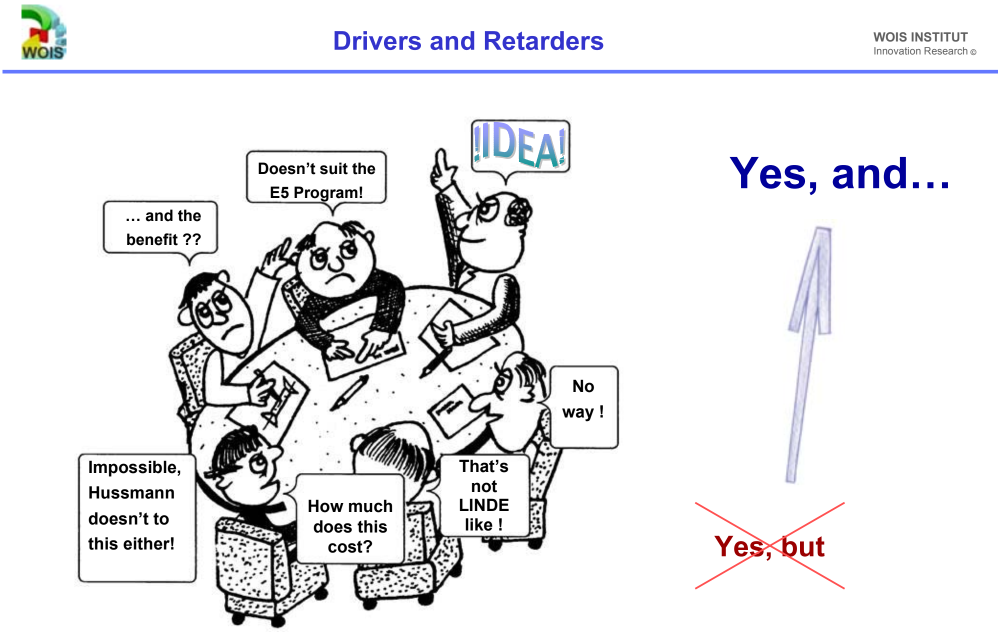
Nowadays the resource question became even more complex. Business relations need to cover so vast issues that it is nearly impossible for one person to integrate the brainpower to develop new ideas from the initial stage to its market introduction. This indicates at the same time, that the brainware of individuals is no longer the ultimate resource for business success.

It seems to be the ability of a business to implement a climate of coware - of cooperation, communication, contradiction, coalitions, common … - that characterises its potential for competitive change.

Despite of the cultural aspect of coware, forward thinking businesses are able to implement a challenging, resource focusing common vision that helps to align development activities toward a commonly shared target system.

The western culture is based on logic and is, as a consequence used to assess and judge new ideas at once. This is helpful to prevent substantial misunderstandings and wrong conclusions.

The strength of logical conclusions during later development phases is at the same time the limiting factor for the early ones.

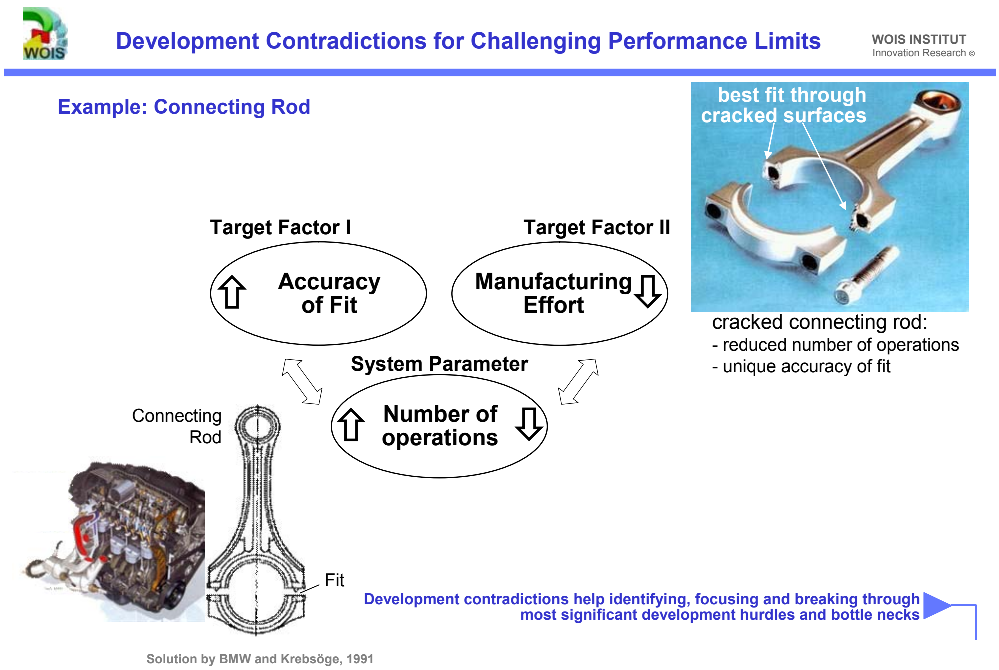


As soon as one comes up with a new idea, untrained people are used to start validation. At once all reasons are in our mind, why this new idea might not work.

Innovation processes require a climate that searches for the 'good idea behind' and to develop this seed to a growing plant.

Innovations break through current performance limits and thus also aim beyond current barriers and hurdles. The innovation strategy WOIS utilises this characteristic of innovations to focus available development resources on challenging such contradictions. By describing the logic of the constraints of existing leading edge systems the boundary of available technologies is characterised.

The example of a connecting rod development in 1991 of the companies Krebsöge and BMW shows the idea behind the model of development contradictions and its use to aim beyond existing boundaries.



The ever increasing efficiency of engines required the fit of the connecting rod to be machined ever more accurately.

At the same time the machining effort had already developed to a level that demanded a decreased manufacturing effort.

→ Such a situation describes a typical target conflict. The targets seem to contradict each other and target conflict management tools could assist in finding the most suitable compromise.

Real innovations are not based on compromises and the theory of WOIS provides a model that assist in overcoming such development contradictions.

WOIS searches for the reason behind the target conflict by defining a parameter that links both targets in a logic manner.

To increase the accuracy of the fit, the number of operations has to increase.

At the same time, to reduce the manufacturing effort, the number of operations has to be reduced as possible.

Now this is a typical catch 22 situation. The number of operations has to increase and decrease at the same time!

The approach of WOIS is to define the favoured growth direction of the parameter and to require the target to be fulfilled that is usually linked to the opposite growth direction.

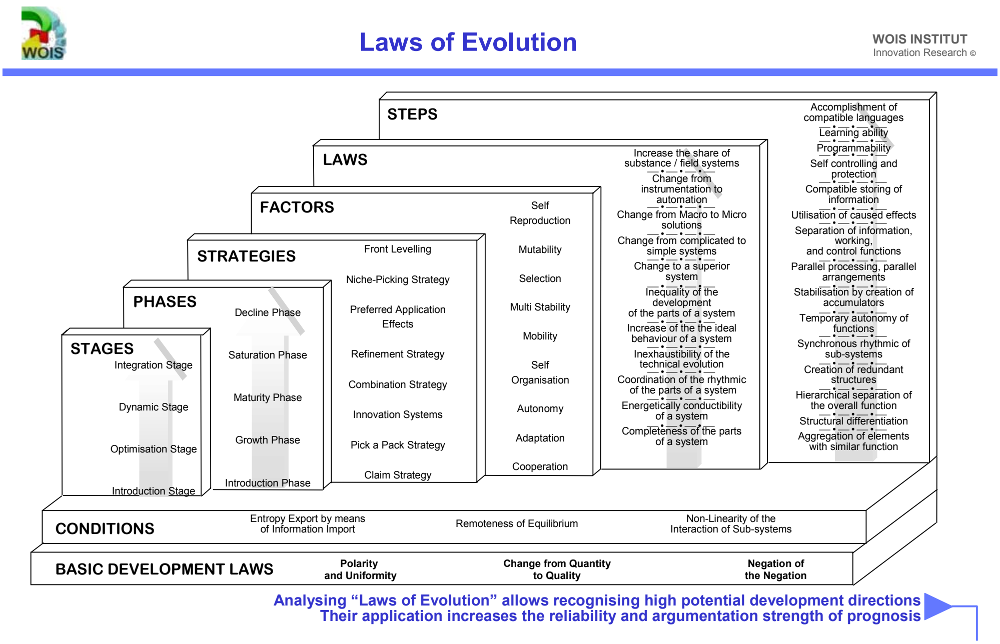
In the case of the connecting rod there would be ideally no operation, but at the same time the accuracy of the fit as high as possible.

The solution to this paradox task was the development of a cracked connecting rod:

Realising the highest possible accuracy with only one machining operation.

Frequently situations occur where fundamental decisions are required, but directions are hard to decide due to a lack of available information.

At the same time systems are usually already developed to a level where nearly everything seems to be ideal, resulting in the question of possible future oriented development directions.

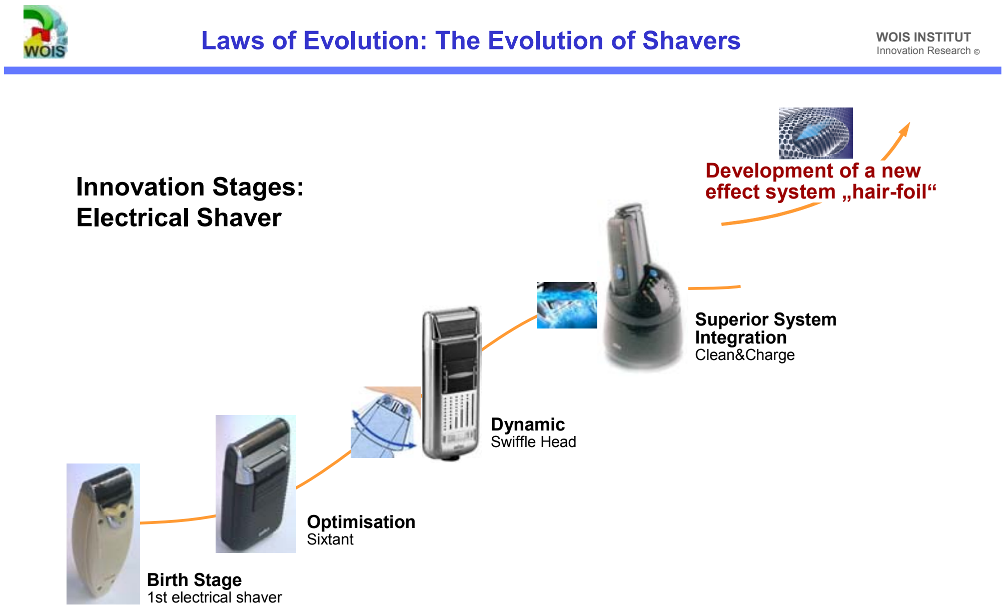


In such situations the laws of evolution help to characterise the current development level to then indicate on an abstract level likely future development paths.

They assist development processes as guidance for strategic orientations and possibilities for innovative shortcuts.

The following page describes as an example for the laws of evolution the group of "Development Stages"

During its life cycle systems usually follow the path of development stages:



At any time systems exist for the first time. Technologies become INTRODUCED - working the first time.

Subsequently, engineers OPTIMISE structures to suit the demand in an overall optimised manner. Typically competitive systems become more and more alike during this phase.

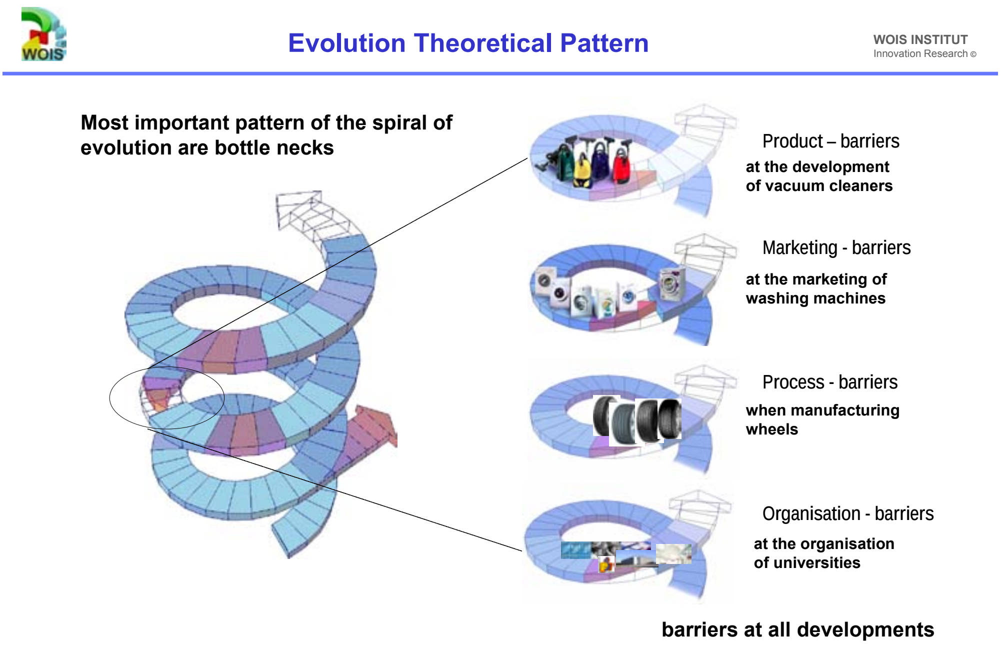
In such situations additional innovation potential can be gained by introducing DYNAMIC effects, such as to make the system behave ideally during distinct use phases. An example would be the dynamic connection of the shaver head that allows the shaver to adapt to the convex and concave curvature of the skin.

When having exploited the chances of the dynamic stage, the potential of systems becomes expanded by INTEGRATING additional subsystems or by integrating the entire system into its superior system, or by adding additional sub-systems - such as a clean and charge station for the Braun shaver example. This step then opens up a new field for innovations.

Besides the stages, also Development Conditions, Basic Development Laws, Phases, Strategies, Factors, Laws and Steps exist as Laws of Evolution. All together the Laws of Evolution build a rich source for inspiration. They can be understood as a strong argumentation basis for increasing the reliability of arguing future development directions.

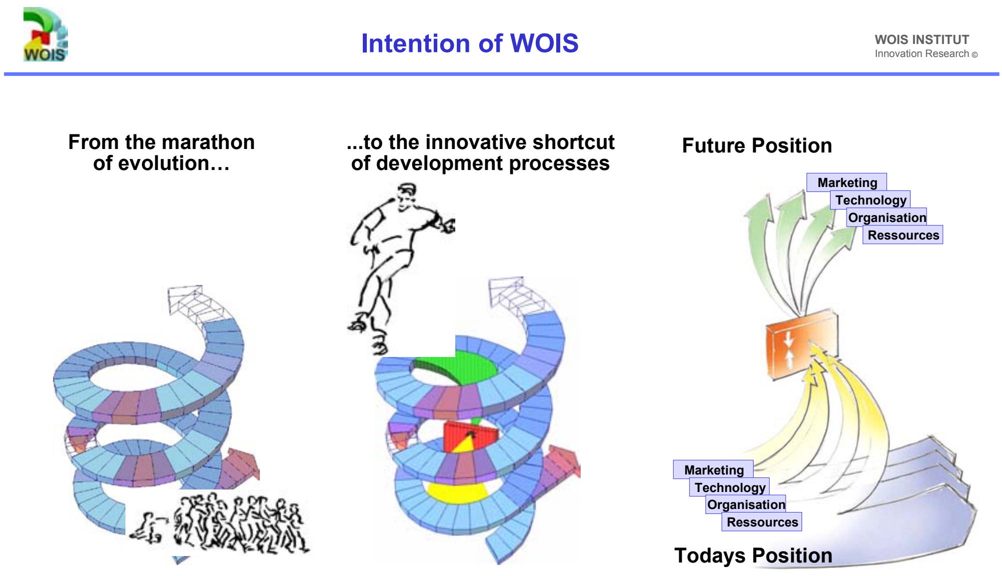
A general pattern of evolution are ever reoccurring development barriers.

Such bottle necks and hurdles can be observed during the development of all systems, no matter whether products, processes, organisations, marketing concepts or entire businesses are developed.



It is the intension of modern innovation strategies to use the pattern of development contradictions as a strong crystallisation points for developing future chances.

All development processes aim at shortcutting the spiral of evolution and breaking through development barriers.

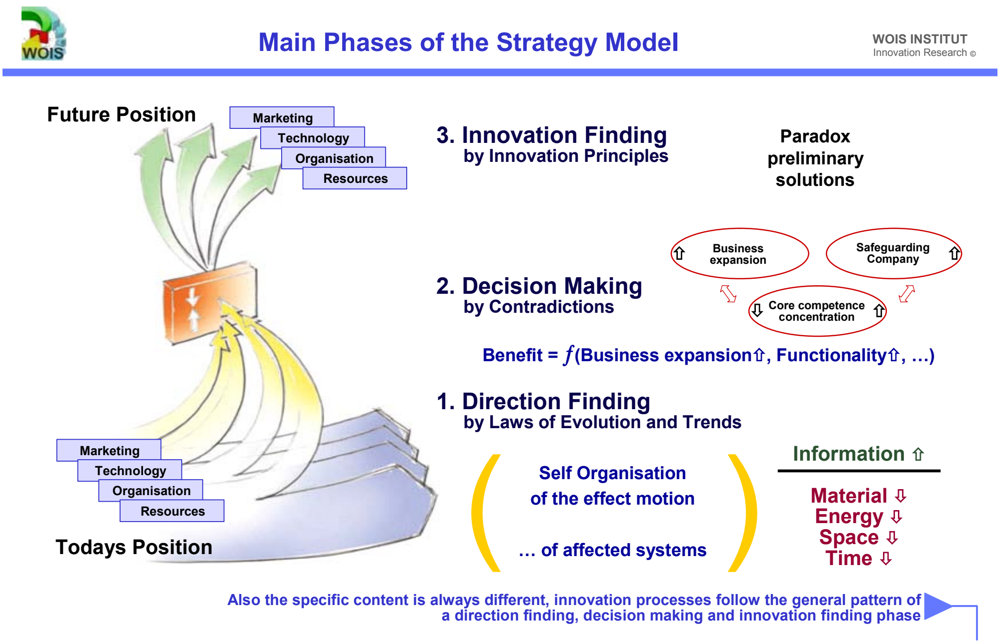


It is only the strength of few approaches to provide distinct models for doing so.

Generally applicable models need to consider that innovations relate not only to technological, but also to marketing, organisation, resource developments and their special interactions.

In general, decision making processes can be described as a process that can be structured in three phases:

- An orientation,
- decision making and
- innovation finding phase.

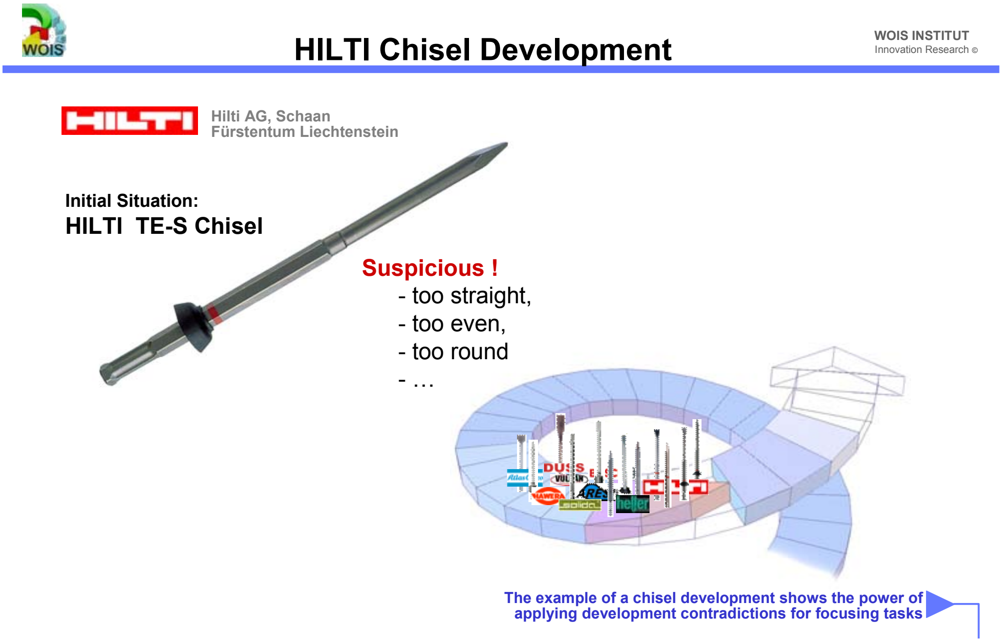


The innovation process of WOIS provides analytical models and strategic orientation tools for each of the phases.

An example for a surprising, but simple technological solution is given by the HILTI chisel development project on the following pages.

The project has been run as a corporation of HILT and the WOIS INSTITUT.

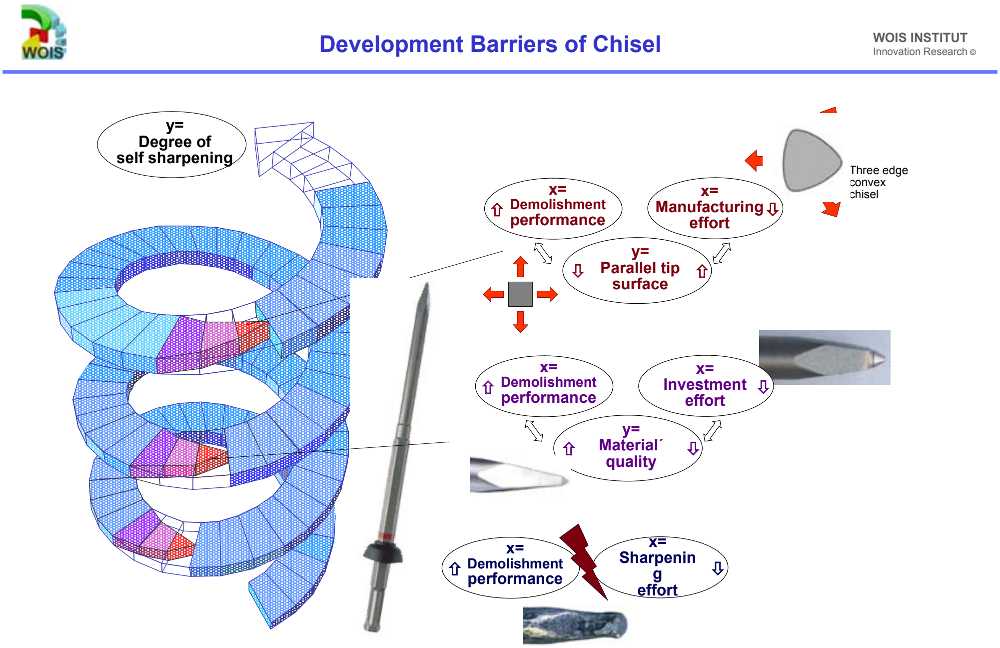
HILTI chisels are highly competitive, professional tools.



Even though it seems to be an extraordinary challenge to search for innovation potentials at such simple geometries, it is at the same time suspicious that the chisels are as straight, even and round as they are.

Nature does not build exactly straight, even our round structures either.

During the initial orientation phase it was found, that the “degree of self sharpening of the chisel” is one general development direction that would be worthwhile to be followed up.



Accordingly the initial target conflict was defined as follows: on the one hand the demolishment performance of the chisel should be increased, but at the same time the sharpening effort reduced.

A preliminary search direction was to attach a high quality material tip onto the chisel.Nevertheless, all promising technologies would result in either immense manufacturing or material investment effort.

Therefore, this search direction was left.

It would be advantageous to come up with a solution that would not require ever more high quality material, but at the same time would increase the demolishment power.

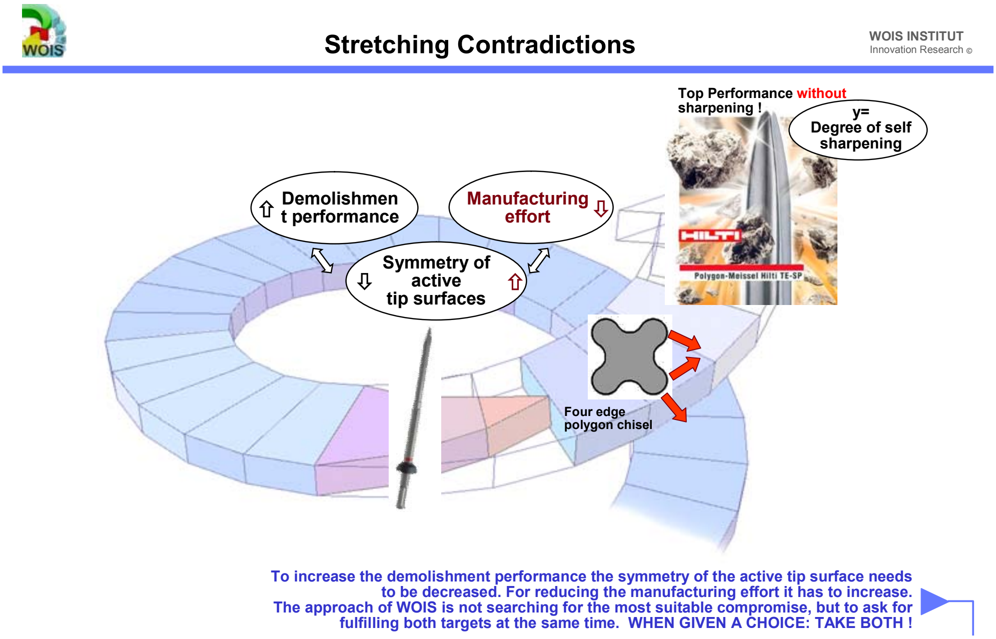
Geometrical effects seemed to open up interesting possibilities.

Based on the idea that parallel tip surfaces are not an ideal geometry to introduce demolishment forces, a convex chisel geometry became developed.

This chisel had a significantly increased demolishment performance, but the self-sharpening effect was not jet developed to the desired level.

It seemed as if there would be too much material in the sole of the chisel. Furthermore it was suspicious only to divert the force vectors, as demolition is highest where force vectors intersect!

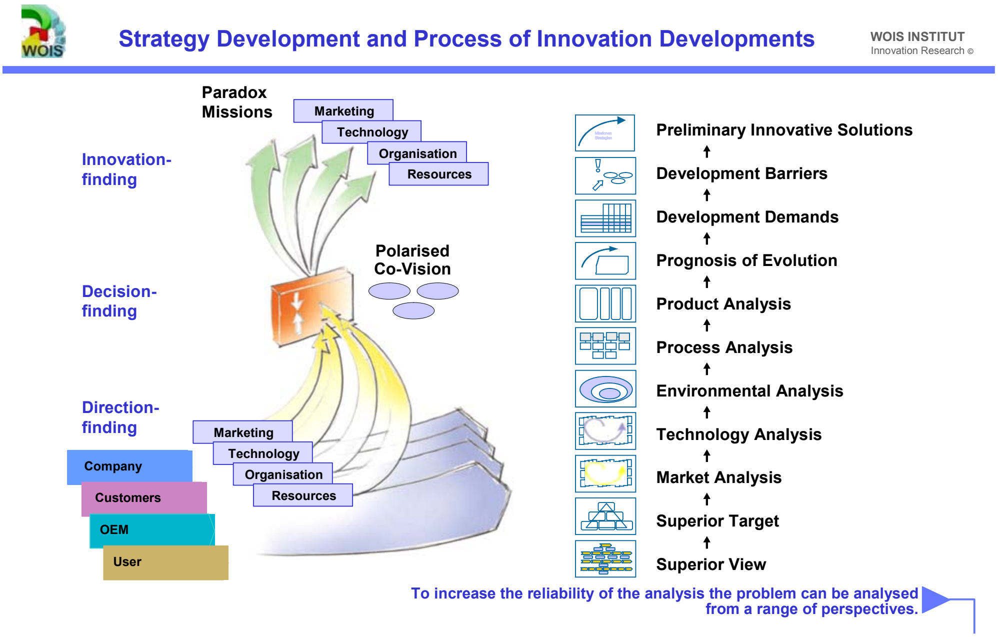
A geometry that focuses the defocused force vectors by a concave surface geometry became the breakthrough.



But there is no breakthrough without facing new barriers. The manufacturing requirements were the reason for designing the final shape of the shaft.

Nowadays HILTI can advertise this new chisel generation as a self-sharpening tool with an increased demolishment performance.

Behind such solutions there is always a detailed analysis phase.



The definition of a superior point of view prevents overseeing significant changes within neighbour business fields.

The superior target defines the general current challenge of the business field.

The market and technology analysis results in identifying significant changes of the market environment and corresponding technologies. Social and technological trends provide further orientation to this analysis.

During the environmental analysis the boundaries of the system and its interaction to the environment becomes investigated to identify integration potentials.

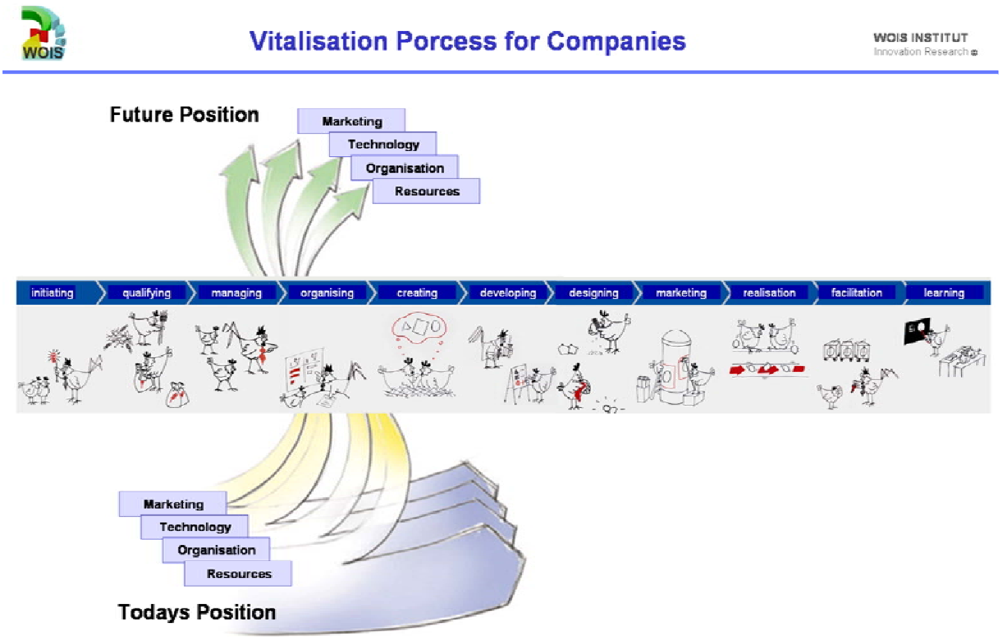
The product and process analysis investigate the configuration of the current system in detail, to then use the laws of evolution to predict possible future development directions.

Throughout the entire analysis development targets and parameters are collected and assembled to a matrix of development contradictions.

Investigating this matrix, subsequently to all the analytical work - it is now possible to extract the most important key contradictions as key development barriers.

During the solution finding phase innovation tools, such as the innovation principles, help to overcome these barriers.

When changing the focus from specific product and process development projects to business development programs, the focus of the analysis phase changes from product and process analyses to the analysis of the entire business process.

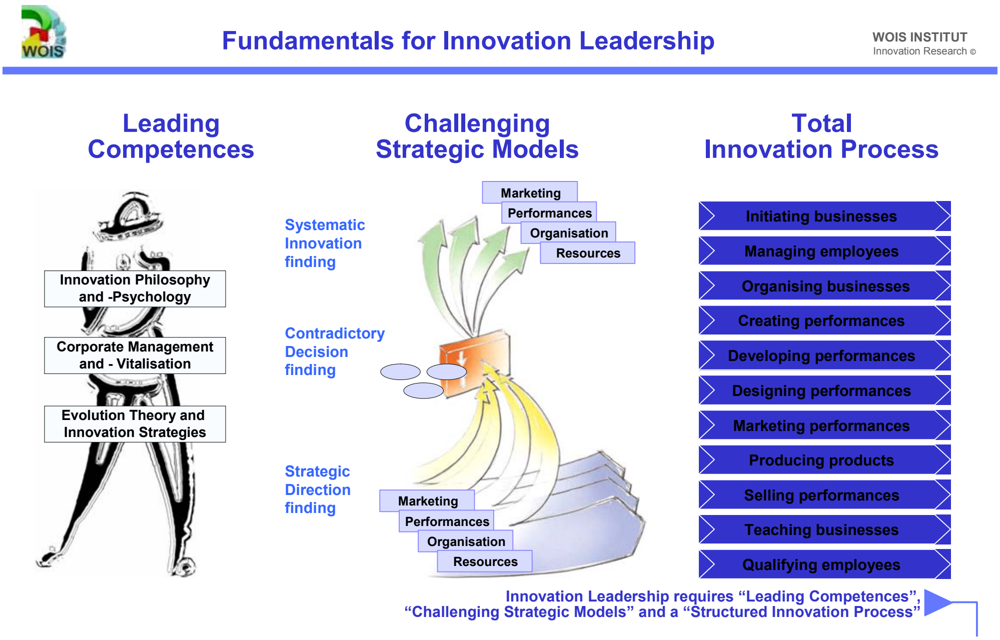


The processes and structures from "initiating businesses" to "learning from experience" need to be analysed and developed toward a shared "CoVision" with challenging missions that support surprising strategies.

To summarise, modern Professional Innovation needs to integrate.
Leading core competences, such as an

- innovation philosophy and psychology,
- corporate management and vitalisation structures as well as elements of
- leading innovation knowledge.

This knowledge needs to be combined with challenging strategic models that assist in anticipating measures for company developments.



Innovations need to influence the way that companies work. Therefore it is essential to reflect both, the analysis as well as the solutions to the entire “Total Innovation Process” of the company.

CASE STUDIES

LIGHTING HELMET FOR FORMULA 1

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Abstract
The paper explains the development of a new helmet concept for racing-drivers based on TRIZ methodology. Resolving of the system contradictions, the usage of SUFIELD models and the appliance of the trends of evolution brought out a brand new technical concept – the lighting helmet. It is shown how the different TRIZ tools where applied and how the technical concept is build up finally. It is pointed out how the basic idea could be enriched very easily due to this basic approach and which practical benefits the car-drivers get. At the end of the documentation the verification of the system concept and the validation of the methodology are explained.
Keywords: Lighting Helmet, Technical Contradiction, Evolutionary Trends, TRIZ methodology.

1. Introduction

The basic consideration starts with the fact, that the adaptation of the human eyes due to different conditions as object distances or light intensities can take about one third of energy consumption of a human being. The weariness as a result of eye - adaptation and accommodation (see Figure 1) leads to enlarged delayed reaction times and hence to possible failures. The eye-stress will be multiplied if we consider the situations of racing-drivers as in Formula 1 because of changing lighting intensities, difficult racing courses and high speeds. Courses with increased shadowing or tunnels (e.g. Monte Carlo) showed more risk potentials. When we analyze existing helmet constructions we make out that also different parts inside the helmets are not designed for lighting issues perfectly. This lead us to the question, if there are new technical approaches to reduce eye-stress under above mentioned conditions, to reduce failures, to increase the security of racing-drivers and take into account their physical fitness. Since TRIZ can be used for new product concepts very efficiently, the idea for the Lighting Helmet for Formula 1 was covered with the knowledge of TRIZ methodology.

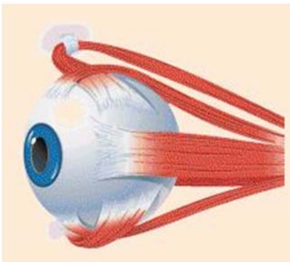

Figure 1. Eye adaptation and accommodation lead to high energy consumption of human being

2. Formulating the Technical Contradiction

If we consider the situation, when a car drives through a tunnel and is getting out of it (end of the tunnel). The lighting conditions are changing very abruptly with lighting intensities ranging from few 100 Lux (unity of the lighting intensity) values up to approximately 100.000 Lux values e.g. at a sunny day. The eyes will need 10-30 seconds to adapt to this change but meanwhile the driver is confronted with a very limited visibility. Blinding effects will enlarge this problem at the transition from dark to bright light.

The first main question we have to ask is: which system parameter has to be chanced to force or reduce the problem? The problem occurs if we change the *speed* of the action. For very slow motions the eye adjustment and the speed of the car are coordinated in terms of time. The contradiction arises with high speeds, where the visibility is getting lost. Therefore we can define SPEED as the improving parameter and ADAPTABILITY as the worsening parameter (SPEED vs. ADAPTABILITY) out of the 39 technical parameters. We used the software Goldfire Innovator from Invention Machine Corporation (USA) to define the problem and finding out new concepts based on the Goldfire Innovator software modules Researcher and Optimizer (see Figure 2).

Altshuller's Contradiction Matrix shows us statistically the following three inventive principles to solve this technical contradiction.

A) Dynamic Parts B) Preliminary Actions C) Copying

These principles which are described in more detail in literature and in software programs have the highest probability to solve the formulated contradiction. A technical contradiction can be conveyed into a physical contradiction where only one parameter is in conflict with itself. We'll explain this approach later on in this report.

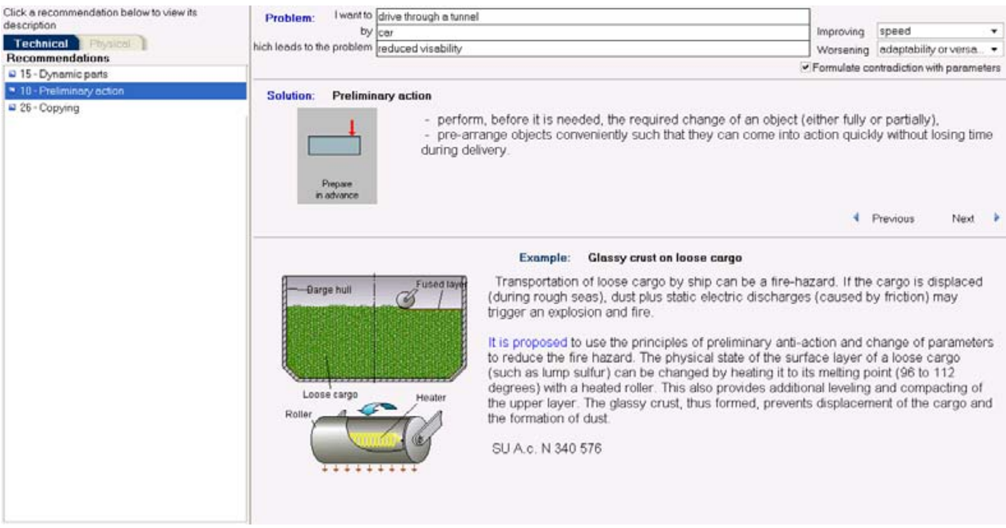

Figure 2. Inventive principles as a result to the formulated technical contradiction (Goldfire Innovator – IMC)

2. Basic Concept Idea based on solving the technical contradiction

Within the next step we try to combine all founded inventive principles into one technical concept, because we're looking for solutions where all inventive principles are included in the invention. To getting rid of all existing thinking barriers, we start from the scratch. The system we are looking at exists out of mainly three elements: room 1 which is a dark tunnel, room 2 which is bright and is outside the tunnel, the eyes which are the passive objects and finally the sun which is the subject. This segmentation we can use for a further SUFIELD model. If we assume there's no existing technical system used at the moment (we have no helmet) and we try to combine the three inventive principles to the zone of operation (light is getting directly to the eyes) we can define a system that should act as following (see Figure 3).

1. Dynamism of the light > use artificial light and control it
2. Use the light before > use the artificial light before the transition (end of the tunnel)
3. Copying the daylight > use artificial light and use different light

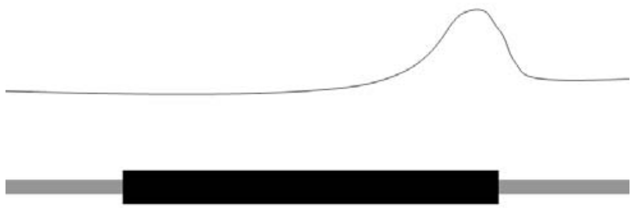

Figure 3. Upper curve shows the brightness of an artificial light source, which is increased at the end of the tunnel; the lower curve demonstrates the street (grey) and the tunnel (black). The driving direction is from left to right side

Using all of these inventive principles (our concept target) we recognize that the human eye is "adjusted" and "prepared" before the change to high illuminations occurs. The pupil is more closed and less light is coming into the eyes (see Figure 4). It's important to recognize the fact that this solution will lead to a secondary problem. This problem appears through information losses. The further documentation doesn't go into details in respect to this secondary problem. It can be noticed that due to the increasing illumination at the end of the tunnel (daylight and normally also artificial light) this secondary problem is not a killing factor for the technical concept in the application. An interesting aspect of the technical concept is to mention that the luminaries for tunnels act partly concerning our inventive principles (Nr. 2 und Nr. 3 in the above list). The invention to implement these principles into a much smaller technical system can be seen as a transition from the supersystem to the system level. Miniaturization at lower system levels combined with Dynamism could be recognized as the overall technical concept derived from the inventive principles.

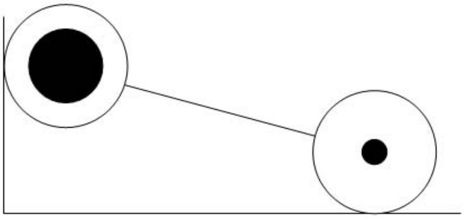

Figure 4. The pupil of the human eye will be changed in size, when artificial light prepare the eye for the light change. On the horizontal axis we define the brightness of the artificial light and on the vertical axis we define the depending pupil size

As a next step within the TRIZ methodology we use the SUFIEL model in the operating zone where the light, the eye and the excessive action blinds are coupled directly. Again we used the Goldfire Innovator Software to model the system. Especially helpful we obtain that the standard solutions are grouped depending on the target issues of the problem. We define “efficiency increase” as the ordering category. Under this aspect the Coordination – Control standard solution is the first item. Additionally the software underlines the evolutionary trends for this solution: Controlling action directly on the object – Action through actuating mechanism – System with feedback (see Figure 5). These items are valid for Automatic control which has the highest priority. If we consider the inventive principle Dynamism (Nr. 1 of above list) and the standard solution we are disposed to set up the concept with a fully automatic control of the light sources together with a feedback loop for regulation the lighting intensity.

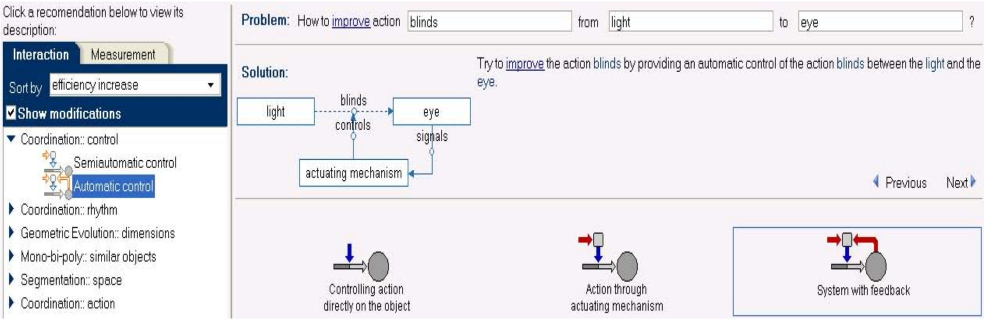

Figure 5. SUFIELD model of the operating zone and evolutionary trends for the standard solution
(Goldfire Innovator Software – IMC)

Now let’s come to the physical contradiction as mentioned above to verify our concept idea. The critical parameter we’ve defined SPEED. This parameter should be small for optimal adaptation and high for racing – speed of the car. One of the four separation principles is dividing in system area. We understand that high speed is necessary for the application (supersystem) so low speed has to be achieved on system level. There we’ve the basic idea again. We’ve to reduce the speed on system level to enlarge the transition time for the eye – that’s the solution.

3. Technical concept of the lighting helmet based on the TRIZ analysis

If we convert these ideas into a technical concept we combine a standard helmet with an additional artificial light source insight the helmet or light which is transmitted into the inner part of the helmet. An outer and an inner lighting sensor detect the lighting intensity. A control unit measures the sensor values and supplies the light sources which are defined as LEDs (see Figure 6). The control unit is a PIC microcontroller from MICROCHIP and transmits the lighting intensity information to the LED driver from MAXIM MAX6965 (see Figure 7).

The energy supply for the whole electronic circuitry is placed outside the helmet, because the weight of a helmet is a very critical parameter and should not be increased very much due to the additional components. The helmet has an interface for the supply lines (24 Volts) and also an optional digital interface to the Microcontroller. Via this interface information about the lighting conditions can be transmitted to a central controlling station. Vice versa the central controlling station can set predefined values depending on different conditions in the environment.

The controlling schemes are very different and can range from a constant inner light control or mixtures between inner and out lighting sensor values. The inner sensor detects the light in the eye area where the outer sensor detects the light level in front of the car. The detecting angle is an important parameter because the transition form dark to bright light at the end of the tunnel is recognized by the outer sensor on the top of the lighting helmet. The principle of the lighting helmet concept is shown in Figure 8.

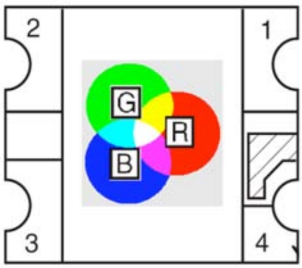

Figure 6. Miniature LED modules as light sources can generate RGB light

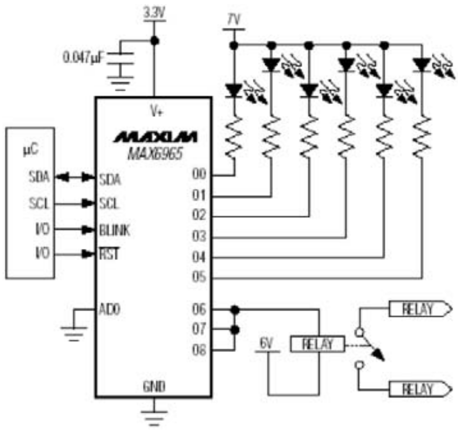

Figure 7. Electronic circuitry with PIC Microcontroller, MAXIM LED driver and LED light sources

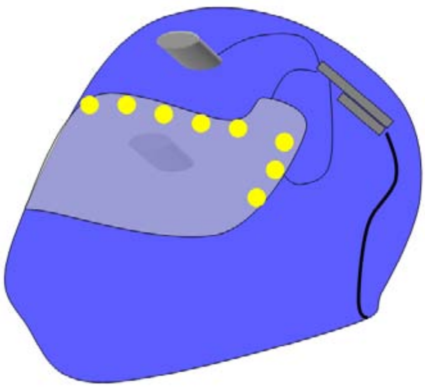

Figure 8. Basic concept of the lighting helmet

4. Further developments based on the lighting helmet concept

Within the field of vision there are parts inside the helmets which influence the lighting contrasts. Now depending on weather, speed or driver psychology the lighting intensity and the lighting colors are changed. These lighting effects are positioned at the outer areas of the field of vision. Due to these effects we can increase the concentration and optimize the lighting contrasts.

For driving into a tunnel the helmet is equipped with an electrical controlled visor. Before driving into a tunnel the visor will be darken, so that the pupil will be opened (reverse action). This eye pre-adjustment helps to get a smoother change when reaching the tunnel area. In the same way the lighting sources will be active if the car reaches the end of a tunnel. The pupil will be closed and pre-adapted to the very high lighting intensities outside. After every adjustment the visor or the lighting sources will be changed to a nominal value.

During constant driving there are always changes in the lighting intensity coming from shadowing of trees, buildings, etc. Especially at high speed this leads to a very high eye stress and hence to energy consumption of the driver. A lighting sensor positioned insight the helmet hold the lighting intensity constant and is able to reduce the pupil adaptation. The amount of compensation is variable and can be optimized to different parameters.

Light has an enormous influence of the human behavior. Light controls the hormone called melatonin and this hormone is responsible for getting tired (see Figure 9). We know these influences also together with depressions and jet-lags. The lighting sources within the helmet are used now, to take this relationship into account and focus the driver with light the get the best concentration value e.g. before starting a race or in other critical situations. Newest research in that field showed also, that blue light with a wave length of 446-477nm could control melatonin on the best way.

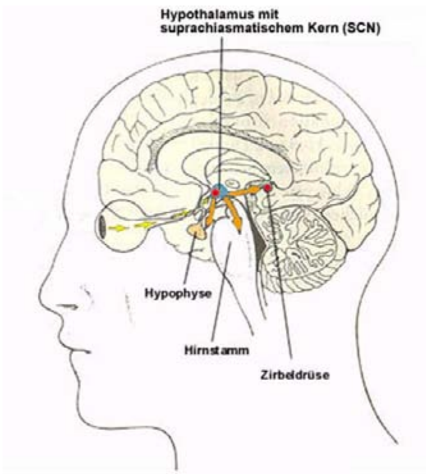

Figure 9. Light controls the hormone called melatonin

5. Overall advantages for racing car-drivers with the lighting helmet concept

- Perfects adjustment of visibility depending on surroundings and driver psychology
- Optimized contrasts and color impressions within the field of vision (see Figure 10)
- Improved security due to reduced tiredness
- Improved physical fitness
- Reduced blinding
- Reduced eye stress

Figure 10. New visibility due to color contrasting with the RGB light sources

6. Conclusion

For concept verification the system was build in a MATLAB / SIMULINK model first. Suitable regulation parameters for the control loop could be evaluated with this simulation approach. To enlarge simulation capacity we set up a “hardware in the loop” tool called LogicLink for high speed digital simulation together with MATLAB / SIMULINK models. The system was build up practically in hardware and software. A development team consisting out of five engineers has designed all necessary components for prototyping the lighting helmet. The lighting helmet concept lead to cooperation with leading helmet manufactures for Formula 1. This TRIZ based concept lead to European patents and afforded new innovation pulses in the helmet industry.

The advantage of using the TRIZ methodology could be seen in skipping out all hindering thoughts coming from existing experiences because we’re looking at the problem in a very abstract way first. To open the mind the formulation of contradictions and concept searching based on inventive principles were very important. To analyze the system hierarchically and focusing on the operating zone lead us to a new problem view. Further more it could be seen, that different TRIZ tools, as contradictions, SUFIELD and trends of evolution, forced us to think in similar directions. This gave us the necessary confidence that the approach has a great potential and other companies couldn’t find much better alternative systems at the moment. TRIZ has a huge variety in tools. We found out, that the multiple uses of these tools and also the common explanation out of the different tools is most important for secure concept description. Finally the TRIZ methodology is able to invert the customer – product process relationship where the system defines the product first and where the customer needs are matched against the product view later on. At the end the customer is the king, but TRIZ can tell what the customer in his current situation doesn’t know. With TRIZ you find essential new ways to create customer needs and find ways to satisfy them. All above – secure long term innovation and market leadership.

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AN EXAMPLE OF SYSTEMATIC INNOVATION IN A VERY SMALL ENTERPRISE: A NEW PACKAGING FOR FRESH VEGETABLES

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Abstract
Technological innovation is commonly associated with medium or large companies, which are thought to have the resources (both cultural and economical) and the drive essential to produce new or improved artefacts.
This assumption is true in many cases; there are, however, small companies that actually produce innovation, though more often than not this innovation can hardly be considered "systematic".
In this paper we show that even a very small enterprise, active in a business where innovation seems, to put it mildly, unlikely, can generate a new product when properly assisted.
The idea was to create a new packaging for fresh vegetables that could be placed unopened directly in a microwave oven prior to cooking. The paper shows all the steps taken in solving the problem. Finally, in the conclusion we deal briefly with our approach to the problem of the dissemination of systematic innovation practices in a prevailing environment of small and medium enterprises.
Keywords: packaging, contradictions matrix, TRIZ.

1. Introduction

Technological innovation is commonly associated with medium or large enterprises, which are thought to have the resources (both cultural and economical) and the drive necessary to produce new or improved artefacts.

This assumption is true in many cases; there are, however, small companies that actually produce innovation, though more often than not this innovation can hardly be considered "systematic".

Our experience in dealing with technological problems in small and medium enterprises lead us to the conclusion that, even when they are *innovation oriented*, their way of dealing with innovation has more to do with the *skills* and *tacit knowledge* of the owner than to a systematic approach to the problems. Also, these companies almost always lack the cultural resources needed to produce real innovation : they do not have R&D personnel and tend to rely on the support of external consultants whom they trust when looking for the solution of a technological problem.

In this paper we show that even a very small enterprise, active in a business where innovation seems, to put it mildly, unlikely (washing and packing of fresh vegetables like lettuce and spinach), can generate a new product when properly assisted.

Anyone who has been shopping at a grocery store will be familiar with the fresh vegetables sold in a sealed plastic bag, already washed and ready for use.

The idea was to create a new packaging that would lend itself to be put unopened in a microwave oven, for the direct cooking of the vegetables.

Although there are several kinds of packaging designed to allow the microwave cooking of food, none of them seemed to be matching the requirements of the company as regards to low cost, convenience of use and minimal impact on the actual packaging process.

This paper shows how the problem has been addressed using some of the TRIZ tools, until an elegant solution has been found for a new artefact which has been patented.

2. Problem definition

Micro waving can be conveniently used for the preparation of fresh vegetables, using either their natural water content or adding some water as needed.

This convenience can further be enhanced if it would be possible to cook the vegetables directly in the same packaging used for their storage.

This packaging is often a thin polymer bag, sealed at the edges, in which the washed vegetables are kept protected by possible contamination.

If the packaging is placed in a microwave oven, the microwaves action quickly turns the water into vapour; the resulting increase in pressure, along with the vapour temperature, actually causes an effective "steaming" cooking of the vegetables.

Unfortunately, because of this pressure increase the packaging can experience a sudden, explosion like break; there is also the risk of being burned by a stream of hot vapour when opening the package.

There are several known solutions to deal with this problem. They mostly try to control the pressure level, either by using different types of pressure relieving valves or by introducing one or more opening in the package so that the maximum level of pressure in the bag is limited because some vapour is let to escape.

These solutions were not meeting the requirements set forth by the customer, a small business owner with a keen eye on the overall cost of the solution to be implemented; special valves are expensive to build into the existing packages and any kind of opening made on purpose on the bag would jeopardize the safe storage of the food.

It was clear to us that we had to find a solution closer to the Ideal Final Result (IFR).

3. Contradictions of the system

A sound definition of the contradictions that are present in the system is a requisite for the use of the TRIZ Contradiction Matrix. This has been accomplished following separate stages, as described in Reference 1:

1. Define the elements of the system that should be improved
2. Map these elements according to the terms of the 39 parameters of the Contradiction Matrix
3. Identify the solution directions that can help remove the problem
4. Identify the contradictions between the feature to be improved and these elements

5. Map these according to the term of the Contradiction Matrix to get pairs of improving-worsening features.

The element of the *system to be improved* is: the packaging can break.
On the Matrix this could be expressed as: *harmful factors developed by an object*
The *solution directions* that can help remove the problem could be:

- Make the package stronger so that it can withstand the pressure generated by the vapour
- Make an opening in the bag so that some vapour can escape keeping the pressure within acceptable limits

Identify the contradictions:

- strength of the packaging material: if the bag is strong enough, it can stand the steam generated pressure without breaking; however, a strong packaging would be more expensive to manufacture, more difficult to open and more likely to be cause of undesired burns to the consumer before of hot streams of escaping vapour under pressure during opening.
- Opening in the bag: if the packaging is provided with one or more openings, the pressure level can be controlled by the amount of vapour that can escape, such as that the pressure stays high enough to steam cook the food and low enough to not break the bag; however, the safety of food can be seen as a worsening features because it becomes impossible to seal it from the possible contaminants in the environment.

Mapping these in the Contradiction Matrix:

- Strength of the packaging material: “Strength”
- Opening in the bag: “Harmful factors acting on an object from outside”

The identified pairs of improving-worsening features yield the following inventive principles:

Harmful factors developed by an object vs. Strength: 15, 35, 22, 2

Harmful factors developed by an object vs. Harmful factors acting on an object from outside: none

It is interesting to notice that the second contradiction doesn’t yield any principle; we can however express a physical contradiction because an opening in the system must be present to relieve the excess of pressure, but must not be present to avoid contamination of the food.

The contradiction is solved using the separation principle: the bag must be close during storing and when carried home from the grocery store, but must be open when the food is cooked.

This is suggesting the use of a relieving pressure valve: the valve will open only above a defined pressure level.

4. Developing a solution

To figure out how the concept suggested by the separation principle could be developed let’s look into the principles n. 15, 35, 22, 2.

Principle n. 15 – Dynamicity

Characteristics of an object must be altered to provide optimal performance at each stage of an operation: this is suggesting to provide the bag with a valve, but it might also be suggesting to get the bag acting as a valve itself.

Principle n. 35 – Transformation of properties

Change the physical state of the system: this is suggesting to introduce in the system, for instance in the sealing, a material that can change its physical state (from solid to liquid or vapour) when the temperature increases. In this way we may have an opening to let out the excess of vapour.

Change the degree of flexibility: this is suggesting to make the bag flexible enough so that the pressure stays within acceptable limits.

Principle n. 22 – Convert harm into benefit

Utilize harmful factors to obtain a positive effect: this is suggesting to use the excess of pressure to create an opening in the bag.

Principle n. 2 – Extraction

This principle suggests to remove the pressure in excess from the bag.

In order to move closer to IFR, we must try to exploit the existing resources of the system.

This means that we do not want to introduce a specifically designed valve into the system, but rather we want to get the bag itself acting as a valve.

The actual bag was obtained by sealing two edges of a cylindrical shaped plastic film with a profiled clamp applying pressure and temperature for a certain period of time.

What has been suggested by the principles can be implemented in two ways:

1. Use a specially designed film with weak spots over the surface, that can be opened by the action of either the temperature and/or the pressure.
2. Make one or more weak spots in the sealing, that can be opened by the action of either the temperature and/or the pressure.

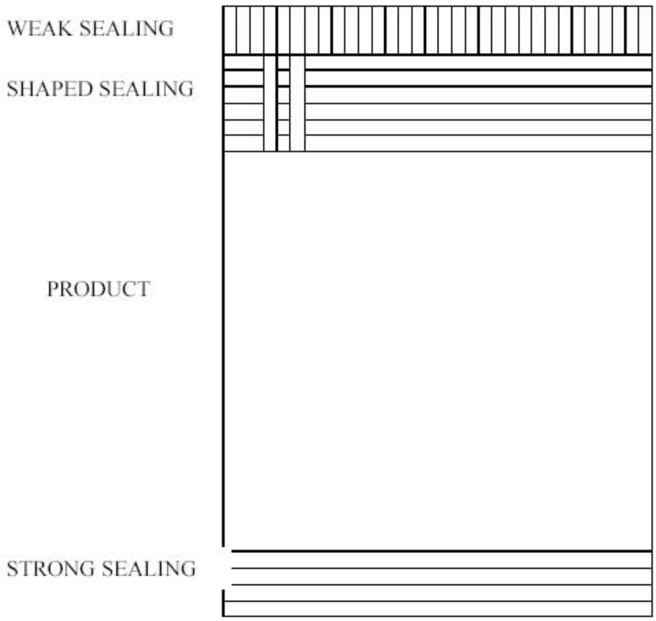

Fig. 1 (by permission of Barduca Ortolano s.rl.)shows how the above second suggestion has been implemented; a specially designed clamp has been developed that produces a sealing that can be opened by the pressure in a weak part only. This concept has been patented.

Going back to the original idea of steam cooking of packaged fresh vegetables, it must be stressed that only the spinach seems to have the right natural water content to yield a good cooking.

For other vegetables it is necessary to add some water.

To use the same concept of placing the bag of vegetables directly in the microwave oven, the water for the cooking must be present in the bag; unfortunately we can not store the vegetables with water in excess if we do not want to compromise their conservation.

Again we have another physical contradiction: the water must be present to allow cooking, but must not be present for the best conservation of the food.

Using the separation principle we devised a way to keep the water separated from the food until cooking time (Fig. 2, by permission of Barduca Ortolano s.r.l.).

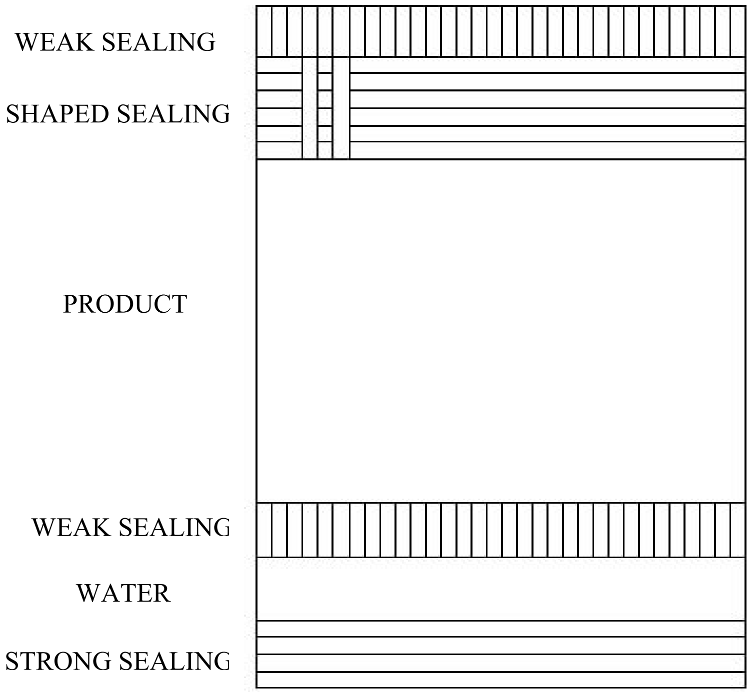

Fig.2

A weak sealing was put in place between water and product, which would open during micro waving by the steam generated pressure.

5. Conclusions

This paper shows how physical and technical contradictions and the Contradiction Matrix have been used to develop a new packaging for fresh vegetables that would lend itself to be put unopened in a microwave oven, for their direct cooking .We have illustrated the solution that has been patented. Other solutions are possible, and they may be already clear to the readers.

In this case a very small company had enjoyed the benefits deriving from the use of TRIZ, which was brought to it as an external resource by the consulting team. We regard this as more of an exception than the rule, since when small companies need help when addressing technical problems they seek the assistance of an expert who is well known in the specific field. These experts are skilled in the problem codification and are very good at finding the right solution more often than not; the drawback is that their knowledge is restricted to their field of expertise, and this prevents their chances of finding better solutions outside their technological environment. We feel that a technical problem can be solved in the most elegant way when we work closely with these expert and use tools as TRIZ.

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USING TRIZ TO ACCELERATE TECHNOLOGY TRANSFER IN THE PHARMACEUTICAL INDUSTRY

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Abstract
In the pharmaceutical industry, "technology transfer" refers to the processes that are needed for successful progress from drug discovery to product development to clinical trials to full-scale commercialization. Challenging, seemingly impossible problems arise at all of these interfaces. Case studies demonstrate that TRIZ can solve these problems, and speed the progress of new pharmaceuticals to market. The TRIZ concepts of increasing ideality, elimination of tradeoffs, and elimination of inherent (physical) contradictions are applied to the improvement of testing, reduction of toxicity, and scale up for production in several areas of the pharmaceutical industry.
Keywords: TRIZ, TRIZcase study, pharmaceutical industry, technology transfer.

1. Introduction

In the pharmaceutical industry, "technology transfer" refers to the processes that are needed for successful progress from drug discovery to product development to clinical trials to full-scale commercialization. Challenging, seemingly impossible problems arise at all of these interfaces. Figure 1 shows the time scales and the financial investment in each of the 4 phases of drug development. See Mlodozeniec, 2004 (1) and (2).

1.1 The New Drug Application Process

The New Drug Application (NDA) is the full record of the development and testing of the drug, presenting the case that it is ready for human use, and including validation of all test methods, and proof that the medication produced by the full scale, commercial production system is the same as the medication that was developed and tested in the clinical trials. See ISPE 2003 for detailed descriptions of the requirements in each phase.

The process from beginning of research to release of the drug may take anywhere from 5 to 20 years. There are 2 reasons that the pharmaceutical companies want to accelerate this process, which we call the business and the humanitarian reasons:

1. Business: The part of the drug's lifetime during which it is covered by patents is the most profitable part. The longer the development time takes, the shorter the available patent life.
2. Humanitarian: The sooner the drug is brought to market, the more people will benefit from it.

The use of TRIZ problem solving methods to accelerate the process will help pharmaceutical companies accomplish both goals simultaneously.

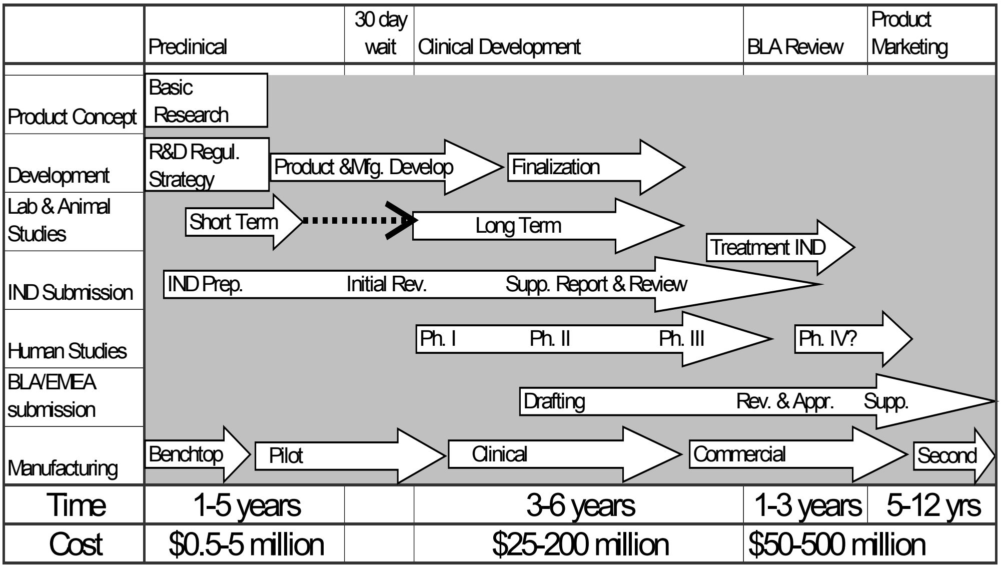

Figure 1. Typical New Drug Development time scale. Regulatory reviews refer to the FDA, the US Food and Drug Administration. EU systems are similar. See Mlodozeniec 2004 (1) and (2).

1.2 Selection of Case Studies

Technology transfer in the pharmaceutical industry refers to the transitions between the 4 primary phases of the New Drug Development process:

1. Drug Discovery
2. Product Development
    2.1 Delivery method
    2.2 KADME (Kinetics of Absorption, Distribution, Metabolism, Excretion)
3. Clinical Evaluation
    3.1 Pre-clinical toxicity evaluation
    3.2 Animal and human studies
4. Full scale commercialization ~ Technology Transfer
    4.1 Active Pharmaceutical Ingredient (API)
    4.2 Drug Product (Dosage Form or Delivery System)
    4.3 Analytical Methods

In each phase, researchers attempt to optimize five attributes:

1. Flexibility
2. Cost
3. Dependability
4. Innovation
5. Product Quality

The TRIZ case studies have been chosen to illustrate improvements in all attributes in stages 2, 3, and 4 of the New Drug Development process. Stage one is equally subject to the use of TRIZ, but the authors have not been working in that area and have limited this paper to their own experiences with TRIZ and technology transfer.

This paper is a continuation of the work presented by Domb and Jacklich in 2003 demonstrating that the use of beginner-level TRIZ techniques can have major impact on development of new technology. Several of the cases could be analyzed in terms of the patterns of technical evolution, but that analysis is not included since the work was done using only ideality, the 40 principles (elimination of technical or tradeoff contradictions), and the separation principles (elimination of physical or inherent contradictions). See Rantanen and Domb, 2002, for discussions of the basic TRIZ techniques.

2. TRIZ case studies in technology transfer

2.1 Improve test models

In the pre-clinical test phase of New Drug Development, it is necessary to demonstrate that the medication will be both safe and effective for use in humans. Traditionally, testing has been done in animals. Numerous tradeoffs have been required to select the animal species to be used for a particular test. It should closely match the characteristics of the human body, particularly for the organ system being studied, but cost issues require that the animal be small and easily cared for. The need to do a statistically significant number of tests makes the cost issues even stronger, leading to the popularity of laboratory rats, mice, and rabbits as test animals. If the animal is not subject to the same diseases as humans, it may be necessary to do the toxicity/safety tests on one animal and the effectiveness tests on others.

2.1.1Eye medication and rabbits

Rabbits have been used to test the irritation index of both medication and consumer products for many years, and to test the rate of absorption of medication. But, rabbits have a very different blink rate from humans, and a different pattern of eyelid shear during blinking. Making them an imperfect test model, since blinking is a very important mechanism for distributing tears in the eye.

The diffusion flow cell has now replaced rabbits. The diffusion flow cell is an assembly of monolayers and bilayers of cultured human cells that have the exact properties of the human eye. They make it possible for researchers to isolate the effects of tears and of the boundary layers between the parts of the eye, while entirely eliminating the complexity of dealing with animals. This solutions demonstrates the use of 2 of the 40 principles for problem solving:

Principle 17: Change Dimensionality
Principle 27: Cheap Disposable Parts

2.1.2 Vaginal microbicide development, rabbits, and baboons

Rabbits have also been used to test products for human vaginal use, and they are also an imperfect model for this use, since the rabbit has a vaginal pH of 7, while the human has a pH of 4.5. Consequently, medication that matches the human pH is severely irritating to the rabbit. The mismatch can also result in medication that kills the beneficial lactobacillae, which then allow yeast infections to flourish.

The alternative to rabbits has been baboons. They are a much closer match to humans, but they are extremely expensive to acquire, and to care for.

The diffusion flow cell again is the solution, since it can be made from the specific cells of the organ being tested, and will therefore have exactly the right parameters for the test.

2.1.3 Skin: trans-follicular kinetics

During the pre-clincal phase of development of medication to be applied to the human skin, researchers need to determine the kinetics of the transport of the medication through the skin. Because of the high variability of the number and size of hair follicles on human skin, it has been difficult to isolate the trans-dermal (skin) and trans-follicular(through the hair follicles) effects.

Snakes have no hair! Snake skin is an excellent model for the hairless skin, and tests on snake skin can be used to isolate the trans-dermal and trans-follicular effects.

This solution demonstrates the TRIZ concept of using effects from another science combined with Principles 2 and 3:

Principle 2: Take out: Use only the necessary parts

Principle 3: Local quality. Make the system have the exact properties desired.

2.2. Distribution

In the pharmaceutical industry, distribution includes the typical industrial activities of packaging, shipping, warehousing, retailing, etc., and also includes issues of customer use. The case studies demonstrate both.

2.2.1 Eye medication—assure correct time and dose

Eye medication is usually dispensed in liquid drops, since it is very easy for non-medical personnel (the patient himself, or a care giver) to dispense the proper quantity, by relying on the shape of the dispenser and the surface tension of the liquid. But, the time that the medication stays in the eye is unpredictable, since liquids drain into the cul de sac of the eye. See figure 2.

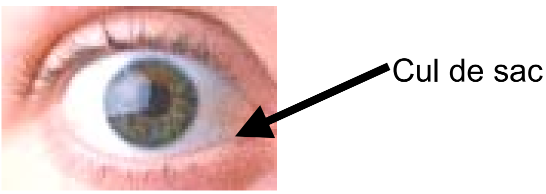

Figure 2. The human eye. Liquid medication drains through the cul de sac, and does not stay in the eye.

From a TRIZ perspective, this is a physical (or inherent) contradiction: *you want liquid medication but you don't want liquid medication.* The solution comes from the separation principles: separate liquid and not-liquid in time and in space. The solution is a formulation of the medication that is liquid in the bottle, and when being dispensed from the dropper, but which binds with the tears in the eye to form a gel when it contacts the tears, and is activated by body temperature. This could also be thought of as demonstration of Principle 35, Change Parameters.

2.2.2 Protect potency of proteins during shipment

Proteins are often difficult to ship in liquid form. They are physically unstable, subject to aggregation container surface adsorption, easily damaged by temperature changes, and in general have short shelf life. The containers themselves are subject to breakage of walls and difficulty with creating a secure closure.

The solution to all these problems came from the application of the "itself" form of the Ideal Final Result: "The protein should protect itself during shipping." (See Domb 1998, Mann 2003 and Belski 2000). The solution is to freeze-dry the protein material, ship it in the dry powder form, and reconstitute it at the point of use. This solution could have come also from the application of Principle 35, or from use of the principle of separation in time, for the physical (inherent) contradiction: *The protein should be liquid (for easy use) but it should not be liquid (for easy handling and shipping)*.

2.3. Scale up for full commercialization

"Technology Transfer" refers to the initial stage of transferring the drug system out of the laboratory, into pilot-scale plants, the intermediate stage of transferring to full commercial-scale plants, and, if the product is successful, to secondary commercialization, which frequently involves transfer to numerous facilities in multiple countries. See ISPE2003 for discussions of the regulatory concerns in each of these transitions.

TRIZ applies to the technical and management problems encountered during each of these transitions, as demonstrated in the following brief cases.

2.3.1 Avoid foam problems

When liquids are moved from one station to another (such as a reactor to a storage tank to a mixing tank, etc.) turbulent flow at an air interface can lead to the formation of foam, and the non-scalability of flow parameters makes the occurrence of foam unpredictable. A very simple TRIZ solution does not solve the problem of foam creation, but it make foam not cause problems for downstream processes: apply Principle 13 (do things in reverse) and extract the liquid from the bottom of the tank, to get pure liquid without any foam.

2.3.1. Improve medication uniformity by electrostatic deposition

Although pill production by compressing powder is a well-established technology, there are many drugs that require higher accuracy and uniformity than the powder compression method can provide. Considerable improvement in uniformity has been achieved by electrostatically depositing the material on a continuous web of edible material.

The TRIZ pattern of evolution "Object Segmentation: Divide the object into smaller and smaller parts, and eventually replace the object with a field" would have predicted this solution. The "Beginner TRIZ" methods from the 40 principles, using Principle 28, "replace mechanical objects with fields" was used.

2.3.2. Reduce production loss and improve product quality using continuous testing instead of batch testing.

Batch testing for quality can be extremely expensive, because a bad test may require either extensive re-testing, or discarding the entire batch. Decisions about batch intervals are subject to trade-offs between test interval, test cost, and cost of scrapping bad batches. By replacing the batch test with a continuous scan by means of FTIR (Fourier Transform InfraRed Interferometry) and by doing continuous statistical process control analysis on the data, production discrepancies can be detected immediately, and the rejected material reduced to a very small fraction of a batch.

This is another example of the improvement of ideality (same benefit with less cost and less harm) by means of replacing mechanical, batch testing with continuous electromagnetic testing and statistical analysis.

3. Conclusions

Case studies never "prove" anything. This collection of case studies from technology transfer in the pharmaceutical industry is designed to demonstrate that the skills of beginner-level TRIZ can make substantial contributions to the problem solving that is necessary to move a new drug along the exhaustive pathway from basic research to clinical research to full commercialization.

For pharmaceutical audiences, this may answer the question: ***"Does TRIZ work in my environment?"***

For TRIZ audiences, it may answer the question: ***"Can I start using TRIZ when I've just begun learning it? "***

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INNOVATION AND TRIZ METHODOLOGY ALONG THE PRODUCT DEVELOPMENT PROCESS: STUDY CASES IN TEXTILE AND MEDICAL FIELDS

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Abstract
PLM is becoming a must for those enterprises that consider the product development process a core competency. A PLM process is supported by several IT elements, such those for product definition. Among them, during these last years, methodologies and tools for systematic innovation and problem solving are assuming more and more importance in order to make companies able to innovate their products and processes.
In this paper we describe the integration of TRIZ and PLM methodologies and tools along the different phases of the product lifecycle, from concept design, to manufacture, assembly, marketing and disposal.
Two study cases, related either product development or company's process, are presented. The first application is mainly focused on product definition in textile industry, specifically it concerns a weaving loom. In the second one, TRIZ approach is used and integrated with BPR techniques for product design and process re-engineering together with risk and quality management.
Keywords: Triz, Product Lifecycle Management, inventive principles, textile, weaving loom.

1. Introduction

The growing complexity of the market, customer demands for increasing quality and service, together with the need of lower prices and more timely delivery challenge companies to improve performance on every aspect of their products and processes. Continuous advances in Information Technology (IT) allow companies to understand and exploit the changes of this fast-moving environment, providing the capabilities to efficiently support the company's product lifecycle. In fact the management of product development in a whole-life-comprehensive perspective focuses on the fragmentation of existing tools and processes with the aim of gathering a fluid flow, an efficient definition and a ready use of product information throughout the organization.

In such a context a Product Lifecycle Management (PLM) system can provide a valid support for the coordination and integration of processes and applications used to define and manage the virtual product with those used to manufacture and maintain the real product (Fig.1) [1].

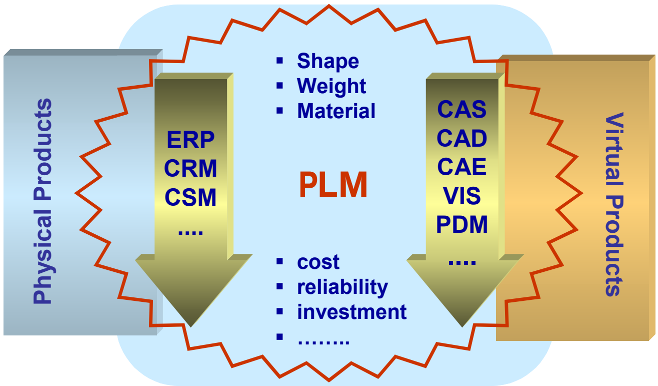

Fig 1. PLM as an integrator between the physical and virtual products

As said, a PLM system/process is supported by several IT elements that can be grouped into three main categories [2][3]: Product definition, Planning and Control and Infrastructure.

In this paper the attention is put on methodologies and tools for product definition, and in particular, on those ones devoted to systematic innovation and problem solving since they are assuming more and more importance in order to make companies able to innovate their products and processes.

2. Context fields

A Triz-based methodology and related tools can be employed to manage and support simultaneously several phases of the product lifecycle, from concept design, to manufacture, assembly, marketing and disposal. The aim of this work is to show some successful case studies in which Triz tools are used in different phases of the product lifecycle.

We describe the integration of TRIZ and PLM methodologies and the tools to redesign product development and related company's process. The case studies refer to two industrial fields: mechanical-textile and medical field. In the first one, several studies have been carried out on a weaving loom focusing on design, production, marketing, disposal and intellectual property rights. The other field of investigation concerns the introduction in a medical device manufacturing company of a methodology based on the Triz approach for simultaneous product and process remodelling together with risk and quality management. Therefore the first application mainly concerns the product definition while the second one is more related to product process re-engineering and management.

3. Case study: weaving loom

This application shows some of the benefits obtained with the introduction of Triz methodology and tools in the product development department of a manufacture company that designs and produces textile looms. The devices analysed are subsystems of the loom and to clarify the following discussions here we give a short introduction to the main features of weaving machines [4].

A weaving loom generates automatically an interlacing between a set of longitudinal yarns (warp) with another set of yarns normally disposed (weft), in order to create an established pattern or drawing. This is achieved following five main steps (Fig. 2):

1. Opening of the warp yarns;
2. Weft insertion;
3. Movement of weft towards the tissue;
4. Feeding of warp yarns;
5. Collection of tissue.

A textile loom is as much as complex as a car and has a lot of systems and sub-systems that can be taken into account to innovate it. The studies accomplished so far regard two main systems of the loom, the weft insertion device and the warp yarns feeding system.

The weft insertion is the core activity of weaving and it determines the productivity of the entire machine. This is the main reason why substantial differences between different looms are concentrated on this system while others devices are quite the same. The kind of weaving machine we focused our activity on is an "air loom", i.e. a loom whose weft insertion device exploits an air-jet apparatus that shoots the weft yarn from one side of the of the tissue to the other with an appropriate air flow. In this case, Triz methodology has been used to solve technical problems affecting the loom productivity. Working parameters optimisation could not give any more advantage and the solution of technical contradictions and the introduction of new technologies were needed. This case involved mainly the conceptual design but important changes were made to the production and assembly phases. Moreover this application concerned also patent matters.

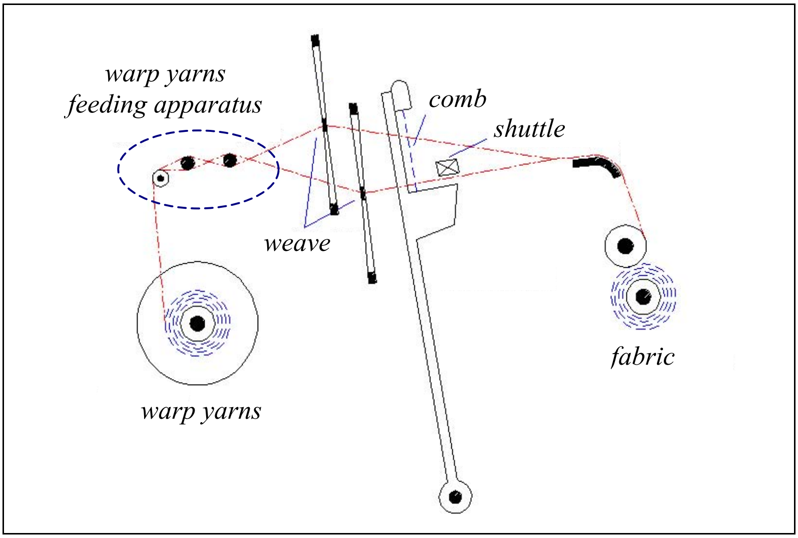

Fig 2. Weaving loom function scheme

The other sub-system analysed is on the back of the loom and its function is to provide the correct tension to the warp yarns in each instant of the weaving process. In fact weft insertion requires yarns to go up and down creating a determined angle. Warp opening and closing induce a harmful discontinuous tension on the yarns that is decreased by the movement of a cylinder that adjusts the yarns pattern and length effectively engaged in the loom. This application of Triz methodology has brought to the complete re-design of a complex system actively linking quite all the product development areas, achieving useful effects to other phases such as marketing and disposal.

3.1 Weaving loom: air jet device innovation

At first, a high level approach to the technical system for the weft insertion was used to create the first functional model of the whole apparatus. In this phase, after collecting information from different sources, the model was used to highlight critical areas for further investigations. Both the analysis of the functional model and the discussion with company's technical staff drew the attention to the sub-system made up by main launch nozzle, by little nozzles uniformly disposed along the loom width, by valves and by the compressed air circuit feeding them all. The function-based model of this sub-part is shown in figure 3.

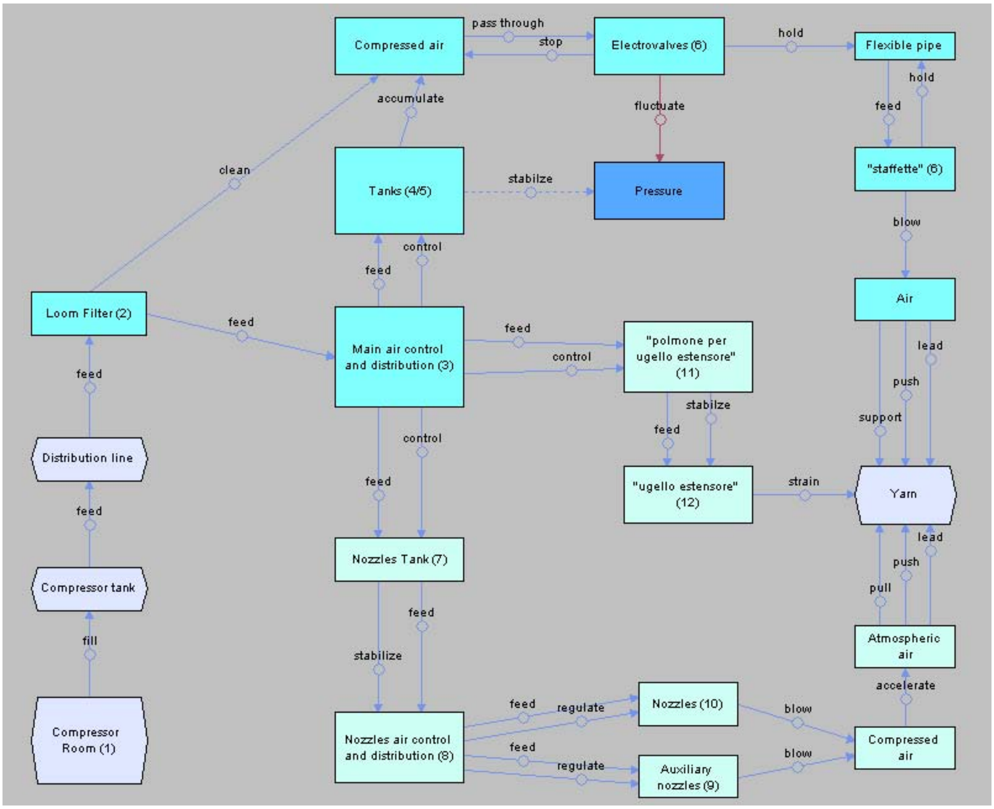

Fig.3 Detailed model of weft insertion apparatus

The biggest problems we discovered with this apparatus were strictly related to some specific elements such as compressed air tanks or electro valves. Thus, to solve the problems of this system, we decided to adopt the methodology known in TRIZ literature as *trimming*. Trimming is a strategy/tool that perfectly embodies the Triz philosophy because its approach to problems and contradictions is quite radical.

In fact this tool suggests at first to dramatically eliminate those elements affected by harmful function and then to find a new functional balance between the remaining ones. As a consequence the first functional model was reviewed and different scenarios had been analysed. In particular in the most interesting solution both the electrovalves and the nozzle tanks were trimmed, as shown in figure 4, and a new element was introduce to perform only the useful functions removed. The following step consists in the application of the classical Triz problem-solving tools: Effects, Principles and Predictions, to find a technical device resembling to the one theoretically introduced into the model. Different sets of solutions were found depending on the trimming scenario considered, but the general guidelines always suggested following segmentation of the air feeding system using small low-cost mechanisms exploiting the piezoelectric effect.

After the decision of the best fitting solution but before to proceed with the detailed design phase both a commercial and a patent search were done to identify eventual already existing solutions. Together with the company's patent office staff we discovered that there were no such devices available on the market, but unfortunately we found that a patent, describing a similar solution, had been deposited two month before by a competitor. Anyway the use of Triz tools on that patent highlighted some weakness and opened the way to further analysis in order to improve the device enough to create a brand new patent.

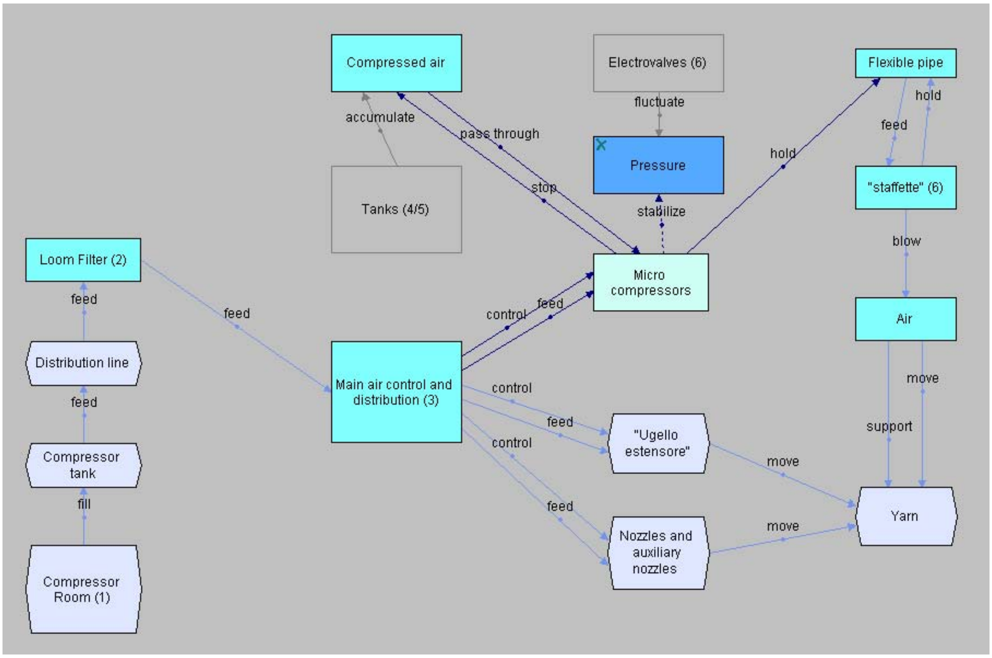

Fig. 4 Trimming variant of weft insertion apparatus model

3.2 Weaving loom: warp feeding apparatus

Another great area of interest we found was the warp feeding apparatus, mainly because of its complexity and high cost. As previously introduced this system is made up by a mechanism controlling a high precision chromate steel cylinder on which the yarns overrun. The cylinder at each weft insertion is subjected to great accelerations, and due to its high mass elevated forces is required.

The reason why such a device is built in this way is due to the correspondence with the technology used in paper production industry. A large group of regularly disposed yarns or a fabric, in fact, for some aspects is supposed to have the same properties of a sheet of paper. This analogy is so strong that even the EPO (European Patent Office) classification joints the textile and paper field in a single section, and in literature there are many examples of successful technology transfer between the two fields. Anyway this has strongly conditioned the design of textiles devices, limiting the development of solutions independent from those built for the paper industry. This study highlights how the psychological inertia deriving from this approach has turned engineers aside from finding bright and simple ideas to innovate the mentioned loom system.

The functional analysis and modelling phases of the warp feeding apparatus according to the basic rules of Triz theory, and the application of the tools suggested by the Ariz algorithm were quite enough to completely redesign the entire system. In particular, the *segmentation* and *intermediary* principles were applied to take advantage of the higher versatility of yarns in respect of a continuous sheet of paper. In particular the new designed devices focus on two main aspects:

- the feasibility of applying forces and/or imposing displacements straight on a single yarn, or on arbitrary large groups of yarns;
- the possibility of the yarns to locally move in whatever direction normal to the feeding direction.

This considerations lead to the design of a small and light device composed by repetitive elements, with the advantages of being highly customisable and that the assembly can be done by the final user. Modifying the traditional solution into a "construction kit" solution impacts on several company's activities further than conception and design. Manufacturing radically changes because only a few kind of parts are required, storing, logistics and transport efficiency are increased because of the reduced mass and dimension of equipment. But even the marketing and disposal activities are involved and improved by the radical change of this apparatus.

Further details about this new equipment are not reported in this paper because they are still confidential, but the exhaustive description will be available in the related patent that will be published in the next months.

4. Case study: re-modeling the process of medical products design

The second case study concerned the design process re-engineering in a company working in the medical field. The aim of this work was to satisfy Vision 2000 standards [5] that oblige the use of Risk Management techniques during the design process. The medical field is intrinsically exposed to questions related to product safety because of the serious damages malfunctioning and failures of medical equipment can cause.

The specific product we worked on was an aerosol-therapy device used to introduce a medicine, trough inhalation, in the respiratory apparatus for therapeutic purpose. The methodology used to re-engineering the design process is illustrated in figure 5.

This methodology puts together modelling and simulation strategies and provides to the technician a step-by-step roadmap, techniques and tools for technological product and process innovation [6]. In our case the actual business process (AS-IS) is first analysed retrieving information from quality procedures and from interviews to the technical staff, and then it is represented with IDEF0 technique. This permits to highlight process problems and area of possible improvements and constitutes the term of comparison to evaluate quantitatively the effectiveness of the new organizational paradigm. The following phase consists in modeling the new process (TO-BE) that implements the new technological solutions.

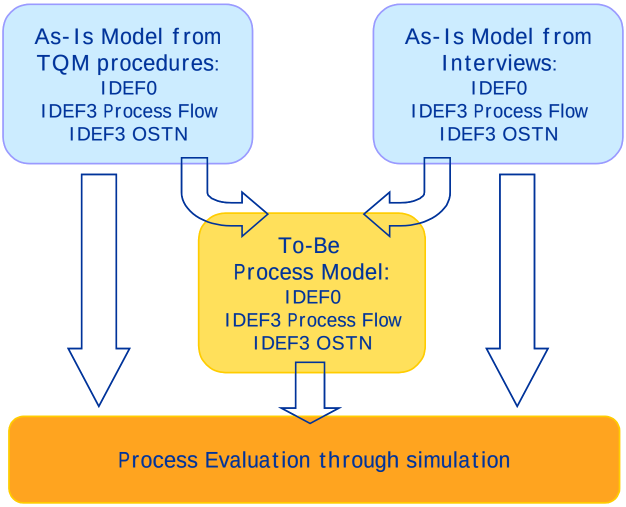

Fig. 5 Process modelling methodology

The main change that occurred in the specific case was related to the introduction of risk management activities (identification, evaluation and control) during the design process [7]. One of the most used and accredited techniques for risk management is the FMEA (Failure Mode and Effect Analysis) technique. It is a bottom-up tool that studies the effects on the whole system generated by the malfunction of every single device composing it. The results obtained are summarized into a scheme and the risk related to each possible failure mode is quantified. By the way this approach reveled same weaknesses: the ability of finding potential failure causes is strictly dependent on the technician experience; only the lack of the designed functions are reveled and excessive or incorrect ones are not taken into account and, finally, FMEA does not suggest any action to improve the project defects. To overcame these limits the AFD technique 0 has been introduced and used together with FMEA not only to widen the point of view of the technician and systematically discover all the possible failure configurations, but also to exploit the Triz tool to innovate the product.

The AFD module is based on a cause-effect diagram that models the system starting from the main function (the patient inhales the medicine) and going back to all the others making the first one feasible. At this point the critical areas are highlighted and all the possible weaknesses of the system are found and then a list of potential risks is created. After that, for each weakness identified, the analysis tool suggests a way to magnify the defects of the system. As an example in the following a guideline is reported. "Determine what typical harm can be provided to [the] (compressor + ampoule)" is the first guideline obtained from the cause-effect diagram of figure 6; the tool proposes 10 different failure typology and the first four are: explosion, combustion, corrosion and electric failure.

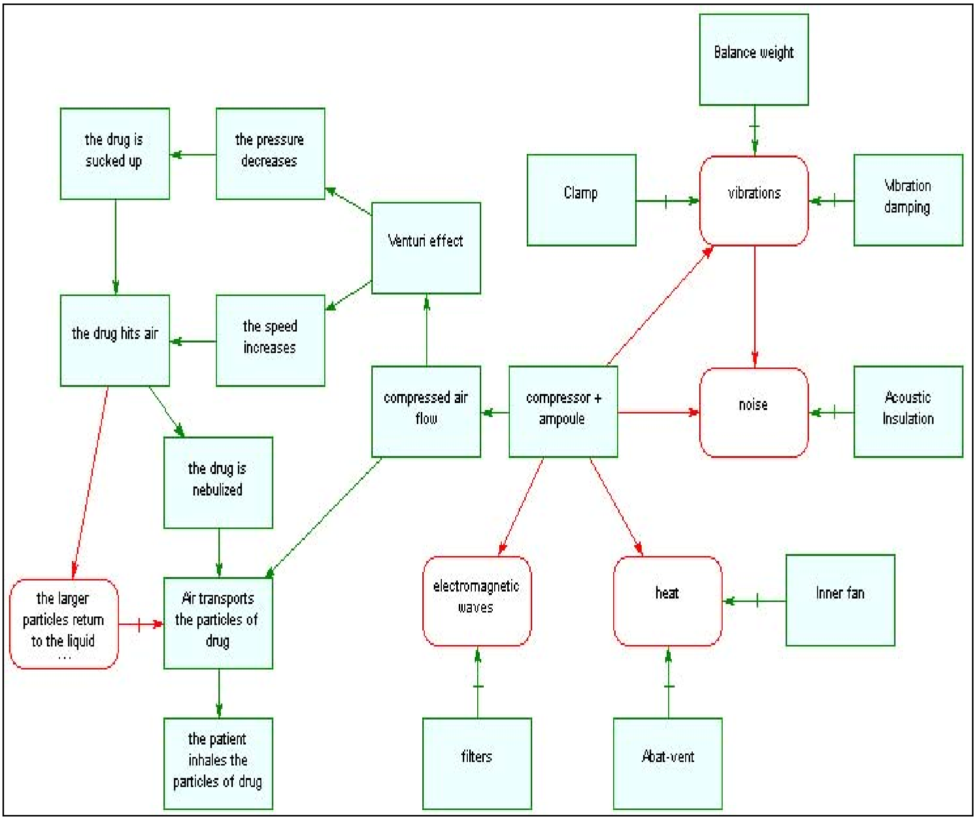

Fig. 6. Cause-effect diagram

For each of them specific information about the most common problems are reported: for an electric malfunctioning due to an undesired contact, for example, the tool provides the possible causes (a), and the potential impact on the product and on the user (b).

a. Undesirable electrical contact can results from:

- *damage to electric insulation due to high voltage;*
- *reduced resistance of insulation due to dampness, pollution or mechanical damage;*
- *embitterment, damage to insulation due to overheating or repeated heating/cooling cycles (heating can be caused by exceeding current limits);*
- *insulation damage due to mechanical impact (deformation by other parts, friction, vibration);*

- *combined impact of the above effects.*

b. Undesirable electric contact can cause:

- *system malfunction;*
- *increase in electric current through the system, excessive heating of parts, acceleration of harmful processes that can "avalanche" to produce system failure;*
- *damage to the system's electric parameters resulting in pressure drops, current leaks, etc;*
- *electric voltage applied to system parts that cannot withstand voltage, which can in turn cause result in:*
    - a. *personnel injuries;*
    - b. *short circuits, undesirable heating;*
- *electric arcs or sparking that:*
    - a. *destroys insulation in the contact area, increasing the damage;*
    - b. *become sources of high temperature that can destroy other elements;*
    - c. *causes electro-magnetic interference that affects various electronic devices;*
    - d. *causes an explosion or fire (in the presence of explosives or combustibles).*

At last, after the identification of failure scenarios and evaluation of risk, solving tools (Effects, Principles and Prediction) can be used to innovate critical devices in order to decrease the risk of the product.

5. Conclusions

In this paper we have described the application of a Triz-based methodology in different phases of the product lifecycle, from concept design, to manufacture, assembly, marketing and disposal. The attention has been put not only on product definition but also on company's processes engineering, trying to consider both aspects simultaneously.

The study cases refer to two industrial fields: the mechanical-textile field and the medical field. In the first one, several studies have been carried out on a weaving loom focusing on design, production, marketing, disposal and intellectual property rights. Technical knowledge has been retrieved and several functional models have been done to represent the product. Models were used as a starting point for following analysis and as a tool to uniform and spread knowledge between different company's departments. An iterative procedure has been adopted to find a set of solutions improving the final product and, at the same time, taking into account other phases of product lifecycle, such as production, marketing and disposal.

The other field of investigation concerned the introduction in a medical manufacturing company of a methodology based on the Triz approach and in particular of the AFD (Anticipatory Failure Determination) technique that allowed to create a new organizational paradigm for concurrent product and process development with particular attention to quality and risk management. The integration between FMEA and AFD procedures was successfully tested and represent a new method to manage quality and risk of industrial products.

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DEVELOPMENT OF NEW MOSQUITO TRAPS BY USING SUBSTANCE FIELD AND RESOURCE ANALYSIS

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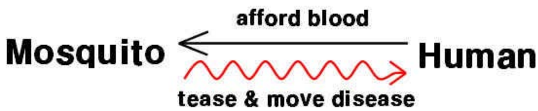
Abstract
New mosquito traps were developed by substance-field analysis and resource analysis. At the concept development the useful and harmful relationship between mosquito and human was modeled by substance field model and resolved by one standard. The resource analysis and technology forecasting stimulated to generate the new mosquito traps by using the photo catalysis, TiO_2 (titanium dioxide). The new traps implemented catch over 10 thousands a one night near cattle shed in Korea, in summer.
Keywords: TRIZ, Su-Field Analysis, Resource Analysis, Mosquito Trap, Photo catalysis, Ideality.

1. Finding the problem related to mosquito

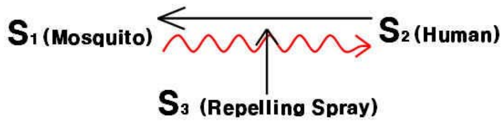
Summer in Korea is hot and humid like Italy. There are so many mosquitoes. Specially, the summer in 1998 was so hot with high humidity. At that time I with our undergraduate students at Korea Polytechnic University thought that who invents the method to protect human from mosquitoes may make big money.

2. Su-field modeling for mosquito problems and the conventional remedies

The fall in 1998, we tried to model the problem related to mosquito by using Su-field modeling in TRIZ. For the conventional methods to protect mosquitoes biting human, we drew the Su-field diagrams. Specially, for repelling spray (“DEET”) the Su-field modeling was as follows;



The repelling spray on human body is not sufficiently effective and harmful to human body a little. It is one extra substance S_3 between mosquito S_1 and Human S_2 in Su-field model as follows;



In the problem above, all kinds of methods against mosquito are complete yet.

By using one standard solution in TRIZ, the S_3 (the third substance) is recommended by the substance modified from S_1 and S_2.

The S_3 may be imaged as substance modified from S_1 (mosquito) or from S_2 (human).

The idea on system like artificial human (S_3) seducing more mosquitoes than real human, might be generated easily from that the S_3 is the substance modified from the S_2 (human).

So the system would be the mosquito trap. The S_3, mosquito trap protects mosquitoes against going to human.

At that time we got the initial conceptual idea for mosquito trap as an artificial human to seducing the mosquitoes more than real human.

The ideality of the mosquito trap may be written down as follows;

$$\text{Ideality} = \frac{\text{Functionality}}{\text{Cost + Harmful}} = \frac{\text{Capability to seduce mosquitoes more}}{\text{Cost of System + Other Harmful functions}}$$

On capability to seduce mosquitoes more, we get the advise from some experts related to mosquitoes at Korea NIH.

3. New mosquito trap with photo catalysis TiO_2 based on the ideality concept

Most mosquitoes like the CO_2 (Carbon dioxide) gas very much. To generate CO_2 gas cost effectively is very difficult besides CO_2 or propane gas bottles with high pressure.

We investigated the many methods to get the CO_2 cost effectively with other good functionality and low cost with little harmful function based on the ideality concept.

We found the mosquito trap using ultra violet light lamp with suction motor fan for catching some mosquitoes. Through the directional search for methods to generate the CO_2, we knew that the photo catalysis material, TiO_2 (Titanium dioxide) generates CO_2 after purifying airs by OH- (Hydrogen oxide radical) generated by ultra violet lamp as the source of the photo catalysis.

The process to generate the CO_2 is as follows;

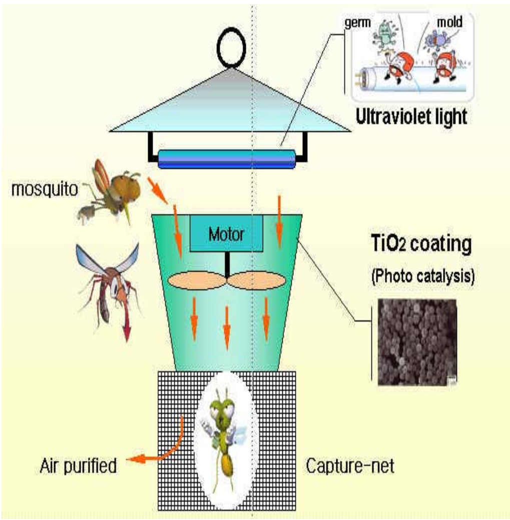
1) The UV light onto the TiO_2 surface generates much OH- as the source of photo catalysis.
2) The much OH- purifies the dirty air with smell and organics including carbon.
3) The by-products from the purifying are $CO_2 + H_2O$ (water vapor).
4) Both CO_2 and H_2O are some attractants for mosquitoes.

So we modified the initial idea with mosquito trap by the new traps using photo catalysis TiO_2 with ultra violet lamp.

The ideality was increased as follows:

$$\text{Ideality of new trap} = \frac{\text{higher capability to seduce mosquitoes + air purification}}{\text{A little cost up (for } TiO_2 \text{ coating) + no harmful function}}$$

The structure of the new mosquito traps is below schematically and was pended as the patent internationally (the number of patent is PCT/KR/01-00427). The prototype was made and evaluated as an invention with bronze medal in one of German international invention completion, IENA 2000 in Nurnberg, Germany. The new traps implemented catch over 10 thousands a one night near cattle shed in Korea, in summer. The prototype was commercialized and the products are being exported to the world such as U.S.A and Europe including Italy.



Principle of new mosquito trap

Product

4. Development of recent new mosquito trap through resource analysis and ideality concept

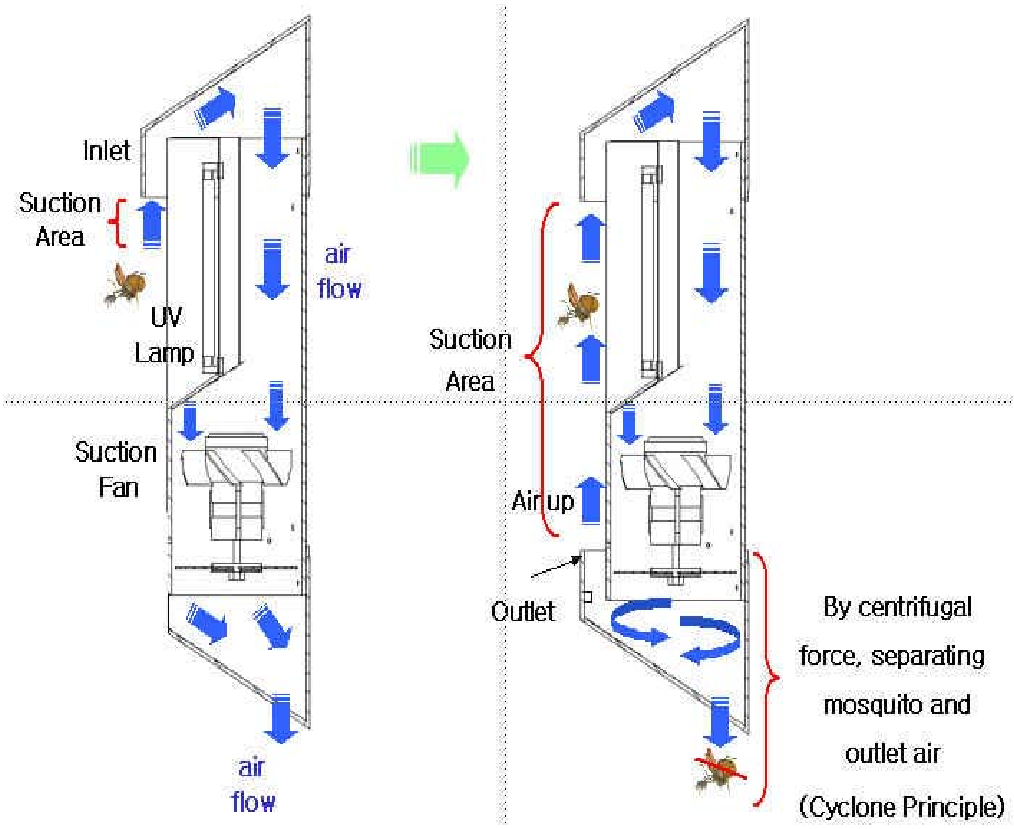
Meantime, some customers of the new mosquito trap complained the burden to clean up the cylindrical capture-net with numerous mosquitoes captured every morning and the suction power is not powerful.

We designed the recent new mosquito traps as shown in the figure below through resource analysis.

The power suctioning the inlet air is too low and the burden to clean up the numerous mosquitoes captured over night may be eliminated everyday for some customers.

Through the resource analysis of the new designed mosquito trap, the outlet air from the trap was not used and discarded. We decided to guide the outlet air upto inlet for empowering the suctioning power.

In addition, for the automatic cleaning up, we devised the cyclone principle with centrifugal force generated by rotating motor and fan. That is, the centrifugal force separates the mosquitoes captured and outlet air. The outlet air is guided up for empowering the suctioning power at inlet and the mosquitoes fall down automatically by gravitational force as shown in figure.



$$\text{Increased Ideality} = \frac{\text{more higher capability for mosquitoes + air purification + automatic clean up}}{\text{a little cost up (for } TiO_2 \text{ coating + extra simple structure) + no harmful function}}$$

Hence the concept and products on the hand-free and clean-up free excellent mosquito traps were generated and implemented.

Prototype of recent new mosquito trap and the figure attached pole of street lamp

5. Conclusions

The new and recent hand-free mosquito trap and the products were invented using the Su-field analysis and resource analysis based on the ideality concept. Also, we can conform that every (technical) system has evolved to the new system based on higher ideality. Through the products and its development process, TRIZ was conformed as a powerful tool to generate new innovative ideas. We hope that our concepts and products would be one excellent remedy to eliminate mosquitoes efficiently, specially, environment friendly.

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LAWS OF SYSTEM EVOLUTION IN THE DEVELOPMENT OF THE THERMAL BRIDGE PROBLEM

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Abstract
TRIZ problem analysis with additional study of laws of technical system evolution (LTSE), significantly improve a comprehensive solutions creation. In this paper, stress is put on the clear and basic utilization of laws of technical system evolution, in order to guide and support the regular TRIZ inventive problem solving process. Study of LTSE has always a strong position in the TRIZ problem solving practice, here it is presented separately form the main stream, developed at the basic level. Case study, investigated in this paper, is a problem of suppression of the heat bridge (HB) in the built environment. The goal is to underline the role of LTSE in the logical solution generation and preparation for further evolution steps into the future solutions.
Keywords: laws of technical system evolution, heat leakage bridge.

1. Introduction

The law of evolution of the technical systems is the one of three fundamental laws laying the basis for TRIZ theory. Whether hidden or exposed, in the problem solving process, law of technical system evolution (LTSE), gives a significant aid and drive the action into the right direction. In the presented briefly problem analysis, LTSE will be utilized to enhance the comprehension of solutions obtained with classical TRIZ tools. Technical system evolution puts into the logical array the set of "already made solutions" and orders them into the comprehensive sequence. This procedure enriches regular TRIZ analysis. Problem definition becomes much more complete. Then proposed solution goes ahead on the evolution line, their position is well defined and grounded for the next jump.[1,2]

Problem analyzed in this paper has its origin in the built environment. This fact sets some additional conditions, interesting restrictions and particular situation conditions. These extra pieces of information define the solution area and make the problem analysis even more interesting.

2. The problem

The problem has been submitted by the civil engineering company. During whole process of problem solving the assistance of the professional engineers from the company has been offered and utilized. The problem is defined as follows, it is required to suppress the effect of heat bridge (HB) at the connection of floor slab and external wall of the building. The phenomena of the HB occurs in points and regions of discontinuity in the structure of the external wall with different temperature on both sides. Figure 1. The most known locations of such discontinuities are edges of wall openings, linear HB and metal anchors suspending the external insulation materials, spot HB. In this particular example the HB has a shape of line, drawn by the intersection of floor slab and external wall. Figure 2.

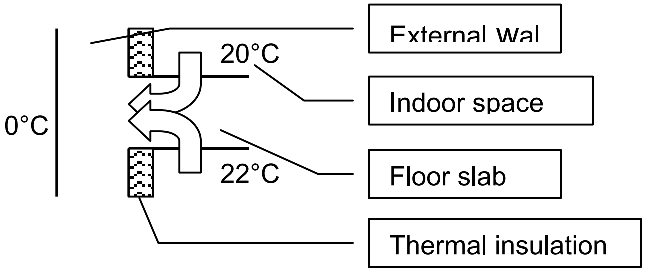


Figure 1. Heat bridge phenomenon

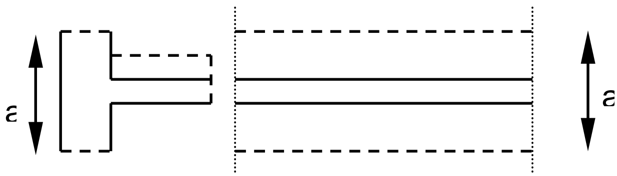


Figure 2. Shape of the studied heat bridge (section and front view)

2.1. Additional problem conditions

The goal to suppress the HB means in fact a significant reduction of the heat loss. In order to set parameters of the successful solution, the limit has been agreed for minimum 50% reduction of the heat loss from the measured area in the connection zone.

This connection is applied in the apartment building constructed in the technology of reinforced concrete, meaning that walls and floor slabs are produced in place at the building site. In this case study, building is located in France. Such location set parameters of indoor and outdoor temperatures. Consequently there are also some particular technological restrictions for the construction of apartment building in France.

The most important restriction for this task is, that utilization of any thermal insulation substance on the external wall surface is forbidden. This fact increases the heat loss from the region of considered connection in comparison to the nearest region. This makes a problem more significant and interesting.

Powerful solution to this problem should be easily applicable at the building site and should not require any specific knowledge, assistance of specialists, sophisticated technology or training. It should also fulfill all acoustic and flameproof standards.

3. Preparation – structure of the problem

In order to prepare the data for the analysis of the technical system evolution, let's focus on the construction of the wall-floor connection itself. What role does it play in the building structure? Which are the main functions of such connection and its elements? How, along the history, this problem has been managed by constructors?

3.1. Functions

Considered connection consist of two main elements, these are external wall and floor slab. External wall is a border between interior and exterior of the building, it supports also the floor slab. Floor slab supports all the equipment, it's a barrier for acoustic vibrations, noise and fire between floors. At the junction of external wall and floor slab, where the problem of the HB appears, these functions, mentioned above, overlap.

Functions of the wall-floor connection:

- keeps the weight of the floor and walls
- transmits the weight of the floor to the wall
- keeps the structure of the building, a part of the building's frame
- transfers the heat energy towards outside the building, HB phenomena
- transfers vibration from the floor to walls and vice versa
- creates the barrier for the fire and sound propagation

3.2. Common constructions in use

Firstly let's have a look on the traditional constructions, which are applied in the most common cases. There are plenty of variations, but in general, they may be classified into few main groups. The most appealing is a classification into two groups:

- constructions composed from few elements
- construction consolidated into one piece.

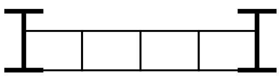
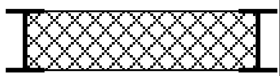
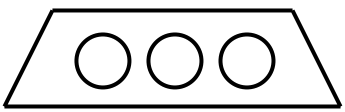
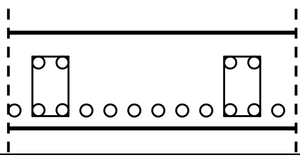
<table>
<tr><td colspan="6">Construction composed from few elements</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2">Timber beams + covering boards + thermal insulation</td><td colspan="2">Steel beams + bricks feeling</td><td colspan="2">Steel beams + precast element</td></tr>
<tr><td colspan="6">Construction consolidated into one piece</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">Precast concrete element</td><td colspan="3">Reinforced concrete (beams in the structure)</td></tr>
</table>

Table 1. Floor slab structure – constructions in use

4. Focus on the problem

Before, the problem of HB has not been so significant. Nowadays subject of economical use of energy becomes more and more crucial. Finally comes a time to drive our attention even to small leaks of energy lost from our systems. Problem of HB at the floor-wall connection stimulated an effort to develop a more heat proof constructions.

Problem of the HB has been resolved by slight modifications introduced into the regular constructions. Some representative examples of these modifications are presented on Figure 3.

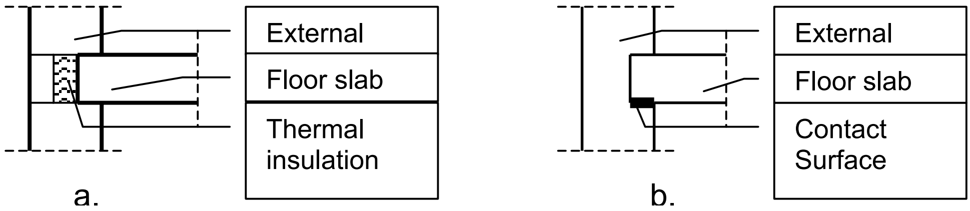


Figure 3. Conventional solutions proposed to the HB problem

5. Lines of evolution

In order to analyze a correct line of evolution, which will be helpful in the inventive problem solving process, two sets of solution examples gathered in point 3. and 4. should be investigated together. Models of connections presented in point 3. are on the one end of evolution line, models from point 4. representing attempts to solve HB problem, set here a direction towards future evolution.

Basing on examples 3.a. and 3.b. presented on Figure 3., there are proposed two initial lines of technical system evolution.

5.1. Thermal insulation

Example 3.a. (Figure 3.a.) represents the conception line of application of thermal insulation. Thermal insulation element should be applied in the optimal location and shape.

5.2. Supporting area

Example 3.b. (Figure 3.b.) draws the attention to the support area of the floor slab on the external supporting wall.

6. Solutions from TRIZ problem analysis

In-between the regular TRIZ problem analysis had been performed. Set of initial solutions, proposed for the HB problem, is used here to describe and continue evolution lines initiated in point 5.

Solutions have been gathered after two attempts. In the first trial problem of HB has been defined to the stage of physical contradiction defined as heat conductivity vs. strength. By means of Matrix of Inventive Principles, first set of indications for solutions have been gathered. After reconsideration the first group of initial solutions was generated. Second group of initial solutions has been obtained as a result of ARIZ-85C analysis applied to the studied problem of the HB. ARIZ analysis has been initiated on the same problem definition base as the first trial. ARIZ analysis reached part 3 and then it became possible to generate initial solutions.

All initial solutions, gathered after first and second (ARIZ) analysis, are presented below, together, in order to get a clear view. These solutions may be divided into two groups along two proposed lines of evolution. This way, discovered set of initial solutions, draw next points to show the more precise direction on the evolution path.

6.1. Enhancement line

Solutions, situated on the enhancement line, develop the idea of optimal utilization of thermal insulation element in the construction of wall-floor connection. Thermal barrier, an X element, takes different shapes, it may be the thermal insulation substance or additional system providing the similar effect. Table 2.

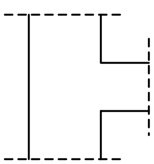
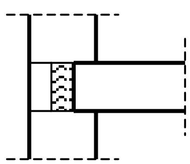
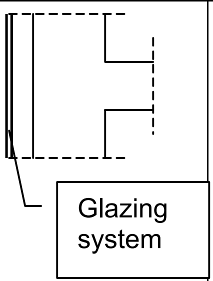
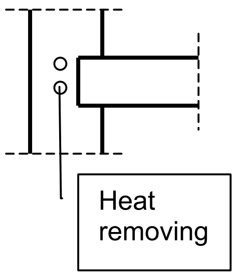
Enhancement			
No solution	Insulation panel	INITIAL SOLUTIONS	
		External glazing system introduces a new quality to the system	Heat removing system transfers the leaking heat outside the Operational Zone
Problem situation	Not sufficient solution		
INITIAL	Looking for ideal solution		

Table 2. Enhancement – evolution line development

Following the enhancement line, analysis focused on the problem of location for X element. The question arose, what is the true reason for these different locations? Answer has been already put in the problem definition, prepared in the TRIZ problem analysis. It’s a temperature difference between three temperature areas existing in the operation zone. Then, taking an advantage of TRIZ problem analysis made before, there is a short way to point the region, which causes the heat loss and where the heat barrier should be applied. Figure 4.

6.2. Void line

Solutions put in the category of *Void* line form an extension to the initial idea 5.2. where the contact surface between floor slab and wall is minimized. Reduction of the contact area may be performed (Table 3.):

- on the micro scale – bearing area is covered with low heat conductive substance (thermal boundary resistance) or porous metal replacing iron reinforcing rods,
- on the macro scale – size of bearing element itself is reduced.

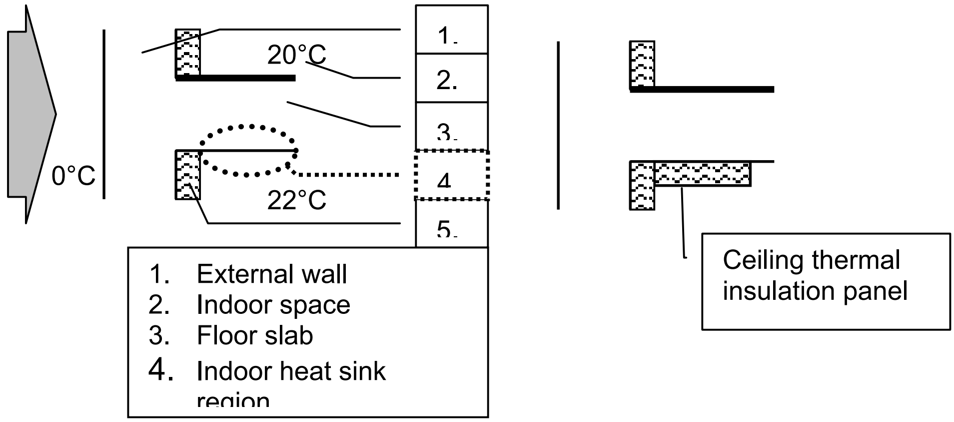


Figure 4. Weak point identification and proposed Solution (Enhancement line)

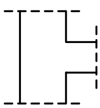
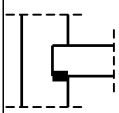
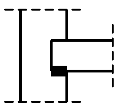
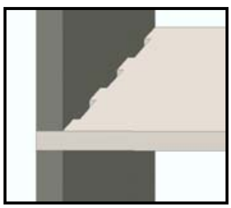
Void				
No solution	Contact surface	INITIAL SOLUTIONS		
		Improved contact suface – low heat conductive substance	Replacement of iron reinforcing rods by pourus metals	Size of bearing element itself is reduced Solution on macro scale
Problem situation	Not sufficient solution		Solution at micro scale	
INITIAL	Looking for ideal solution			

Table 3. Void line – evolution development

TRIZ problem analysis supported with performed study of technical system evolution, results in new solutions following the *Void* line. Proposed solution introduces “no” element, a void, heat conductive element is being removed. Figure 5.a. Functions of the wall-floor connection are transformed to load bearing walls of the super-system, the building structure. The moderate version of this concept is a solution with slight modification introducing stabilizing elements, beams, which support the external wall and assure the building stiffness. Figure 5.b.

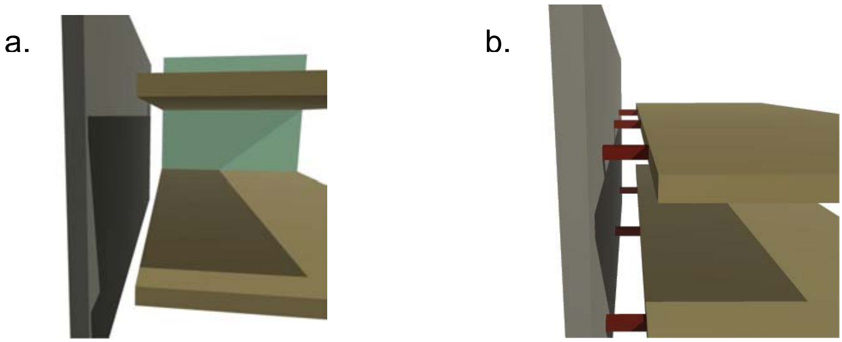


Figure 5. Solution – Void line
a. “no” element b. moderate version

6.3. Efficiency

Both solutions, *Enhancement* and *Void*, offer interesting solutions to the HB problem in this particular situation. *Enhancement* continues the evolution on the same level of system integration, thermal insulation element is applied in the new place. Efficiency of such solution has been measured in the 2D temperature field numeric simulation. Application of the 0,5m wide and 2cm thick thermal insulation element on the ceiling surface, saves 57% of heat loss from control area. Figure 6.

Void concept has much more potential. It has been resolved on the super-system level. Functions of the wall-floor connection element have been transformed to the building’s structure. This solution, in its moderate version, with linking elements, has been introduced into certification process, by some French building companies.[3]

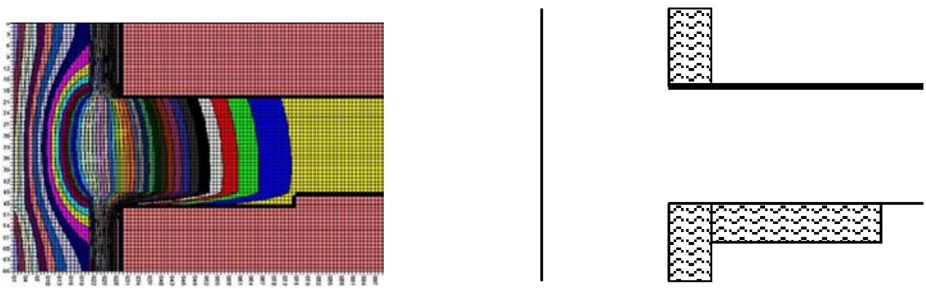


Figure 6. 2D Temperature field numeric simulation

7. Conclusion

Following the definition, law of technical system evolution says, “During the evolution of a technical system, improvement of any part of that system having already reached its pinnacle of functional performance, will lead to conflict with another part”. Performed analysis followed this rule and introduced improvement or exchange of the crucial element in the studied system of wall-floor connection. Application of LTSE caused, that TRIZ problem analysis, terminated at this stage, is very well prepared for further development, into the new upgraded S-curve of technical system evolution.

Analysis of the technical system evolution, introduced into the study of the HB problem, with utilization of TRIZ theory, created a significant reinforcement of the logical continuation in the problem analysis. In this combination, it became possible to obtain successful solutions, as a result of single student work, similar to those obtained by professional teams. [3]

Acknowledgments

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SOLVING A REAL WORLD INVENTORY MANAGEMENT PROBLEM USING A TECHNIQUE FOR INTEGRATING IDEALITY WITH THE SYSTEM OPERATOR

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Abstract
This paper discusses the application of a novel technique for integrating ideality with the system operator to a real world supply chain inventory management problem. The system operator and ideality are TRIZ tools that allow one to develop an understanding of a problem as well as lead to novel solution generation. Integrating the two tools may provide new insights into the problem at hand. Ideality and the system operator are briefly summarized along with the methodology for integrating the two tools.
The preponderance of the paper discusses a supply chain inventory management problem for a large textile company. The company is faced with global competition and in an effort to retain market share the company is attempting to lower finished goods inventory while maintaining or increasing customer service levels. Additionally, the company is unable to support acceptable customer service levels even with large inventories that often led to obsolescence. As a result, the company would continue to raise inventory levels across the board to higher levels until customer service reached an acceptable level. This approach, in most cases, resulted in increased inventory levels and therefore costs without really addressing the service problems. In fact, product service levels generally remained unchanged but with higher inventory. The solution from the technique of integrating ideality with the system operator pointed the company to a different solution of maintaining inventories at the stock keeping unit (SKU) level.
Keywords: Ideality, System Operator, Use of Resources, Supply Chain, Inventory.

1. Introduction

Difficult and enigmatic problems can be found in the functional areas of supply chain management. Examples of such problem areas include: demand forecasting, raw material inventory planning, customer management, inventory allocation, order management, manufacturing planning, capacity planning, marketing, pick management, distribution, transportation, plant and shop floor scheduling, and finished goods inventory planning. Each of these areas yields difficult problems to solve; owing in part to the complex interrelationships between the functional areas. The existence of a supply chain management problem may be easily identified, but the scope, complexity, and ultimate solution are often difficult to define. Finished goods inventory planning is a prime example. Within the functional area of finished goods inventory planning, the optimal amount of inventory to be carried must be determined such that inventory is minimized while fulfilling customer orders at an acceptable rate or customer service level. Other supply chain areas such as forecasting, capacity planning, transportation, distribution, manufacturing, and marketing significantly influence the optimal amount of finished goods inventory to maintain. The complex interrelationships between finished goods inventory planning and other supply chain function areas present challenges for understanding, defining, and ultimately solving problems.

TRIZ provides numerous tools for solving problems such as the finished goods inventory planning just described. In particular, the system operator and ideality are two TRIZ tools that provide systematic and methodical approaches to understanding and defining a problem that leads to solution generation. The system operator and ideality are indeed individually effective tools. Moreover, the tools can be integrated to produce a methodical and systematic solution generation technique [5]. The technique defines a tool that identifies resources at each of the interfaces delineated by the system operator matrix. This paper discusses the application of the technique for integrating the system operator with ideality to a finished goods inventory planning problem for a large textile company.

2. The System Operator, Ideality, and the Integration Technique

2.1 The System Operator

The system operator is a key TRIZ tool that provides a systematic approach for problem definition and solution generation. The system operator is useful throughout the problem solving process. The tool may be used for problem definition, idea generation, solution identification, and solution implementation. The TRIZ literature suggests that the system operator is used under a variety of different conditions: 1) to define the problem, 2) to look for the solution to a problem, and 3) to determine the trend of a system development [2].

The system operator directs thinking in terms of time and space by dividing the problem in to three levels and three time zones [4]. The three levels comprise the system, super-system, and subsystem. The three times zones suggested by the system operator are the past, present and future. The division results in a three-by-three matrix as shown in Figure 1. Each box represents a particular space and time. The matrix directs systematic thoughts at each level, thus overcoming "the psychological inertia of present and system level only thinking [4]."

The system, the super-system, and the subsystem levels of the system operator direct thinking outside of the system itself and into the system's environment and sub-processes. It is important to not only consider the problem at hand, but also to give consideration to the environment and sub-processes in which the problem resides as solutions may reside in either or both of these spaces. The three time zones of the system operator facilitate thinking in terms of time. The times zones are the past, present, and future. Even though the system operator breaks time into discrete categories, it is important to continue to think continuously with respect time. The system operator's categories provide the systematic framework for thinking in terms of time. Thus, the combination of space and time in the system operator helps to think more completely about the problem to be solved thus maximizing solution generation possibilities.

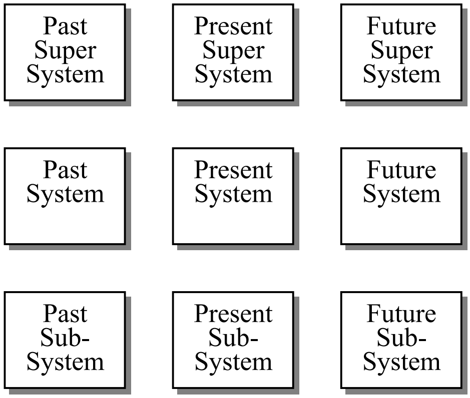

Figure 1. The system operator matrix

2.2 Ideality

Ideality can be expressed in equation form as the sum of all useful functions of a system divided by the sum of all undesired effects associated with the system [6]. In order to increase ideality, the numerator must be increased or the denominator must be decreased. Increasing the numerator yields more useful functions of the system. Decreasing the denominator is accomplished by removing undesired effects such as labour, materials, waste, cost, duplicated effort, etc. Therefore, we can arrive at the conclusion that an ideal system performs a function without actually existing [6].

One approach to increasing ideality is the use of resources. A resource is any substance, field, property, or other attribute available in a system or its environment that is available for improvement of the system [6]. Resources are categorized as substance, space, field, time, functional, and informational resources [6]. Any system that has not attained ideality should have resources available for the improvement of the system. Resources should be used in such a way as to increase the numerator and/or decrease the denominator of the ideality equation.

2.3 Integrating the System Operator with Ideality

Singularly, the system operator and ideality are extremely useful and beneficial TRIZ problem solving tools. Martin et. al. [5] presented a technique for integrating the system operator with ideality. The steps are summarized in Table 1.

Table 1. Steps for Integrating the System Operator with Ideality [5]

1. Define and draw the system operator matrix for the problem (Figure 1).
2. Put yourself inside each of the nine boxes of the matrix.
3. "Look" into the adjacent boxes and identify resources that are available at that particular interface.
4. List any of the resources that can be used or eliminated to increase ideality.

5. List any resource that can be changed to increase ideality.
6. Repeat steps 2-5 for each of the boxes.
7. Analyze possibilities for solution directions.

The combination of the system operator with ideality provides structure to the use of resources to increase ideality. By directing the thought process to distinct space and time zones, resources may be identified that could have been overlooked without the structured approach. Additionally, the combined technique provides a methodical framework for less experienced ideality practitioners.

3. Description of the Problem

As mentioned in the introduction, supply chain management problems are often difficult to define and to solve. The focus of this paper is on a specific problem of determining the correct amount of finished goods inventory necessary to support acceptable customer service levels for a large textile company. The main objective of any supply chain is to supply the customer with a product when the customer wants it and at a price that maximizes profit. In order to achieve both objectives, a balance has to be struck between carrying enough inventories to meet demand but not so much as to significantly impact profitability. At a cursory glance, this may seem to be a fairly trivial problem to solve but as mentioned before, complex relationships exist between the functional areas of a supply chain. In fact, the problem turns out to be quite difficult. The next few sections describe the issues that confound the problem.

3.1 Long Lead-Times

The lead-time of the products of the textile company average six weeks but can take as long as twenty weeks. In an environment where the lead-time is constant, very little inventory is required to maintain customer service levels. However, in the situation of variable lead times where goods have lead-times ranging from two to twenty weeks, large inventories must be carried in order to support customer service levels when the lead-time is longer than the expected six weeks.

3.2 ABC Inventory Targets

The company's existing inventory policy establishes inventory targets using a classic ABC strategy where sixty-five percent of the volume is classified as A, twenty percent of the volume is classified as B, and fifteen percent of the volume is classified as C. All A items received the same target, all B items received the same target, and all C items received the same target. Generally, the C items will be assigned a higher inventory target than the A items owing to the expected volatility of demand on a low volume item (i.e., A items are highly demanded and therefore are produced on a regular basis).

The ABC classification is established at the category level. A category can contain many stock keeping units (SKU) and is part of a family as shown in Figure 2. Therefore, all SKUs within a category will receive the same inventory target. This presents a problem because individual SKUs have significantly different shipping patterns and thus volatilities. In fact if you conduct an ABC analysis at the SKU level, then you will find that within an A category there will be A, B, and C SKUs. Therefore the category ABC inventory target will assign too much inventory to some SKUs and too little to other SKUs. High inventories and low service are a result of this policy. The primary way to raise service levels using this policy is to increase the category inventory target to a level where C SKUs within the category are serviced well. This results in needlessly raising inventory on the A and B SKUs that were already being serviced well. The targets were established at the category level owing to forecast accuracy.

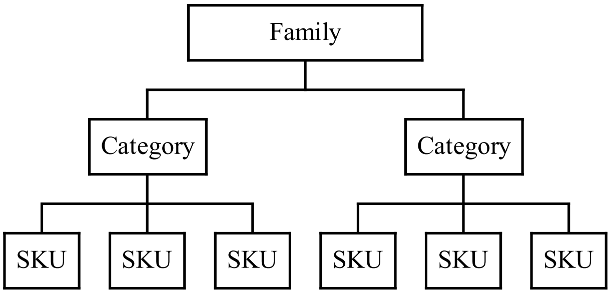

Figure 2. Hierarchical grouping of items at a large textile company

3.3 Forecast Bias

Forecast is one of the most important factors in a make to stock supply chain. Owing to the variable and long lead times, this company has to carry finished goods inventory in order to satisfy customer demand at an acceptable level (i.e., they cannot receive an order and then produce it). Therefore, they have to guess on what the customer will order and hope it comes to fruition. The forecast in this company is done at the category level because aggregating all the SKUs into one item will have more forecast accuracy (i.e., one is able to predict that a customer might order a 1000 of category of A better than to predict an order of 12 for SKU 1). The company then uses a SKU distribution mix (e.g. 10% of the demand is always for SKU 1) to blow the forecast at the category level down to the SKU level for production planning purposes. Currently, the forecast is done on a monthly basis in an effort to lower forecast error. The targets are then based on the forecasted demand. For example, if a target is set at six weeks then the level of inventory for this SKU will be set to the sum of the next six weeks of forecasted demand.

An important issue to accommodate in finished goods inventory planning for this particular textile company involves a significant forecast bias. Forecast bias is defined as the sum of the forecast errors over a given period of time. Forecast error is defined as difference between the forecasted demand and actual demand for given time period. If the forecast is unbiased, then the forecast errors will be randomly distributed yielding a bias near zero. In this case, due to financial and other influences, the forecast may be biased upward or downward for long periods of time. Significant biases over long period of times will result in too much inventory in the case of a positive bias or poor service due to a lack of inventory in the case of a negative bias.

3.4 SKU Proliferation

At this particular textile company there are more than 25,000 SKUs for which finished goods inventory must be planned. Of this number 65% of the SKUs are high volume A SKUs, 25% of the SKUs are medium volume B SKUs, and 10% are low volume C SKUs.

The number of SKUs presents a situation where the system needs to be simple enough for most employees to understand, yet complex enough to handle the myriad of possibilities that may arise from large number of SKUs that are stratified in ABC classifications.

3.5 Customer Ordering Pattern

Customers can place orders for items at any time for any given quantity. This presents a significant problem for finished goods planning. If the forecast is not reasonably aligned with customer demand, then we will have trouble servicing well unless we have sufficient inventory on hand.

3.6 Other Issues to Consider

There are several other issues that confound finished goods inventory planning. Some of the more important items are given in the following list:

- Weekly planning against a monthly forecast;
- Little correlation between the forecast and actual demand;
- Manufacturing capacity limitations;
- SKU distribution mix error;
- Inventory targets are in terms of weeks of supply (WOS) rather than in units;
- The targeted service level is 95% for all SKUs regardless of volume.

4. Application of the System Operator and Ideality Integration Technique to the Finished Goods Inventory Planning Problem

In order to generate solutions to the finished goods inventory planning problem described in the proceeding sections, the technique of integrating the system operator with ideality, outlined in Table 1, was employed. The ensuing sections summarize the results obtained from the application of the technique.

4.1 Develop the System Operator Matrix

The first step in the technique is to define and to draw the system operator matrix for the problem. The system operator matrix provides the fundamental framework for guiding resource identification in subsequent steps. The resultant system operator matrix is shown in Figure3.

4.2 Identify Resources at Each Interface within the Matrix

Once the system operator matrix has been developed, the next phase of the technique requires all resources to be identified at each of the interfaces. As described earlier, a resource may be classified as substance, space, field, time, information, or function resources. The next few sections summarize the resources identified by looking from the present-system into each of four adjacent zones.

Past – Super System Supply Chain	*Present – Super System* Supply Chain	*Future – Super System* Supply Chain Order
Past – System Finished Goods Demand Forecasting	*Present – System* Finished Goods Inventory Planning	*Future – System* Finished Goods Inventory Allocation
Past – Sub-System Forecasting Processes	*Present – Sub-System* Component Inventory	*Future – Sub-System* Inventory Pick

Figure 3. The System Operator Matrix for the Inventory Planning Problem

4.2.1 Present System Looking to the Past System

At the interface between the present system and the past system, we are identifying resources in finished goods demand forecasting that may be used to increase ideality and provide solutions generation directions for the finished goods inventory planning problem. Table 2 summarizes the findings for this interface.

Substance Resources	**Informational Resources**
Forecasting software/hardware	Forecast error
Forecasting personnel	Historical demand data
Database	Historical forecast data
Inventory	Historical trend data
Warehouses	SKU Distribution Mix Error
Raw materials	Database Accuracy
Suppliers	Inventory levels
Customers	Customer requirements
Computer systems	Personnel talent/experience
Time Resources	Raw material levels
Manufacturing lead-time	Supplier quality
Time for between forecasts	ABC Classification
Time to produce the forecast	**Functional resources**
Time between forecast and delivery	Forecasting process
Computing speed	Financial alignment
Man hours	Planning/scheduling processes
Sales seasons	Manufacturing

Table 2. Available Resources at the Present System and Past System Interface

The next step is to employ ideality. The following is a summary list of directions for possible solutions generation.

- Can historical demand data be utilized to predict the required level of inventory?
- Can historical forecast data be used to predict the required level of inventory?
- Is it possible to use forecast error to somehow make adjustments to the level of inventory we are carrying?

- Is it possible to incorporate lead-time in such a way as to influence finished goods inventory?
- Can lead time between forecast and actual delivery be reduced?
- Can the database accuracy of current inventory levels be improved?
- Can SKU distribution mix be used to predict the required level of SKU inventory?
- Can the forecast accuracy be improved?

4.2.2 Present System Looking to the Future System

At the interface between the present system and the future system, we are identifying resources in inventory allocation that may be used to increase ideality and to provide solutions generation directions for the finished goods inventory planning problem.

Table 3 summarizes the findings for this interface.

Substance Resources	**Informational Resources**
Inventory allocation software	Allocation results
Database	Historical allocation results
Unpackaged inventory	Quality data
Customers	Allocation trend data
Shipping systems	Inventory levels
Packaged inventory	Customer requirements
Computer systems	Packaging capability
Distribution center	
Time Resources	**Functional resources**
Allocation processing time	Allocation process
Time between allocation runs	Financial alignment
Time to perform actual allocation	Packaging scheduling process
Shipping time	Distribution
Packaging speed	
Man hours	
Computing speed	

Table 3. Available Resources at the Present System and Future System Interface

The next step is to employ ideality. The following is a summary list of directions for possible solutions generation.

- Can allocation data be utilized to predict the required level of inventory?
- Is it possible to predict a trend in the allocation data that will permit us to get a quicker read on inventory requirements?
- Can quality data be used to predict fallout rates that may affect inventory targets?
- Can we plan inventory in such a way as to only replace what was allocated?

4.2.3 Present System Looking to the Present Super System

At the interface between the present system and the present super system, we are identifying resources in supply chain inventory planning that may be used to increase ideality and provide solutions generation directions for the finished goods inventory planning problem. Table 4 summarizes the findings for this interface.

Substance Resources	Informational Resources
Supply chain planning software	Historical demand data
Planning personnel	Historical forecast data
Database	Historical trend data
Computer systems	Inventory levels
Customers	Production plan
Planning systems	Plant schedule
Manufacturing systems	Personnel experience
Manufacturing personnel	Customer requirements
Time Resources	**Functional resources**
Manufacturing lead-time	Planning process
Raw material procurement time	Financial alignment
DC lead time	Planning processes
Planning process time	Scheduling processes
Manufacturing speed	Manufacturing
Man hours	

Table 4. Available Resources at the Present System and Present Super System Interface

The next step is to employ ideality. The following is a summary list of directions for possible solutions generation.

- Can historical demand data be utilized to predict the required level of inventory?
- Is it possible to reduce manufacturing lead time to give more time to react to changes in demand?
- Is it possible to incorporate manufacturing lead-time in such a way as to tie finished goods inventory?

4.2.4 Present System Looking to the Present Subsystem

At the interface between the present system and the present subsystem, we are identifying resources in component inventory control that may be used to increase ideality and provide solutions generation directions for the finished goods inventory planning problem. Table 5 summarizes the findings for this interface.

Substance Resources	Informational Resources
Inventory control software	Component inventory
Plant personnel	Historical component consumption
Database	Historical supplier lead times
Shop floor scheduling software	Inventory levels
Personnel	Customers
Time Resources	**Functional resources**
Manufacturing lead-time	Manufacturing processes
Time to create manufacturing orders	Financial alignment
DC Time	Scheduling process
Time to receive raw material	

Table 5. Available Resources at the Present System and Present Subsystem Interface

The next step is to employ ideality. The following is a summary list of directions for possible solutions generation.

- Can historical consumption data be utilized to predict the required level of inventory?
- Can we offset finished goods inventory with component inventory?
- Can we reduce the lead time to receive raw material?
- Can we reduce the variability associated with supplier lead time?

4.3 Analyze Possibilities of Solution Directions

The final step in the integration technique requires that each of the solution directions generated by the application of ideality at each of the system operator interfaces be evaluated. The directions suggested by the application of the technique to the finished goods inventory planning problem can be classified into short-term and long-term solutions.

4.3.1 Short-Term Solutions

Short-term solutions were evaluated and identified. Short-term solutions were defined as those which could be implemented in less than six months with a minimal capital investment. The object being to maximize customer service levels using an finished goods inventory planning strategy. The short-term solutions are summarized in the following list:

- Develop a finished goods inventory model based upon historical demand variation, manufacturing lead-time, manufacturing lead-time variation, historical forecast error, and the current forecast;
- Correct for forecast bias in the finished goods inventory planning;
- Fix the errors in the SKU mix distribution;
- Set inventory targets at the SKU level rather than the category level;
- Simply increase finished goods inventory;
- Increase the component inventory to permit quicker response to demand surges;
- Ship finished goods via air to reduce the lead-time and increase manufacturing response;
- Use contractors to increase surge capacity;
- Improve the database accuracy among the series of databases that are used by forecasting, planning, etc.

4.3.2 Long-Term Solutions

Long-term solutions were identified and evaluated. Long-term solutions were defined, as those that would take longer than six months to implement and/or that would require significant capital expenditure. The long-term solutions are given in the following list:

- Reduce our manufacturing lead-time through improved execution, etc.;
- Move manufacturing planning from push to pull model;
- Reduce or eliminate the forecast bias;
- Move to a hybrid planning model in which we push part of the way and pull the rest of the way;
- Add manufacturing capacity in order to respond to demand surges;
- Raise raw material inventory levels and reduce finished goods inventory;
- Implement a new forecasting system.

4.4 The Implemented Solution

Ultimately the decision was made to go with a short term solution. We decide to implement several of solutions generated by the integration of the system operator with ideality. The following is a list of the solutions we implemented:

- Develop a finished goods inventory model based upon historical demand variation, manufacturing lead-time, manufacturing lead-time variation, historical forecast error, and the current forecast;
- Correct for forecast bias in the finished goods inventory planning;
- Set inventory targets at the SKU level rather than the category level.

In fact, we developed a model that implemented all three solutions into a single solution. We developed a model that set inventory targets for each SKU that incorporated historical demand variation, lead-time, and lead-time variation. The model predicted the amount of inventory required to meet demand fluctuations during the expected manufacturing lead-time based upon historical demand. Additionally, we added a factor to correct for bias in the forecast. The bias factor would make gradual adjustments in the finished goods inventory in such a way as to not introduce too much volatility into manufacturing.

4.5 Results

The results of the implemented solution are very encouraging. Figure 4 is a graph of actual inventory for one of the categories used to pilot test the model. Inventory was reduced by about fifty percent while maintaining at least ninety-five percent customer service levels throughout the time horizon. The inventory reduction was primarily due to lowering targets on A SKUs. The service was held by increasing inventory on the C SKUs.

Figure 4. Category Inventory Reduction as a Result of Implementing the Solution

5. Conclusion

The system operator and ideality are very useful solution generating TRIZ tools. The system operator provides a structured framework for analyzing a problem by directing thought into space and time. Ideality stretches thinking to higher level of abstraction and thoroughly exhausts all resources available for increasing ideality.

In this paper, a technique for integrating the system operator with ideality was applied to a real world supply chain planning problem. The system operator was developed and resources were identified at each of the interfaces for the present system. Ideality was used to generate many solution directions. The solutions were evaluated and categorized as long-term and short-term solutions. Ultimately, a short-term solution was implemented that incorporated several of the solution directions developed from the integration technique. The model that resulted from the application of this technique reduced inventory by about fifty-percent while maintaining service levels greater than ninety-five percent during the pilot test.

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ANALOGIES AND TRIZ, TWO CREATIVITY TECHNIQUES USED IN LEGGED ROBOTS

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Abstract
This paper presents the study of walking robots using especially TRIZ (the Theory of Inventive Problem Solving) and Analogies creativity techniques. I consider visual analogy (imagistic representation and relationships, especially mathematical and causal relationships) and elimination of the contradictions, furthered by cognitive historical analysis, as a basis for inventive thinking.
I am going from the structural analysis of carnivorous millipede Litobius forficatus, using performant apparatus. Initially, I realized by analogy a complex structural model. Using inventive principle "the other way round" by an experiment on the glass substratum, I established the law of movements in different directions. The technical contradictions were eliminated using inventive principles suggested or not in Contradiction Matrix.
I realized some structural walking robot models. It was realized an experimental model for one walking robot, and its kinematic analysis. It is presented a micro walking robot with flexure hinges and shape memory actuators, and its analysis with FEM (Finite Element Method).
Keywords: analogies, visual analogy, TRIZ, legged robots, bionics.

1. Introduction

More than 200 different creativity techniques and tools stimulate creative thinking.

The systematic use of biological and botanical analogies for solve new engineering problems characterize the science named bionics.

This paper presents a study of walking robots using especially TRIZ and Analogies.

The analogy is a very powerful tool for creativity and the visual image plays a central role in first and more important phase of it.

Because the analogical reasoning can give only probable conclusions must jointed it with other methods, especially with TRIZ method, for obtain the final target.

I am going from the locomotion of carnivorous millipede "Litobius forficatus" and I apply its features for obtain a functional mini-robot.

2. Description of the process of creation

If somebody try to follow the process of her/his creation, the surprise will be greater to discover the same steps made like many others inventors.

It is amazingly to discover the algorithms of your mind during creative thinking.

In my case, first I created the models, I made all analysis, and after this I explored TRIZ, visual analogies, and other creativity techniques; I asked myself different questions like these:

- Why have I chosen that solution?
- Why have I selected and utilized that realization from the history of science and not others?
- Which is the role of the imagistic representation in my scientific activity?
- Which is the influence of the time from last activated remembrance in the process of analogy?
- Which is the influence of the intensity of the information stored in my long-term memory in analogical process?
- If I follow different steps of the process of scientific creation or different creativity techniques studied and presented by others, the result of my work in the same domain, for the same problem, will be much better, or the same?

So I began to search answers at one part of them.

2.1 The strategy of my work

a) The morphological analysis of the crude source: the animal.

I realise a minute morphological analysis even in future I will make a general imagistic representation, and thus because it must known the relationships determined by morphology.

b) The analysis of locomotion in different directions, on different substratum.

For this analysis I utilised experiments and thought experiments using some inventive principles, like “the other way round”, too. It is necessary to obtain the laws of movement. If it wasn’t possible at this moment, I’ll come back after point c, when a scheme-source will be finished.

c) Summary representation of the initial source – the scheme source.

I consider very important this step, to realize a scheme of the source according with the principal purposes of analysis; by discarding irrelevant relationships of initial source and storing critical ones, a new scheme-source will be obtained.

For me is so important this phase because I considered the visual analogy the basis of scientific creation.

This first enhanced source - the scheme-source with selected relationships, especially mathematical and causal relationships - will be the new source-model; both imagistic representation and analogical reasoning must be used for create new models.

d) Process of retrieval and elaboration of an analogical model – one enhanced source - using scheme-source which is common both crude and target domains.

e) Mapping and transfer between enhanced source and probable target continue the process which will be finished by evaluation.

f) If the probable target doesn’t agree with the wished target, I try to create the target using TRIZ method, by eliminate the contradictions from the probable target which became the new enhanced source and the steps *e* and *f* are repeated.

g) If wasn’t find an acceptable target, the selected scheme-source is compared by analogy with possible different targets which are stored in long-term memory. I consider that this last complex process begins from present to past; it is furthered by cognitive historical analysis [Nersessian, 1992]. In this comparison there are mapped visual similarities and the primordial wished relationships.

If I obtained one acceptable model from long-term memory, the process is continued with transfer and evaluation and can be repeated.

2.2 Experimental analysis of the animal body and of the movement of the animal

It is remarkable the flexional capacity of the body of Litobius forficatus (figure 1) on complex curves in plan and especially in narrow spaces.

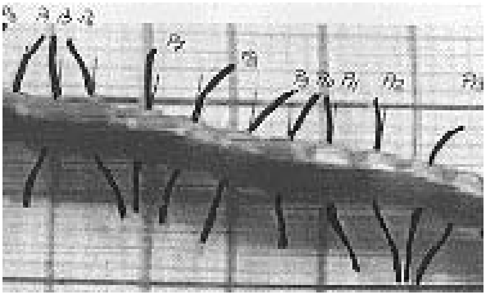

Figure 1. Litobius forficatus going straight

With the help of performant apparatus (video camera, computer with multimedia system - Movie Machine, microscope) I create a base of millipede images during the locomotion, usefully for morphological analysis and for the analysis of the complex locomotion.

Initially was a contradiction between the cognitive field and visual field: I see the movement, but I can't understand the law of movement, going forward and going back, the possible positions of the legs, ones towards another, the positions between segments and legs, and the positions of the body segments. For eliminate this contradiction I utilized the principle „the other way round", it means to utilize the principle of inverse movement by an experiment on glass. I have put the animal on the glass substratum. If the coefficient of sliding friction is not great, the body does not advance and we can see the action of the muscles between the segments of the body. I can observe the law of the movement of the legs (which aren't fixed) with respect to the body. Using the previous principle, if the final segments of the legs are fixed, the body will advance but the law of action of the muscle is the same.

Thus, it was found a cyclical law for the sense of rotation of the legs; if three legs are intersecting in a centre of curvature, it is shown in figure 2.

The angular positions of the selected legs: P6, ..., P12, with respect to transversal axes of the body' segments in table 1 are shown.

Time (s)	P6 (deg)	P7 (deg)	P8 (deg)	P9 (deg)	P10 (deg)	P11 (deg)	P12 (deg)
0,72	-27	5	20	35	10	-28	-5
0,76	-5	20	30	15	0	-30	30
0,8	20	35	10	-30	-20	8	35
0,84	27	10	-10	-30	-5	10	36
0,88	20	0	-30	7	30	30	25
0,92	10	-35	-10	20	35	0	5
0,96	-27	-15	20	35	25	-10	-5

Table 1

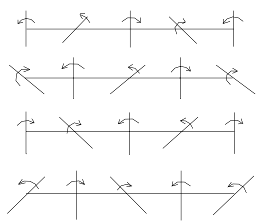

Figure 2. Movement of the legs

The complete experimental research is shown in detail in [Cretu, 1999].

2.3 Summary representation of the initial source

All these: the morphological analyses, the analysis of the movement in different conditions, on different substratum, on different curves, in plane or in space, help me to realize simplified schemes.

Some well made schemes focus the specific relationships of the phenomena.

Figure 3 depicts a simplified scheme, with visual similarities with respect to the animal during locomotion. I observed the same figure – the triangle - between the elements of the "body", and I stored this idea in my memory, because I considered it useful.

This scheme was used for one spatial mechanism (Cretu, 2000).

I can reduce the elements: 1, 2, 3, 4, 5 (see figure 3) to elements type "beam": 1, 2, 3, 4 (see figure 4).

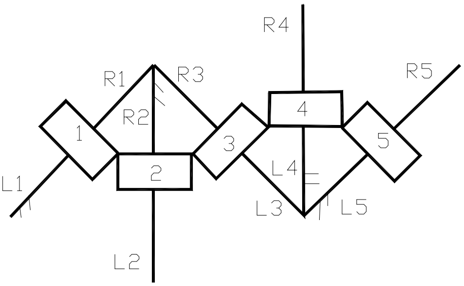

Figure 3. Simplified scheme of the animal

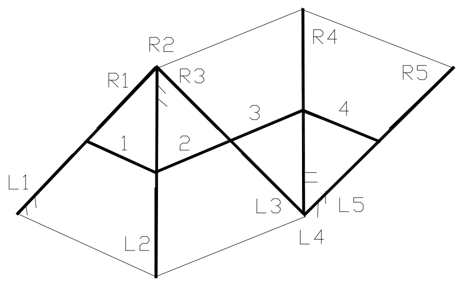

Figure 4. Simplified scheme of the animal

It will be very useful for creating new planar or spatial mechanisms, if we'll add at this scheme some geometrical restrictions and relationships which establish the laws for different types of movement.

The elements 1, 2, 3, 4, are midlines in the resulted triangles (figure 4).

I kept the positions of the legs, and those laws of movement in the plane, and I simplified more the form of the body, but using the same allure, like a wave.

I concluded the law for straight movement: the legs that are on the curve of the body, at a given moment, from an inflexion point to the next, exclusive, which are intersecting in the centre of curvature, touch the substratum, and the corresponding legs in the same pairs are lifted. This feature remains also for the curve with greater curvature radius.

For the going in the curve all elements that are in the centre of curvature touch the substratum with the help of sliding or rotational joints and all kinematic chains in this curve are inactive until the mechanism changes the direction.

The passive chains have a rotational movement around centre of curvature, until the first element becomes in the limited position (at 45 degrees on the direction of going). After this, each element follows the previous law of movement.

The control for leading ''legs" and for main actuator is possible by feedback only after I have determinate the laws of movements in different periods of time.

2.4 Structural analysis

The base of images was useful for realize the structural models by analogy.

I have followed to keep the specific features of the myriapods locomotion, for different types of locomotion creating different stepping mechanisms (Cretu, 1999, 2000, 2001).
I made and analyzed a complex structural model of one walking robot (figure5).

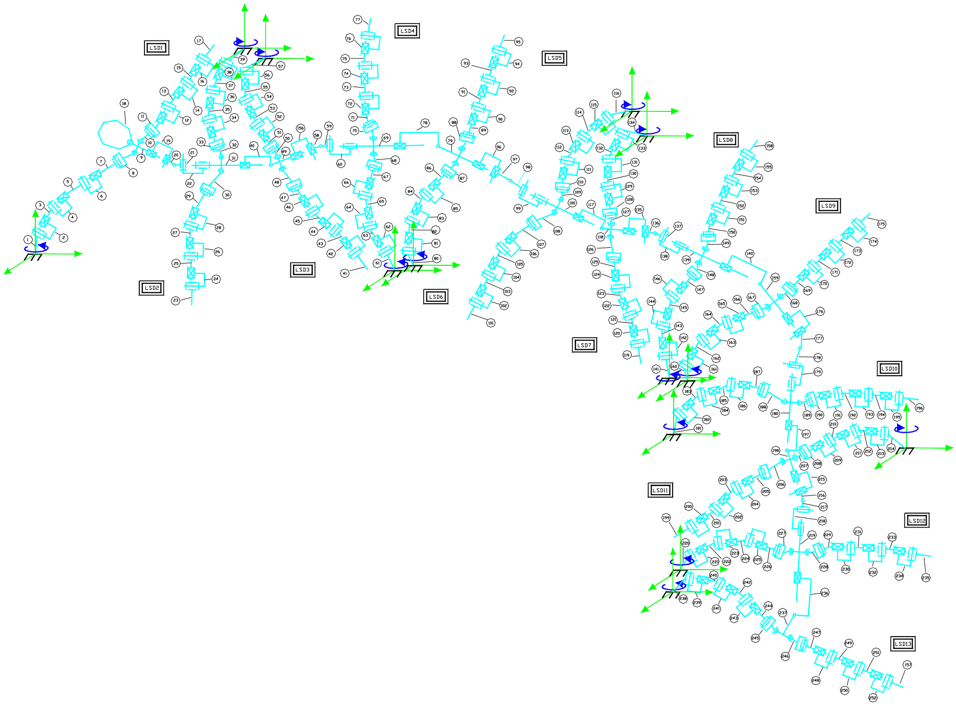

Figure 5. Structural model for a walking robot inspired from Litobius forficatus

2.5 Using TRIZ for eliminate the contradictions

Consciously or intuitively, everybody eliminate contradictions when create something new in domain of science or technique.

In my work were many technical contradictions, like these:

- I want to have the same main law of the locomotion of the animal' body in the plan, but with the simplest structure (in contradiction matrix: adaptability/device complexity, 35/36);

- I want to have a great mobility, but with few actuators (in contradiction matrix: adaptability/ease of operation, 35/33);

- I want to move in narrow spaces, with the same main law of movement, but without great volume of the robot (in contradiction matrix: adaptability/volume of an object that is moving, 35/7).

For 35/36 technical contradictions the matrix recommends: 15, 29, 37, 28 as inventive principles, and for 35/33 technical contradictions the matrix recommends: 15, 34, 1 and 16 as inventive principles.

I consider these two previous contradictions unified. For reproduce principal types of locomotion of the millipedes in the plane, but with a simple device with minimum of motors, I utilize the inventive principles: „discarding and recovering”- 34, „merging”- 5, „periodic action”- 19, “mechanics substitution”-28 and „dynamics” - 15.

I use simplified scheme, obtained by:

- discarding irrelevant degree of freedoms of some kinematic elements (inventive principle “discarding and recovering”- 34);
- assembling similar parts – different kinematic elements of the “legs” - to perform parallel operations: the same movement of the new obtained “legs” (inventive principle “merging” -5).

To coordinate the movement with minimum of actuators it was a priority in my mind and for that, many ideas were mapping with it; it was useful the previous scheme and:

to use electromagnetic fields, fixing some points of “legs” (inventive principle 28);

to design the characteristics of the process to find an optimal number of actuators by using one single rotational motor (inventive principle 15).

The periodic action (inventive principle – 19) of the actuators was presented in other papers (Cretu, 1999, 2000), for different types of locomotion.

The figure 6 depicts the new simplest structural model.

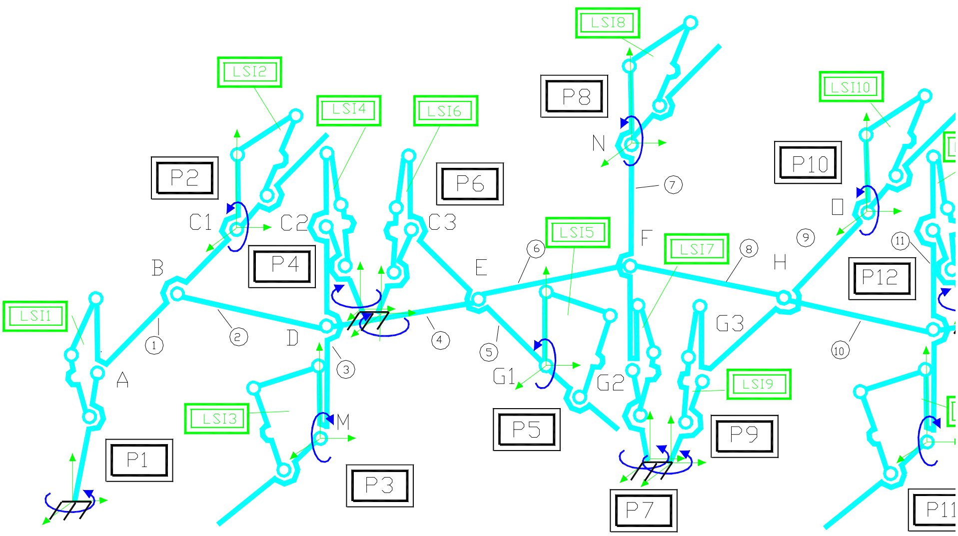

Figure 6. The simplest structural model for a walking robot

At the model presented in figure 6 it is wonderful to remark that one single motor with alternating rotation (in joint B), and two actuating sliding or rotational joints on each of „body” elements (in joints: A and C1, in joints: M and C2, in joints: G1 and C3, in joints: G2 and N, in joints: G3 and O, ...) are sufficiently for the locomotion of multi-legged mechanism, even the set of four body-elements (figure 4) is repeated.

The robot presents certain geometrical restrictions established by analogy with initial source, according to morphological study: the elements 2, 4, 6, 8, ... are midlines in the passive chains.

There are variable kinematic chains during the locomotion, which alternate from active to passive.

It was established the law for the command of the actuators on different curves in the plane.
The experimental robot is presented in figure 7.
The dimensions of this model are: length – 0,4 [m], width – 0,13 [m], height – 0,08 [m].
The type of the model is: planar multi - legged robot.
It has the weight – 1 [kg], and the maximal velocity is 0,1 [m/s].

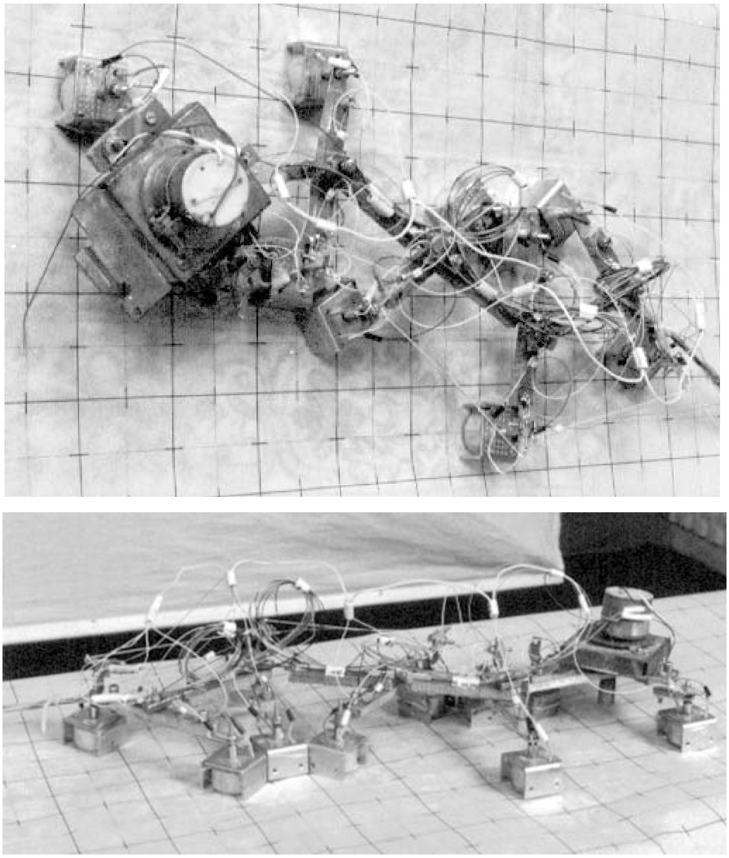

Figure 7. Milli-robot 1- MMS4

To eliminate contradiction: adaptability/volume of an object that is moving, 35/7, I utilized the inventive principle recommended in contradiction matrix: „dynamics"-15, and "merging"-5, „thermal contraction"-37, „spheroidality-curvature"-14, too.
The robot presented in figure 6 can be adapted, becoming flexible, using shape memory actuators and flexure hinges.
Going from the idea that the muscles have three specific properties: elasticity, excitability and contractibility, will be use by analogy shape memory actuators instead rotational motors. Thus, will be applied the inventive principle thermal contraction, because SMAs (shape memory alloys) are metals that "remember" their original forms. SMAs can change shape, stiffness, and other mechanical characteristics in response to temperature and stress.

Other inventive principle witch is applied for the same contradiction was spheroidality-curvature, and for that it was constructed flexure hinges instead rotational joints. The material of the mini-robot will allow that it will become flexible (the principle: “dynamics”).

But, the law of movement on any curve in the plane is the same, and thus the control for leading the “legs” and for main actuator is unchanged.

After an analysis with FEM using COSMOS program for different situations, sure, the results saw that the areas of flexure hinges are most stressed (figure 8 - analysis with FEM).

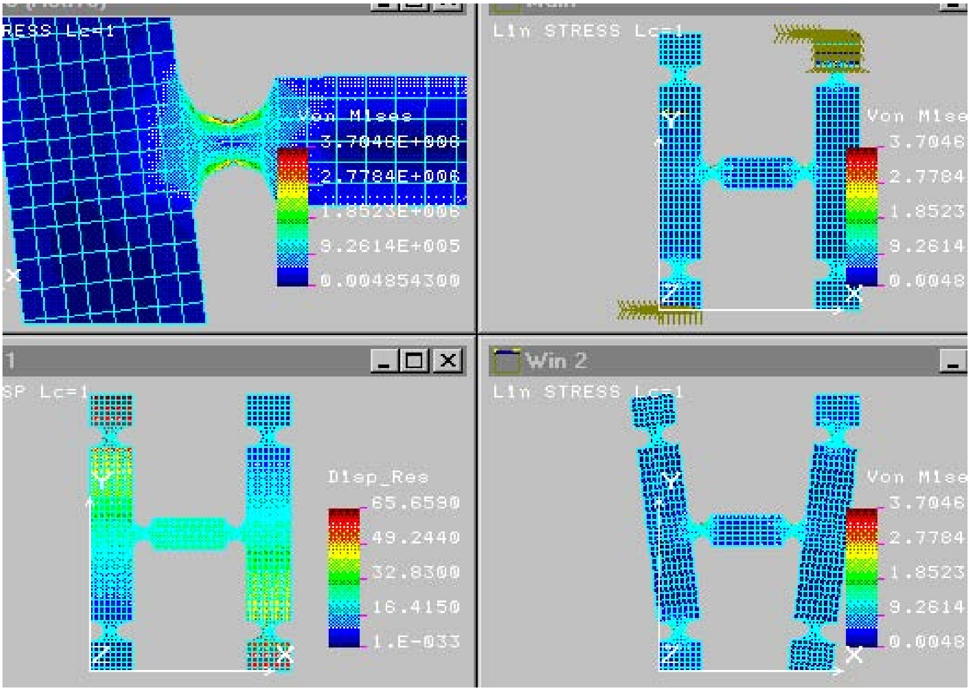

Figure 8. FEM Analysis applied for a robot with flexure hinges

3. Conclusions

I consider that both the visual analogy and TRIZ method have an important role to the creation of some new mechanisms which imitate the locomotion of the animals and their kinematic performances.

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VALUE ANALYSIS AND TRIZ: PARALLELISM OF A NEW TECHNOLOGICAL CULTURE IN MEXICO

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Abstract
Businesses are in a constant struggle to *win*, to be the first in the markets and to remain there forever. This implies achieving two antagonistic objectives: to completely satisfy the client and to decrease costs. To reach and maintain leadership seems to depend on this achievement, capable of contributing a true competitive edge that besides globalization, innovation has played an essential role. The majority of the companies that have come to a standstill, or that have had to close, are due to high operating costs, or deficient quality, or simply the lack of creativity. The main objective of all companies remains the same: to achieve maximum monetary benefit. Under this ideal, the most sophisticated methods of optimization, of problem solving, and even models to increase productivity have been developed. Without a doubt, all these tools have been of great help to facilitate the fulfillment of objectives. This is how we have evolved in technology. In this article, we will center on two of the most important methodologies that allow not only an alternative for technical problem solving, but also a way to propose innovative actions, that today represent the most important source for growth and competitiveness.

1. Introduction

Likewise, talking about innovation implies the introduction of a novelty in a social, technical, or scientific system. This novelty should culminate in a sold product, which implies assuring a *value* increase for the product, considering that *value* means a reason for extra attention by the consumer, an extra attribute to consider that can be summed up in two words: PERFORMANCE and PRICE.

In Mexico, the main precepts of Value Analysis (V.A.) and TRIZ have begun to be studied. They are, in fact, two new visions that complement each other to reach the desired objectives from the technical point of view, and they begin to revolutionize the industrial paradigms that have prevailed since the country's industrialization. We will briefly analyze the parallelism that allows us to broaden the technical solutions that are applied to the most complex technical problems.

1. Under the V.A. approach, it is very important to analyze the technical problems without considering the solutions used in the past, so as not to make the same errors upon trying to decrease costs. It is necessary to take other parameters as reference, which will lead us to new ideas and to research ways to discover new work methods. In TRIZ, under the same

basis, there is the concept of *psychological inertia* which keeps us from seeing reality under another perspective and generating creative ideas. This mental block more or less rooted in the majority of human beings can be neutralized through certain psychological tools that allow us to discover new work methods. For example, the *final ideal solution* that serves as support to consider a creative alternative outside the established paradigms. We cannot attribute this similarity of both methodologies to a mere coincidence, since certainly we want to generate a creative solution faced with a technical problem we need to get rid of the concepts and ideas that the majority have deeply rooted and to think or learn to think in a way that breaks this inertia.

2. The *ideal solution* – that within TRIZ has great importance- is evidently a solution faced with any technical problem, but at the same time unreachable, the *ideal solution* fulfills the desired function perfectly without using resources, nor time nor space, with no extra cost, and without human effort; it is the solution all engineers want, but it is technologically infeasible; however, it allows us to think of a highly creative and applicable solution that tends to the ideal characteristics, using the minimum resources. On the other hand, in V.A. we know that the *maximum value* of the product will not be reached, but this inspires us so this product can be offered to the consumer with maximum performance and reasonable price. Therefore, the *ideal solution* and the *maximum value* have a narrow technical analogy, both were conceived naturally and motivated by the same cause and with similar results.

3. The rising of these two methodologies was almost simultaneous with the end of the forties, when Lawrence Miles and Genrich Altshuller were working independently in very different economic, social and political contexts. The first under the General Electric company (USA) with strong support, achieving great international diffusion, while the second worked in adverse conditions in the old USSR, with no support and with little or no international diffusion. It was necessary to wait for the decade of the nineties, when the conditions were more favorable to inform the world of this knowledge. The talent and creative capacity is a common characteristic of both precursors. Both methodologies were focused on solving complex technical problems, the first from an analysis, and the second from a synthesis. That is, in the V.A., the problematic situation is analyzed in order to generate a condition that leads us to a creative solution. While in TRIZ, the knowledge base is reviewed, backed up by hundreds of thousands of patents to select an adequate condition for the innovative solution of a given problem. In the first case, logic is essential, since it proceeds through “logical” reasoning to define the problematic situation as well as to solve it. While in the second case, it is the analogy that performs an essential function. The problem is stated as contradictions (technical or physical) or in finite possibilities and therefore already known and studied, the tools for solution are also analogical, since the solutions can only be compared to solutions that under similar conditions have been successfully implemented in the solution of an analogical problem. Finally, V.A. and TRIZ are two complementary methodologies, not only due to their analogies in the statement of their objective and in the results, but rather due to their differences in method and reasoning.

4. The way of defining a technical problem is also a point of coincidence, V.A. states to do it in three phases:

1. Identify the functions. This first phase states which are the exact functions that interest the consumer, those for which the consumer is willing to pay the product price. What are the exact functions that each element of the product fulfills? What are

the exact level and grade the consumer wishes to obtain from this function? And later contrast these questions with the current level in which the function is being fulfilled in hands of the consumer.

2. Separate the functions. It always begins with the total or main function the consumer requires, it is necessary to clearly define this total function. Then it is important to separate this function into sub-functions that facilitate a detailed analysis of what will be offered and likewise until coming to the sub-functions that can no longer be separated and identify individual components, it is necessary to identify the real function that each component performs. This process will help discover what the real problem is.
3. Re-group the functions. Finally, it is necessary to group certain sub-functions in functional groups with clear and specific goals, run through several alternative to obtain necessary support functions, and, of course, the main function required. At this level, the original problem has been divided into small specific problems. Now it is precisely known what problems should be solved to generate the most feasible opportunities so the global problem can be solved with precision.

This way of stating a problem allows us to achieve an analysis that will lead us to visualize a highly creative solution. Within the TRIZ, a survey has been developed with seven sections which allows us to bring together the information of the conditions in which the problem presents itself, using a systems approach, where the system can be any object or situation that functions deficiently. A system provides a useful function that is affected by some other function, or sub-function. For this reason, when there is a problem, it is necessary to define in clear terms the interrelationship that exists between these functions in order to eliminate the useless functions and only allow the useful functions to be carried out. The environment in which the function takes place, the resources that intervene and those that can intervene, the history of the development of the problem, and the solution background, as well as other problems that can be discovered or that can arise should be analyzed to see how they can be eliminated are aspects to take into account. Finally, the feasibility of a design change and flexibility of the technology involved and the possibility of studying similar problems in other systems are considered. This analysis is developed always thinking about minimum cost, in such a way that the proposed solution could be classified as innovative. Finally, the problem is described through a graph that illustrates the interrelationships that exist among the useful and useless functions and all the possibilities for its solution. Besides, a problem in TRIZ is always possible to formulate in function of its contradictions. It is said that all technical problems, or problems of other natures, have at least one contradiction that makes the problem exist. Once the problem has been defined, all the work is simplified to eliminate this or these contradictions or to minimize the useless impact they cause. This approach has been very useful above all because the paradigmatic concept of “negotiate” a solution through the optimization or traditional methods has been changed for that of innovative solution.

5. The goal to achieve in V.A. is to efficiently identify the useless costs of a system to eliminate or decrease them and use a technical-human procedure to better visualize the problematic situation that arises, it is necessary to take into account all the variables that intervene, even the most subjective and apparently irrelevant, such as those that have to do with the competition, the employees in other areas, the product, clients, etc.

Then, a work plan consisting of five stages is defined.

a). Information fase. Having on hand all the information associated to the problem is a good strategy, complete and orderly, creating all types of questions and answering them honestly with the help of experts.

b). Analysis phase. Here the essential notion of *function* is studied extensively, the functions and sub-functions are evaluated and the problem is defined exactly. The functions are separated for a better and more detailed study, and then they are re-grouped according to the needs to achieve a better solution. Frequently it is found that there is more than one specific problem to solve. These problems can be classified into three categories.

The type 1 problem. Medium difficulty, its solution allows good possibilities for benefits.

The type 2 problem. Greater difficulty, it requires a deeper analysis and greater creativity, its solution implies an important benefit.

The type 3 problem. Apparent difficulty, its solution does not require new research or creativity, although it can allow for a greater benefit.

c). Creativity phase. Once all the information about the problem has been acquired, it is necessary to use new creative capacity through the free use of imagination. There are techniques that can be applied to achieve better results, such as the proposal by Alex Osborn and by many others, without forgetting that creativity consists of associating various elements of knowledge with new concepts. This action should be done with no limit except that of our own imagination, taking on types 1, 2, and 3 problems in detail, making use of the approaches obtained, then select those approaches that look most promising to study them, develop them and assess them deeper.

To conclude, a phase of judgement and one more of development is necessary, where the most relevant ideas are assessed, determining their limits, those that most contribute value to the product, always seeking to eliminate, reduce, or overcome all the objections. Finally, to work with specialists and suppliers so that together they can find an acceptable solution, look for another solution concept, and proceed with a similar analysis and assessment until one is achieved.

TRIZ has as its main goal to generate an innovative solution before the technical problems. Decreasing costs is a natural consequence of reaching a creative solution. There are various technical tools focused on achieving this objective. For example, one of the most used and best known is Altshuller's matrix which allows us to identify and select two antagonistic parameters o parameters in conflict and determine the principles of innovation that are best adjusted to eliminate a technical contradiction. The work is simplified to interpreting and adapting these generic principles to a particular problem. It is also possible to apply the *separation of principles* to a problem generated by a physical contradiction. This ingenious tool of TRIZ allows us to design a product or improve a process from the separation of elementary principles that cannot be presented simultaneously and therefore TRIZ has developed techniques that facilitate the use of creativity without demanding genius of the analysts, like the use of the scientific effects that facilitate the ideas to achieve highly creative solutions with others' genius. Within the TRIZ Philosophy, innovation is not a random action, but rather a strategic process whose task should be developed systematically, and with a structured methodology, besides the fact that true innovation always presents a radical change, a true jump in the right direction E_2 leaving from an original state E_1 among the gamma of apparently similar possibilities (see figure 1). This new state E_2 should allow companies a clear competitive edge and should always be translated into commercial success. Innovation is not repeatable nor reproducible; it is a singular phenomenon that only makes sense in the context in which it is applied. The difficulty radiates from knowing the right path to take; the methodological tools of TRIZ allow this objective to be achieved.

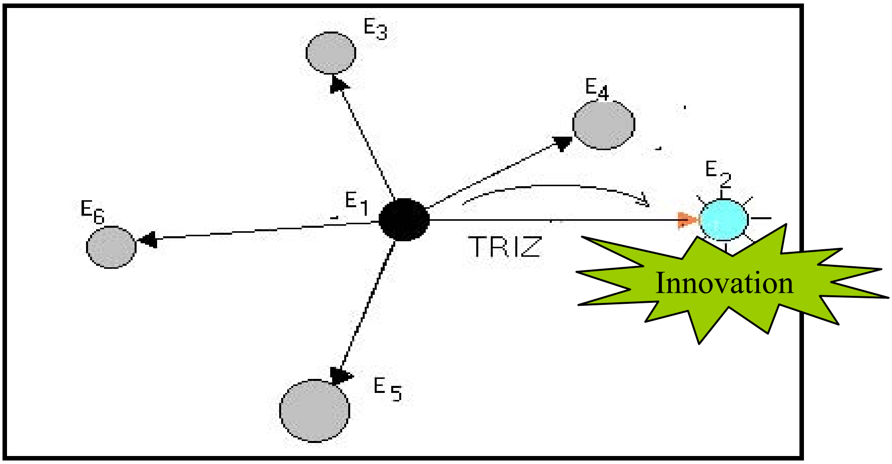


Figure 1. TRIZ systematically looks for the correct alternative among a gamma of possibilities.

A simplified model of the Value Analysis technique can be that which is illustrated in figure 2 where the relationship that exists between knowledge, creativity, and the analysis tools, fundamental in this methodology and necessary to generate the dynamics that lead to a solution characterized by a maximum value synthesized by the triad performance-cost-quality, is emphasized.

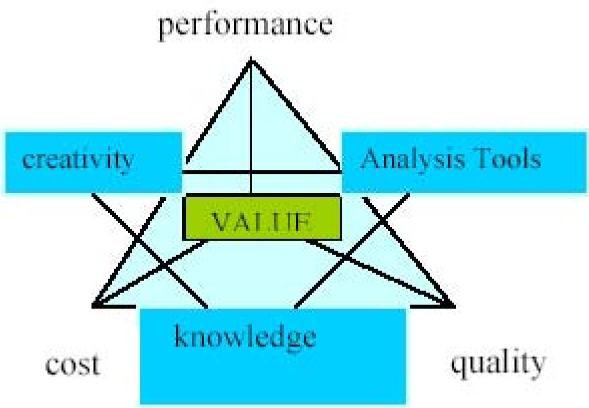


Figure 2. The performance-cost-quality triad under the Value Analysis approach

As for the TRIZ methodology, there is a general model which is very simple as to how the analogical problem solving process operates; however, speaking of the detail of its methodological dynamics, the generic model presented in figure 3 illustrates the relationship of the various TRIZ tools and how they interrelate with each one of the steps destined to generate an innovative solution, from the identification of the problem to the application of the TRIZ tools passing through the modeling and statement of the ideal solution that, as we saw, does not exist, cannot exist, but helps to inspire for a highly creative solution that can be implemented. Besides, this model illustrates how each successful solution nurtures knowledge, based on millions of analyzed and catalogued patents.

Now, a joint model that represents both methodologies as well as their points of coincidence and how they complement each other could be represented in figure 4 where it is observed that both go away from a problem motivated, then use their respective tools (analysis/synthesis) to create an innovative solution (creativity + value).

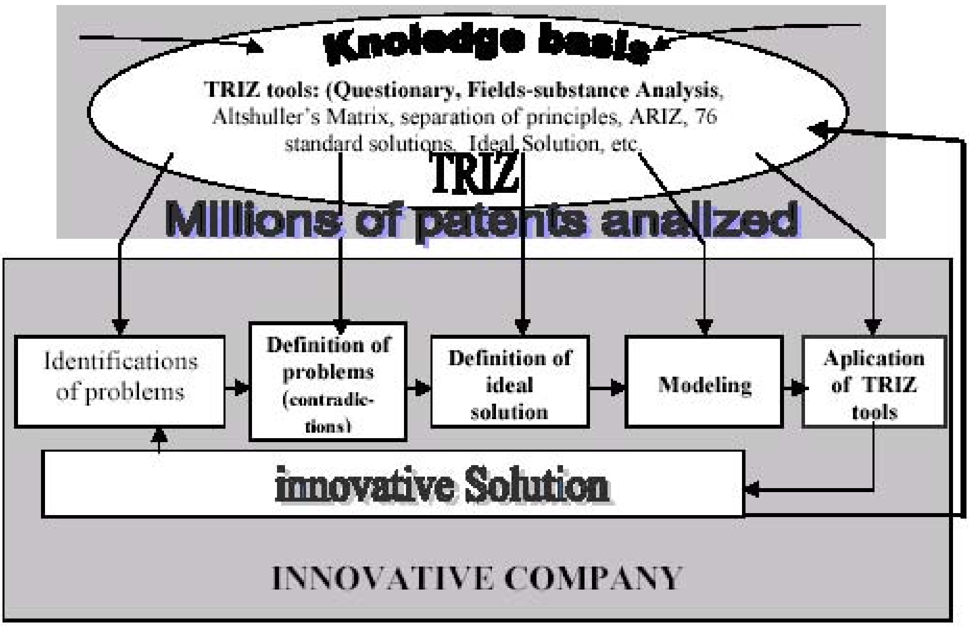


Figure 3. Generic model of innovation according to the TRIZ approach

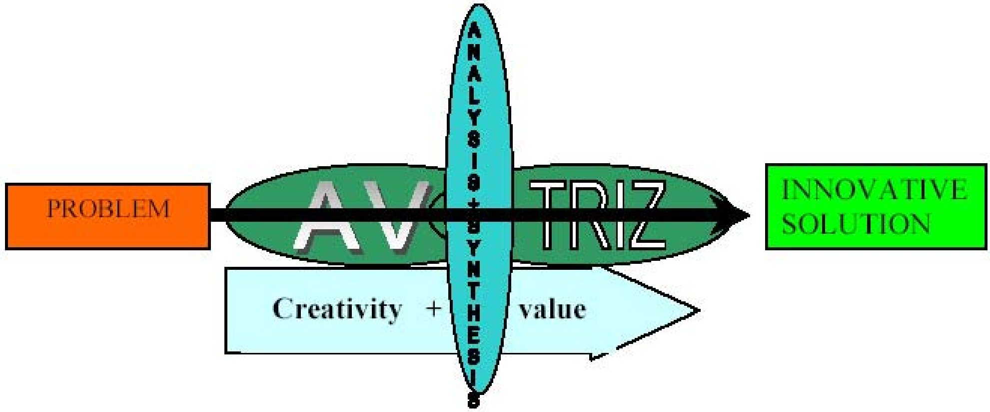


Figure 4. Joint Model that illustrates A.V. and TRIZ methodologies

To conclude, we will present a case study where the solution capacity of these two approaches used together to increase the level is shown. On one hand, V.A. provides a detailed analysis of what it is urgent to do and state the problematic situation with clarity. On the other hand, TRIZ allows for a high level of creativity to assure a really innovative solution.

2. Case Study: a proposal for new run-off paddles

In the melting area of the Volkswagen de Mexico S.A. plant, there is the need to eliminate the excess run-off of the ovens with a device called "paddles" (see Fig. 5 and 6). These paddles represent a high cost for the company, besides the fact that they are a risky alterative for the operators. These run-off paddles have a smooth, circular shape that make collecting run-off so that it can be transferred to deposits found beside the ovens difficult. Due to the same characteristics, these paddles are not very durable, since the run-off process implies some seconds of handling and this causes the steel to slowly melt until the circular paddle begins to "waste away" and finally disappear. This happens to the extent that during two shifts as many as 25 paddles can be used!

According to the precepts of Value Analysis and TRIZ, there is a problem to solve: high costs, risk, and material waste. It is convenient to say that some preventive measures have already been taken to minimize the amount of run-off in the ovens. However, it is still necessary to eliminate the run-off that inevitably forms there.

According to the spherical principle of TRIZ, a more convenient way to produce the paddles to avoid this inconvenience and reach a greater edge, in the process itself as well as in costs, is as follows:

Use circular paddles, but in parabolic form instead of flat, adding a hole in the center to allow the melted metal to pass through and only extract the run-off. These paddles could have a larger diameter to avoid submerging them too long, since the temperature of this metal is greater than 1400°C.

Advantages or the maximum value permitted in present conditions.

1. Take advantage of the paddle surface and extract the greatest amount of run-off possible without increasing its weigh too much, since it will have a hole in the middle.
2. Greater durability, since these paddles are submerged only a few seconds, the collection capacity will be much greater.
3. Less waste of melted metal since it would be recuperated by the center hole.
4. Greater safety by the person collecting the run-off face with the danger that comes with being exposed to high temperatures implied by working close to the oven.
5. Greater effectiveness in this activity and therefore greater cleanliness in the ovens that will surely reflect on the quality of the part manufacture.

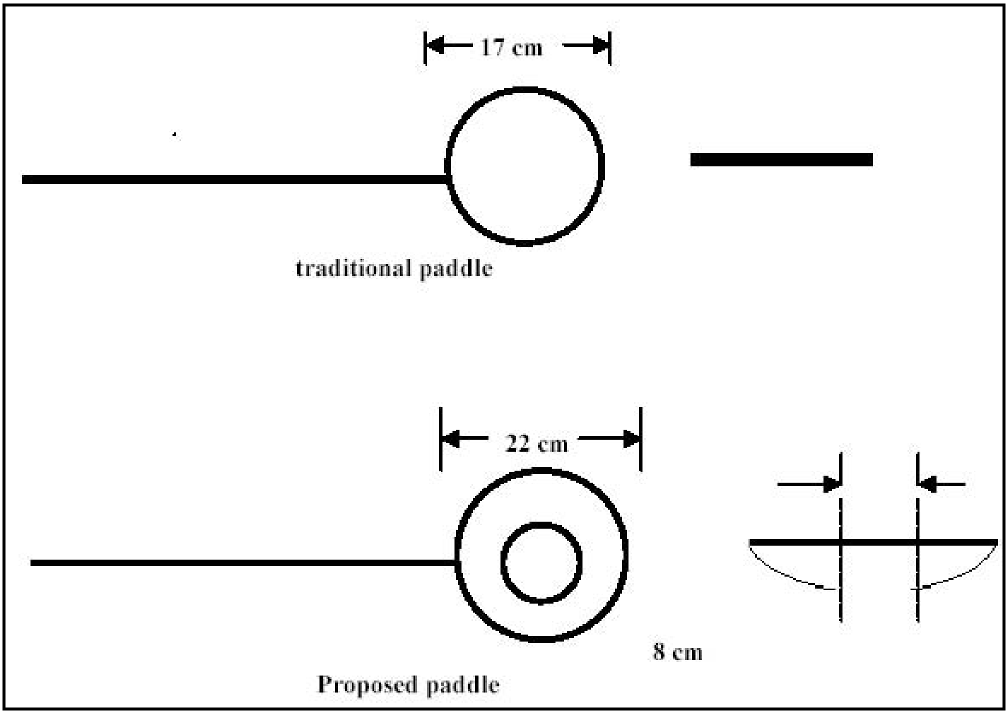
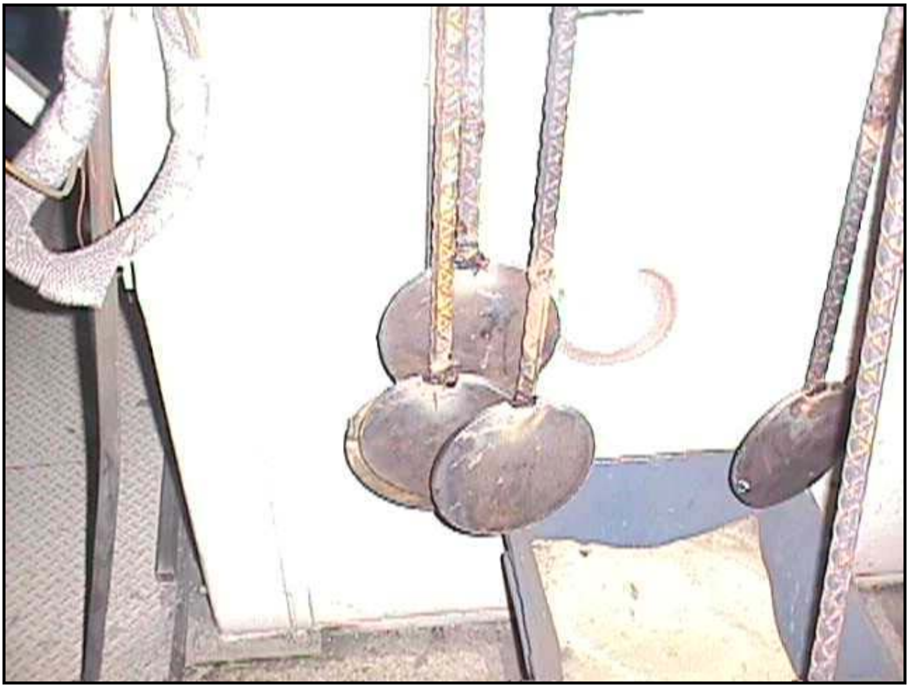


Figure 5. Diagram that illustrates the traditional and proposed paddles

3. Conclusion

We could have stated the problem according to the three main phases for all V.A. study, only changing the methodological approach of analysis and statement to search for a creative solution.

If traditional paddles cost about 4 dollars each at 25 a day, we have a total of 100 dollars a day. With the new paddles, the total cost was considerably decreased, since a modified paddle costs more (7 dollars), only 5 paddles are used daily, the total cost is now 36 dollars, which allows us an approximate annual saving of 15 thousand dollars !



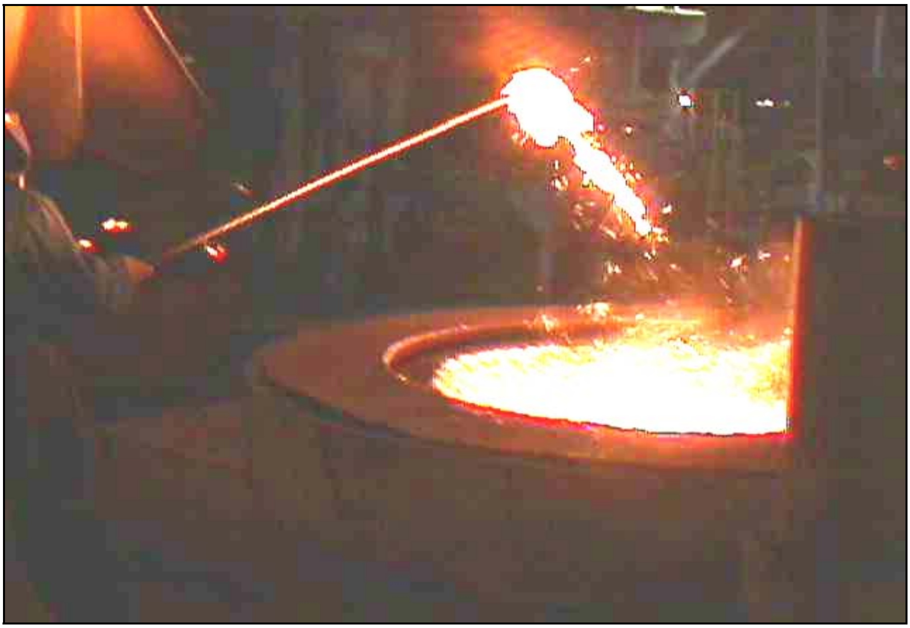


Figure 6. Illustrates the traditional waiting to be used and their use.

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METHODS INTEGRATION AND INTERACTIONS

THE NEXT COMMON SENSE: PHILOSOPHY-LEVEL INTEGRATION OF TRIZ INTO AN INTEGRATED BUSINESS AND MANAGEMENT INNOVATION PROCESS

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Abstract
The paper describes a philosophy-level integration between different innovation-related methodologies. The paper illustrates the high level of convergence between techniques that have started from quite independent roots. It also describes some of the conflicts that exist between some of the methods, and possible means by which they might be resolved such that a higher level integrated business and management philosophy might emerge.
Keywords: TRIZ, SixSigma, Lean, conflict, contradiction, Sustainability.

1. Introduction

The world of business books is big business. With over 1800 management-related texts published every year, the choice facing any manager is overwhelming. The level of choice often becomes a serious problem when it comes to deciding which texts are appropriate in which circumstances.

One of the main underlying ideas behind the original TRIZ research was to distill best practice from any and every kind of source and place it within a global knowledge framework. Few if any innovation philosophies have taken such a broad-reaching perspective. The initial focus of the TRIZ research was, of course, in the realm of technical knowledge. It is a strong testament to the initial researchers that when the first attempts to translate the basic pillars of TRIZ into a Western business context, much of the framework remained valid. Given the initial success in applying TRIZ to business and management problems, a concerted programme of research to model and integrate successful business solutions has been in place since 1998. As with the original TRIZ research, the goal of this business research has been to define, identify and integrate best business practice into a coherent business and management innovation toolkit, methodology and philosophy (Mann, 2004).

The paper records some of the key findings of the business and management research that now act as the foundations of a fully integrated systematic innovation capability bringing together the best features of TRIZ, Lean, Six-Sigma, Quality Function Deployment, Neuro-Linguistic Programming, Complexity Theory, Cybernetics, and a host of other successful business tools. The emphasis throughout the paper will be on the presentation of a philosophy-level integration of each contributing school of thought. The paper pays particular attention to the conflicts and contradictions present in many of the different management perspectives, and shows how each one can and must be successfully eliminated in a win-win way before successful integration can occur. By way of an illustration, both TRIZ and Lean philosophies suggest that waste is a bad thing that needs to be 'eliminated', whereas it is viewed as an essential innovation enabler in complex adaptive systems. A win-win resolution of this waste and no-waste contradiction is therefore necessary before any of the three methods may be successfully integrated with one another.

As will be discussed in the paper, a host of similar contradictions existing between other methods have had to be understood and resolved. Specific conflicts to be discussed in the paper include:

- the parallel need for simplicity and complexity in organisations
- top down versus bottom up management philosophies (otherwise known as SAP versus common-sense)
- the parallel desire for independent and inter-dependent organisation designs
- variation-reduction as both a good and a bad thing
- the parallel need for both stability and instability in an organisation
- the customer as someone who is always right and often also wrong

A final section of the paper summarises the current state of integration between different management philosophies and projects what the next major business paradigm shifts will occur and their likely impact on the world of business.

2. Philosophy-Level Integration

In the terms of evolutionary S-Curves, the TRIZ-based systematic innovation method is approaching some form of fundamental limit – Figure 1. To go beyond these limits – in other words, to find a new paradigm, higher level of creativity capability – is therefore likely to require an expansion of TRIZ in fundamental ways. Thus, while some integration activities look set to enable small-scale optimisation benefits to be accrued, more substantial shifts in capability seem likely only through more profound shifts in the underpinning philosophy.

The Figure 1 image has previously discussed by Mann (2003 and 2004), alongside a discussion of other tools that are believed to operate at both a philosophical as well as methodological level. Mann (2003), for example, discussed the philosophical pillars of Six Sigma, Complexity Theory and Cybernetics (in the form of Stafford Beer's 'Viable System Model') and speculated on how they might complement or at least influence the application and evolution of TRIZ. Mann (2004) expanded this list to also include Lean, Quality Function Deployment and the general umbrella of tools and techniques that might be thought of as belonging to a family called 'sustainability' (in this case, sustainability in the context of environmental and social sustainability). Bridoux (2002) also speculated on the philosophical level impact to TRIZ, this time through the possible integration with NLP. Whilst not daring to speculate on how the philosophical pillars of each of these different methods might integrate to form the higher level capability suggested by Figure 1, both previous references did speculate on what the combined philosophical pillars resulting from integration of the studied methods might be.

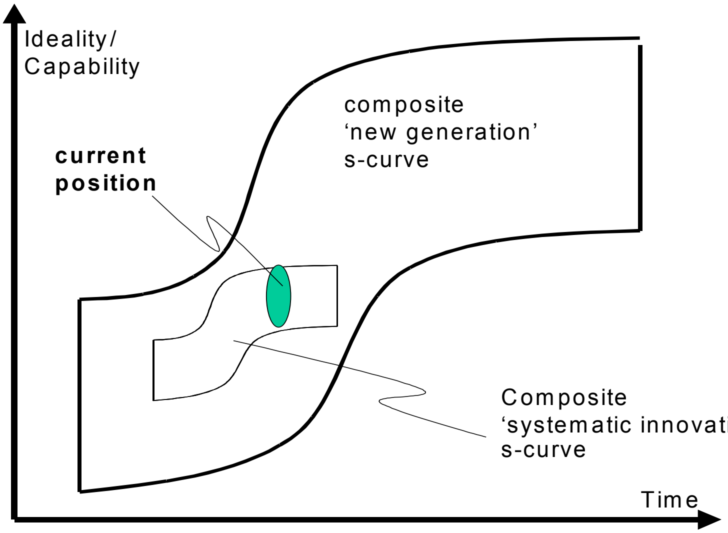

Figure 1. Evolution of Systematic Innovation Capabilities in S-Curve Terms

The total list of pillars resulting from the combination of the different considered philosophies, then, is presented in Figure 2.

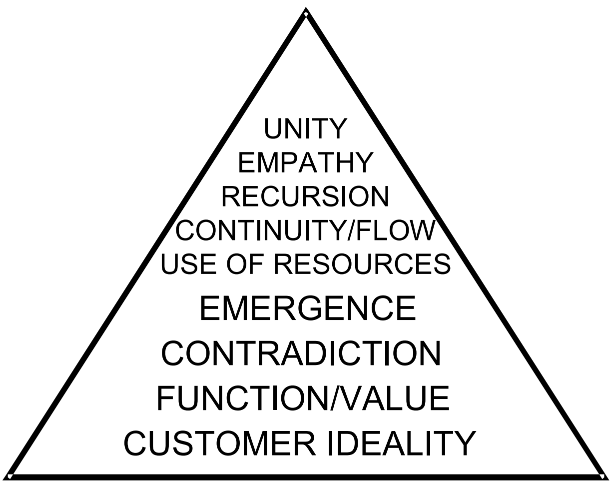

Figure 2. Philosophical Pillars Of Integrated Systematic Innovation Capability

Detailed examination of these pillars reveals a high degree of consistency. The fact that such convergence is achieved from such different start points is encouraging. On the other hand, it is also clear that there are a number of inconsistencies between some of the ideas present. The resolution of such inconsistencies is considered to be an essential step in progressing to a genuine new paradigm in our understanding of the dynamics of innovation and evolution. This then leads us to a discussion about right-versus-right conflict resolution.

3. Right-Versus-Right Conflict Resolution

Right-versus-right conflict means that both sides of an argument are correct. Or rather they believe themselves to be correct. One of the most compelling ideas in 'A Theory Of Everything' (Wilber, 2001) is that in these right-versus-right conflicts, it is necessary to move to a higher level of understanding in order to resolve the conflict. In other words, if both A and B are 'right' and they conflict with one another, there must exist a higher level model in which both A and B are permitted to be correct. The basic idea is illustrated in Figure 3. The basic idea of resolving conflicts by transition to a higher level is, of course, one of the strategies used in the resolution of physical contradictions in TRIZ.

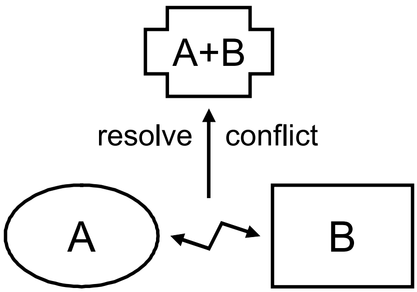

Figure 3. Resolution Of Conflict Between Two Methodologies Occurs Through Understanding At A Higher Level

Knowledge, then, of some of the other physical contradiction resolution strategies found in TRIZ allows us to explore possible means of resolving such right-versus-right conflicts. Specifically we might arrive at an understanding whereby the A and B under consideration may both be right, but at different conditions (e.g. different times or spaces). Looking beyond the separation principles, it may also be that A and B may be 'right' per se, but one or both is an incomplete model. In the next section, we explore these two basic situations – 'conditionally necessary' and 'necessary but not sufficient' in order to begin to explore a resolution to some of the conflicts that exist between different philosophies.

3.1 Necessary But Not Sufficient

One of the main pillars of Lean is the elimination of waste. Bicheno (2003) details the so-called 15 different types of waste required to be considered by management in an organization. The idea that 'waste is a bad thing that should be eliminated' is one that immediately sounds a chord with our common sense. Indeed, waste elimination is a necessary activity for any organization hoping to remain competitive in our rapidly globalizing world; there can be little mercy for any organization that believes they can survive and thrive in the midst of wasteful systems. But then Wolpert (2000) informs us that almost every major advance in the thinking of mankind has run counter to the prevailing common sense. Could it therefore be possible that there is a flaw in the common sense view that waste should be eliminated? The evidence from an increasing number of companies appears to be a resounding yes. Rather than discussing the specifics of any one of such companies, it is easier and more beneficial to consider a case of waste elimination from nature. The natural world is a cruel and harsh place, and in order to survive within it, all life-forms face an ongoing struggle. The careful use of resources, therefore, is an essential factor; anything carrying around resources surplus to survival or reproduction requirements is at an evolutionary disadvantage to one that is living a leaner existence. For the dodo (Figure 4), the need for flight became progressively less and less as the need for an ability to forage on the ground increased. Consequently there emerged an evolutionary advantage to any dodo that no longer 'wasted' resources on wings capable of flight. And so, over time, this evolutionary pressure meant that the wing evolved to be little more than a balance aid during foraging (plus possibly a degree of thermal control). Flight-capable wings became a luxury and thus eligible for elimination.

Figure 4. The Dodo

Everything in this system is fine, until such times as a new threat emerges. In the case of the dodo, as soon as man appeared on their scene, then suddenly the need for flight became an essential survival capability. Unfortunately, however, it was a capability that the dodo no longer possessed. Net result; extinction.

The moral of the dodo story is that while waste elimination is always a good strategy, we always need to keep an eye on emerging new threats that might transform something currently viewed as wasteful into something that might turn out to be an essential resource.

In many ways, the same idea of necessary but not sufficient applies in Six Sigma and the drive within that philosophy for the elimination of variation. Again we may see the innate common-sense of removing inconsistency in manufacture and other processes, but again there is the danger that as we progressively hone those processes towards perfection, we lose the spark that can help us to see the road to better systems. Variation elimination is always great, but always needs to bear in mind that the standard deviation and the mean are two very different things. It is perfectly legitimate, in other words, to seek to work towards a standard deviation of zero, but at the same time we need to be absolutely clear that we are working to achieve the right mean.

We might take this story a stage further by considering another methodology and another animal analogy. Henry Ford once famously quoted that if he'd asked customers what they wanted, they would have asked for a faster horse. The big idea behind this quote is that customers are frequently incapable of seeing into the future and thus incapable of predicting what the future evolution of systems might be. Customers are great at asking for better versions of what they already have, but incredibly poor at asking for things they don't have.

Quality Function Deployment (QFD) exists to help companies to better understand the 'voice of the customer'. Again we might see the idea of necessary but not sufficient present in the philosophy of QFD: Few companies can expect to survive for long if they chose to ignore the needs of their customers. Hence, capturing the voice of the customer is absolutely essential to future success. But capturing this voice is not sufficient if the voice is unable to see beyond incremental improvement of what already exists. An undoubtedly stronger QFD operating paradigm emerges if it is used in combination with the predictive capabilities of TRIZ. Thus the model in which, first, TRIZ trends are used to identify 'possible' futures, and then second a QFD analysis allowing customers (and, importantly, people who are not yet customers) to make their voice heard on the various merits and de-merits of such possibilities is a step towards a more ideal system. Admittedly it is not a complete one since, by definition, we are asking the customer to pass comment on a future innovation from the perspective of a present day context. This indeed may well be the current limiting contradiction that must be resolved in achieving the next level of integration between TRIZ and QFD.

3.2 Conditionally Necessary

The second category of right-versus-right conflict possibilities is that a paradigm is relevant based on the presence of certain conditions.

Perhaps a good example of a methodology that exists in this 'conditionally necessary' category, then, is Axiomatic Design (Suh, 1990). Axiomatic Design is built around two central design axioms; the first that it is important to ensure that the different functional requirements in a system are independent from one another, the second –abstracting slightly - that the more efficient design is the one with the minimum level of superfluous content. The second axiom is directly analogous to the idea of resources in TRIZ and waste elimination in Lean. The first axiom on the other hand is in many situations in conflict with ideas in TRIZ, specifically the evolution of systems towards and Ideal Final Result end stage. In the TRIZ model, the 'ideal' solution is the one that delivers the required functionality with zero cost or harm. Inevitably as systems approach such a destination the different functional requirements and the related design parameters become coupled with one another.

So which is right? Ideal Final Result or the Independence Axiom? It is an argument that requires somewhat more than a simple either/or answer. According to the Wilber model of Figure 3, the answer ought to come from a synthesis of both. On the way to such a synthesis, however, we might again look to nature to see which side of the IFR/Independence fence natural systems tend to fall. Evidence from such systems tends to show that efficient use of resources is the dominant evolution driver, and that the stronger the competitive pressures, the greater this resource-efficiency drive becomes. The 2002 Axiomatic Design conference (ICAD, 2002) reported that natural systems rarely if ever achieved Independence and that the higher the competitive pressures, the further from Independence a solution was. Thus, in order to make maximal use of resources, natural systems tend to produce designs which are coupled increasingly strongly as competition increases. We might, therefore, extract from this early evidence that the relevance of the Independence Axiom is conditional upon the level of competitive pressure. Thus, in a benign environment the Axiom may be true, but in a highly competitive environment, the effective use of resources becomes a more significant design driver.

Other examples of 'conditionally necessary' ideas become apparent when the complexity increases and then decreases trend uncovered by TRIZ researchers is taken into consideration. This trend – illustrated in Figure 5 – is present in all systems, whether technical or business or, in this case innovation and creativity methods.

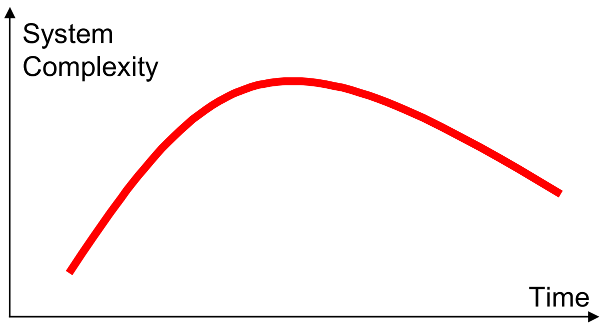

Figure 5. Complexity Increases And Then Decreases Trend

A commonly observed phenomenon related to this trend is the publication of a growing plethora of books following the emergence of a new idea as it gradually enters the public consciousness. A classic example of such a phenomenon may be seen in such 'methods' as Business Process Re-engineering (BPR) and Customer Relationship Management (CRM). In both of these cases we see the emergence of a whole industry of authors seeking to expand and capitalize upon the initial 'common sense' idea of an originating text.

Then, after some period of expansion of the method, along comes a text offering an opposing view – 'why BPR doesn't work' or 'why CRM' doesn't work. Such texts emerge as users of the methods begin to realize that what is a common sense idea under certain conditions becomes exactly the opposite under other conditions. Thus, to take CRM as a specific example, if a company is doing nothing to foster effective relationships with its customers then doing something is likely to prove a better option. In this situation, CRM may be thought of as 'necessary'. But beyond a certain point, it becomes apparent that 'managing' customers is a strategy that is actually the wrong way around. Our TRIZ knowledge of the evolution of systems towards the IFR and the emergence in such situations of systems that operate 'by themselves' should tell us that CRM is but a staging point along a path to that ideal.

The same idea may be said to apply to the increasingly ubiquitous SAP business management tool. If there is one factor that unites delegates attending our workshops it is their dislike of SAP. SAP is the ultimate top-down command-and-control management tool. Anyone subjected to the rigours of such a system tends to find it an uncomfortable process. One hopes, therefore, that the phenomenal growth of SAP is, like CRM, an inevitable rise in complexity that must precede the emergence of a more ideal system. If a company has no means of managing the flow of value in and around the organization, then having something is almost inevitably going to be 'better'. But better is not the same as best. It is merely a stepping-stone to the Ideal system. In this sense, one may see SAP and its equivalents as a system at (hopefully!) the point of maximum viable complexity in its long term evolution – necessary today, but unnecessary in a future model where the complexity versus capability conflict becomes resolved and the system is able to progress onwards to its IFR destination.

4. Summary And Conclusions

Like any complex system, a higher level innovation capability – a new common sense if you will – looks set to emerge through a gradual synthesis rather than from any sudden step-change jump. According to Wilber again, this is a fundamental phenomenon that results from the fact that when we are born we inevitably start from a limited knowledge foundation. Further than this, according to Wilber it is fundamentally not possible for us to leap-frog from one level of understanding to another, but rather that we have to progress through each stage as a linear progression. Without understanding one level of understanding, it is not possible to appreciate the relevance of the next higher level. The evolution of human knowledge is thus constrained by the fact that all of us have to pass through a number of gates and that because the age of a population is inevitably a spectrum, there will inevitably be a corresponding spectrum of different people at different levels of understanding.

This then takes us back to the earlier discussion of simplicity versus complexity. According to the trend uncovered by TRIZ researchers, systems evolve through a trajectory which first sees complexity increase and then secondly, decreases again. Systems fundamentally get more complex and then less complex again. There is little we can do about this trend. The integration of TRIZ with other tools likely to be necessary to deliver the 'next common sense' may be expected to require at least some increase in complexity relative to the complexity that we experience today.

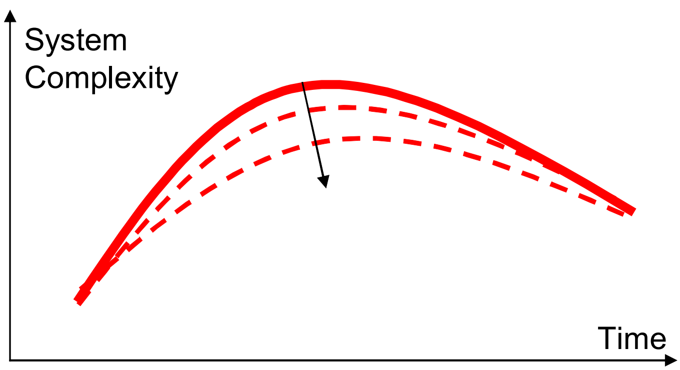

Figure 6. Limiting The Increase In Complexity In Systems

The 'inevitable' increase in complexity, however, can be managed. The experience of the evolution of technical systems says that there are things we can do to limit un-necessary rises in complexity – Figure 6. The road to the 'ideal' innovation and creativity methodology – that methodology capable of delivering the function with no cost or harm – is one full of choices. Methods and tools will come and go, evolving and merging into other ones. Thus, to take a single emotive example, we might ask whether the role of the TRIZ S-Field tool continues to be necessary in a world where function and attribute analysis (FAA) exists. The Inventive Standards might well remain useful as solution generation triggers, but the power and breadth of FAA is both greater and conceptually more robust than that found in the construction of S-Field models.

As TRIZ developers we all have a responsibility to keep the increasing-decreasing complexity trend in mind when we contemplate enhancements to the method. Are we adding unnecessary complexity is a question key to the successful deployment and spread of TRIZ.

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INNOVATION IN PERFORMANCE EXCELLENCE: EIGHT PARADIGMS TO PERFORMANCE EXCELLENCE (8PPE)

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Abstract
The objective of this paper is to present a framework that describes a performance excellence system. Six Sigma is showcased as the operating system on which performance excellence methods may be launched. The framework for what should preclude Six Sigma is presented as well as what should follow. The integration of this system is discussed as well as a maturity progression. A performance excellence model is presented as well as a skill progression for each category of the model. The progression through the model is presented in eight paradigms. An assessment method is also proposed that would be used to track progression in each category as well as maturation through the paradigms of the model.
Keywords: Performance Excellence, Six Sigma, IMPROVE, Eight Paradigms for Performance Excellence.

1. Introduction

Historically speaking, methodologies have a finite life-cycle. Despite the intricacies of each independent cycle, all of these curves have a commonality: decline and ultimately death. This concept may be directly applied to our current understanding of process improvement: Six Sigma; as well as structured innovation: TRIZ. Understanding this progression allows us to be proactive from the perspective of identifying our areas of expertise and involvement in advance of this decline and then death, allowing us to evolve our products or services during a period of financial strength (as opposed to this activity taking place after financial decline has already commenced). We are reacting before we see the “handwriting on the wall”. This proactive capability allows us to evolve while preserving our existing business. This ambidextrousness positions the organization for excellence in evolution (becoming something the company has not been based on the strength of its core competencies).

2. Six Sigma in a Vacuum

The application of Six Sigma has allowed many corporations to optimize existing processes and systems. General Electric and Motorola have publicized billion dollar savings from multi-year mature applications of Six Sigma (DMAIC). This success is not always predictable as the application of Six Sigma in a vacuum allows for the possibility of projects that are not aligned with strategies. Optimization may occur without impacting progress towards goals and objectives and ultimately the vision. This alignment is critical for the maximization of Six Sigma results. This alignment comes from the application of fundamental skills that preclude the application of Six Sigma. In this respect, strategic planning plays a vital role. The organization needs to formulate a service mission and an economic mission. Strategies for the attainment of these missions need to be identified as well as prioritized. These prioritized strategies become the driving factors for conversion to a work-plan. This top-down approach insures alignment of the organization with a vision and progress towards meeting the service and economic missions. A bottom-up approach needs to be utilized in order to involve the majority of the workforce but alignment is critical. This opportunity for alignment does not exist unless the strategic plan has been developed form the top and cascaded throughout the organization. A non-optimization constraint limits the system unless this focusing activity takes place.

3. Preservation: The Foundation for Excellence

The creation of a strategic plan allows the organization to focus its activity on those tasks critical for success. The vision is converted to strategies and these are cascaded to the tactical level (see Figure 1). Management to these objectives is focused and a balanced scorecard approach may be used to track progress. Progress below target may be selected for cause and corrective action activity. Periodic reviews keep the progression towards excellence on track and allow risk mitigation as necessary.

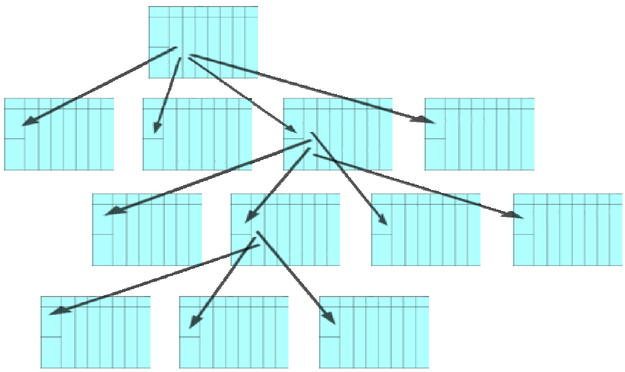

Figure 1. Cascading of the strategic to the tactical using Hoshin

The Hoshin allows for the identification of those processes that are critical to the successful attainment of your strategies. These key processes must then be created and mapped using process mapping techniques. An understanding that each process is linked to every other process is embodies in the SIPOC model (see Figure 2).

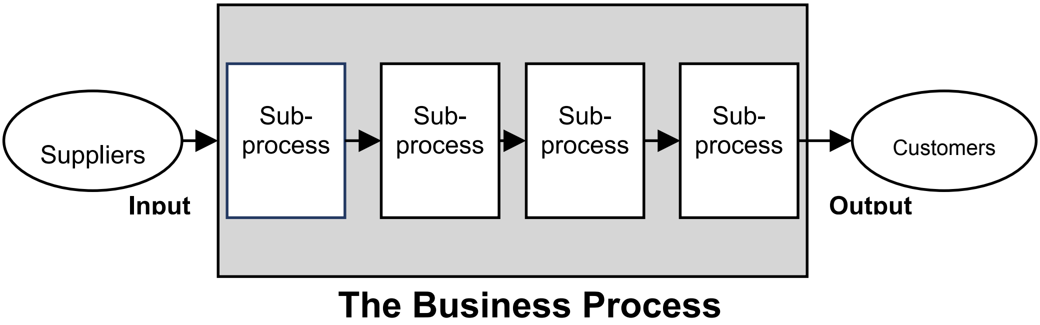

Figure 2. SIPOC, supplier, input, process, output, customer-a model used to describe the interactivity in a complex multi-model system where each output becomes a subsequent input.

Once the key processes are identified, the interrelationships must be identified. An enterprise process model (EPM) needs to be created so that cross process impacts are understood and controlled. This progression brings us to the application of lean principles. Non-value added operations need to be eliminated and flow and throughput optimized. As waste is targeted and removed the process is becoming prepared for process improvement through the application of Six Sigma (DMAIC). This optimization process provides the impetus for driving performance to the six sigma level (or whatever level is appropriate given cost and safety considerations). This progression from Strategic Planning, to Process Management, to Lean, and then Six Sigma is the necessary evolution of the organization at the fundamental level. This means those skills necessary for survivability.

4. Evolution: Becoming Something You Aren't

Once process performance has reached entitlement, design activity must take place in order to evolve performance to new and previously unattainable levels. This Design activity at the highest level of maturity is Design for Six Sigma (DFSS at the macro-level and DMADV at the micro-level). DFSS allows the organization to develop at a high level of performance while meeting or exceeding all critical-to-customer (CTC) requirements with little risk of late-stage failure. Research and Developmental skills enable the organization to respond to societal needs in unforeseen ways. The transition from the closed innovative system to the open innovative system is promoted as well as an increased reliance in structured innovation (TRIZ). See Figure 3 for the complete Performance Excellence Model (Total Performance Improvement Model (TPIM)). The ability to focus on Preservation and Evolution simultaneously is described as the organization being Ambidextrous.

Figure 3. Version of the TPIM used as a means of articulating the integrated nature of multiple disciplines and methodologies.

5. The Model (see Figure 4)

The model is comprised of various elements: foundation (those elements below the facing triangle that are represented by the blocks), base (assessment methodology: IMPROVE[1]), and then a progression of increasing sophisticated and complex methodologies: strategic planning, process management, lean, process improvement, design, and research & development. The triangle is supported on each side by: innovation on the left and change leadership on the right. It is understood that a maturity in each level is possible as is a progression upwards to those methods that increase in sophistication and complexity. This model is an excellent visual representation of the concept but must be modified and enhanced in order to be practically applied as a business practice.

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[1] The IMPROVE assessment is comprised of various phases: I: Investigate the details of the organization in question, M: create Matrices that indicate the performance level for each of the progressions through the 8PPE, P: identify Pathologies that are represented by the matrices, R: identify a Recovery plan that should alleviate the indicated pathology, Observe the recovery plan in action, Validate that the recovery plan has had the intended impact on the pathology, and if it has, Enterprisation follows.

A reduction of the model to a Category Matrix including expansion of the skill progression for each level:

	Basic			Intermediate	Advanced			
R&D	Trial and Error	Derivative Development	Incremental Development	Closed Innovation	Open Innovation	Disruptive Technologies	Structured Innovation	
Design	Design by Specification	GD&T	Tolerance Analysis	Robust Design (DOE)	DFSS (DMADV)			Enterprise Evolution
Process Improvement	Quality System	SPC	TQM (PDCA)	Capability	Robust Manufacturing (DOE)	Six Sigma (DMAIC)		
Lean Principles	Visual Factory and 5S	Elimination of Muda	DFX	Takt Time	Level Loading	Demand Flow Technology		Drive to Six Sigma
Process Management	Establish Processes	Independent Divisional Models		Model Interdependencies	Enterprise Process Management			
Strategic Planning	Vision	Goals and Objectives	Management by Objective	Balanced Scorecard	Hoshin			Fundamental

Figure 4. Total Performance Improvement Model (TPIM)

The Category Matrix is divided in several ways: vertically it is divided into three categories: basic, intermediate, and advanced. Horizontally the matrix is divided into: fundamental, drive to six sigma, and enterprise evolution. The colored differentiations indicate which elements of the, matrix belong to which enterprise excellence paradigm: red = I, yellow = II, green = III, blue = IV, light purple = V, dark purple = VI, gray = VII, and brown = VIII. The paradigms have been identified in order to produce a flow through the fundamental category at the basic level to the enterprise evolution category at the advanced level. The methodologies depicted are considered to be inclusive from right to left – this means for example, that an adoption of Hoshin would contain those elements found in vision, goals and objectives, MBO, and usage of the Balanced Scorecard. The ability of an enterprise to adopt an intermediate or advanced methodology without progressing through the predecessors elements will be predicated on (but not limited to): maturity of the workforce, ability to foster and maintain cultural change, leadership capabilities, economic viability, and development of supporting infrastructure. It is possible and probable that an enterprise would be more advanced in some categories over others. Unequal maturity in the paradigms is also to be expected. Highly disproportionate cross-paradigm development will be discouraged as it will yield the inability to produce balanced and sustainable results in the enterprise. Therefore, the Capability Maturity Model (CMM) will be employed in order to assist the equal development of categories and paradigms.

The IMPROVE assessment methodology will be applied primarily to determine an organizations maturity level for each of the categories: Strategic Planning (SP), Process Management (PM), Lean Principles (LP), Process Improvement (PI), Design Methods (DM), and Research and Development (RD). Weaknesses and opportunities for the infusion of advanced applications and structured innovation will be identified. The infusion of innovation into each category will be of concern. The Investigative stage will be conducted in order to collect relevant information so that the presence and maturity level of each category may be qualitatively determined. In conjunction with this, an assessment of management's ability to lead and support cultural change will be conducted. The output of the Investigative stage will be radar plots (Matrices) indicating the presence and maturity of various key elements of each category. Deficiencies and inefficiencies in the Matrices will yield recognizable Pathologies. The response data may be superimposed on the Category Matrix in order to visually represent an enterprise's evolution through the 8PPE. The CMM will be used to establish the equalization efforts necessary in order to balance cross-paradigm maturity. A Recovery plan will be developed in order to evolve each category to the maximum level that management and enterprise culture are able to support and sustain.

The expansion of each category will include those skills and methods that are historically and critically pertinent to the category. The progression will be right-to-left inclusive meaning that skills in the category to the right will include the necessary elements of skills listed to the left. A top level radar plot will be created for each category. The points on the plot will be those necessary skills that are sub-sets of the main category element (for example: the category would be Strategic Planning, the main element in question would be the Balanced Scorecard, the necessary Balanced Scorecard elements would be: vision, goals and objectives, decomposition of goals and objectives to activity that is measurable, verification of causal relationship of metrics to goals and objectives, etc.). A questionnaire needs to be developed for each main element so that maturity may be determined. It is also possible that an enterprise may select a mature element in a category for adoption without achieving maturity in the elements to the left of the selected element. This needs to be taken into consideration as this model is developed. Also, some elements may not be included in a more mature adoption and special attention should be paid to these instances.

The pathologies and recovery plans will be cross-correlated using a matrix. The practitioner will be able to look-up pathologies (single or compound) and find recovery plans). The model will start as a theoretical construct and then be modified as experience dictates. The category questionnaires will drive the input for the I and M phases of IMPROVE. These questionnaires will also drive the construction of the main, secondary, and tertiary radar plots.

6. Conclusion

In order for an organization to excel from conceptualization to commercialization a number of core competencies must be present. Not only do these capabilities need to be present but they need to be fully integrated. Also, the maturity levels need to be fairly homogenous to minimize constraints on the system. The ability to evolve the capabilities of the system should be focused on while sound process management allows the fundamental operations of the organization to proceed with little oversight or influx of corrective energy.

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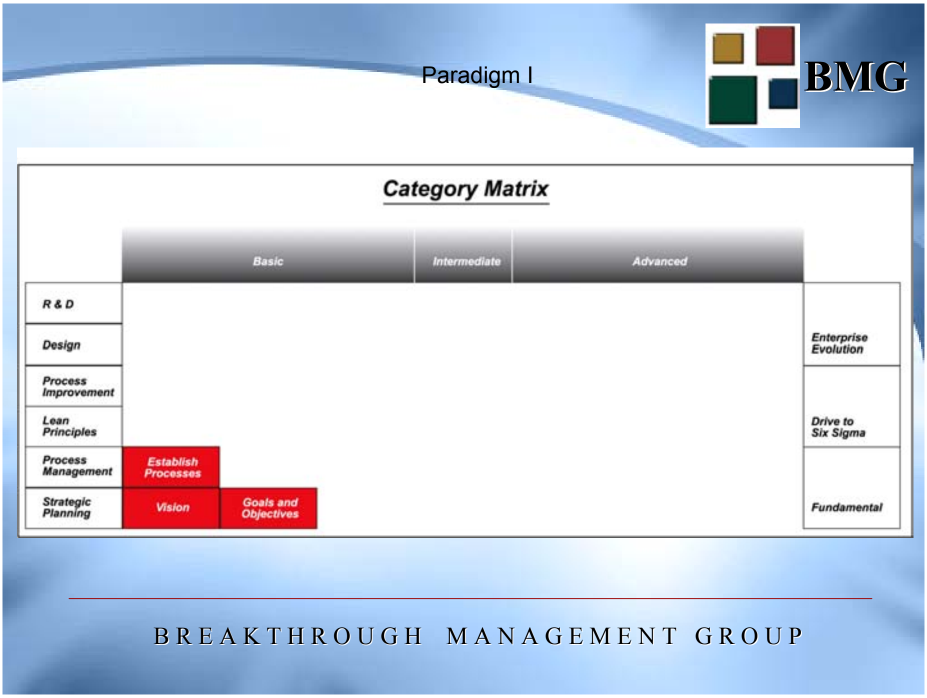
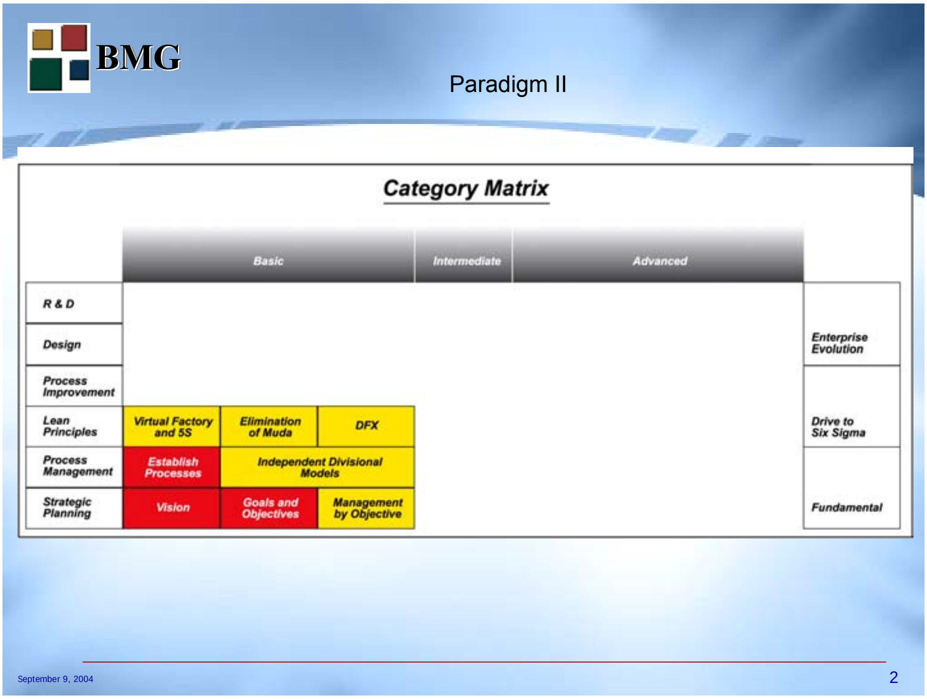
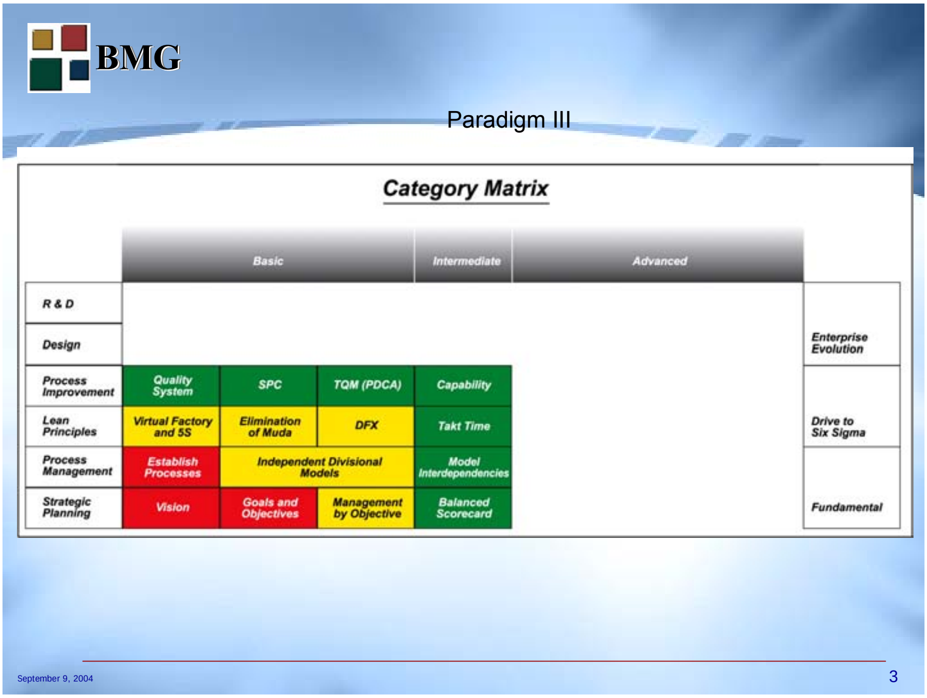
8. Appendix: Eight Paradigms to Performance Excellence



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Process Improvement
Lean Principles
Process Management
Strategic Planning
Quality System
SPC
TQM (PDCA)
Capability
Virtual Factory and 5S
Elimination of Muda
DFX
Takt Time
Establish Processes
Independent Divisional Models
Model Interdependencies
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Management by Objective
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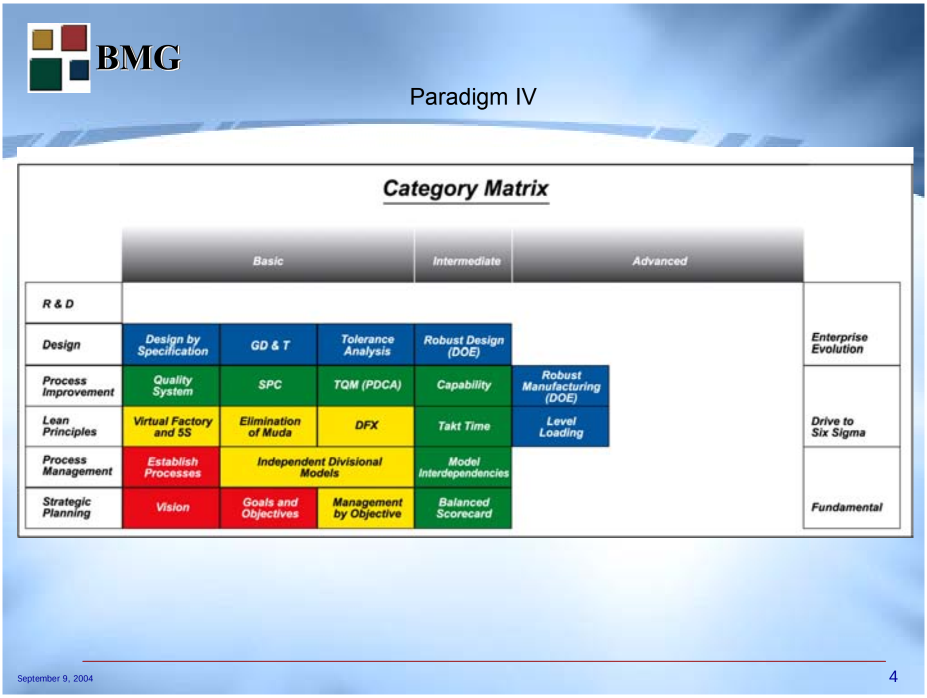
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TQM (PDCA)
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Robust Manufacturing (DOE)
Virtual Factory and 5S
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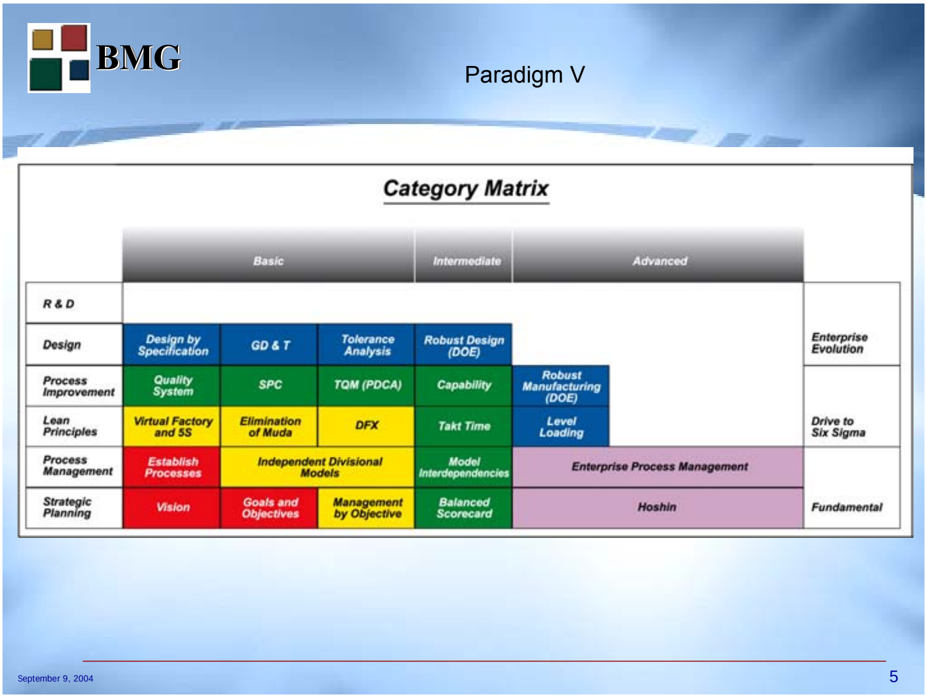
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Robust Manufacturing (DOE)
Lean Principles
Virtual Factory and 5S
Elimination of Muda
DFX
Takt Time
Level Loading
Drive to Six Sigma
Process Management
Establish Processes
Independent Divisional Models
Model Interdependencies
Enterprise Process Management
Strategic Planning
Vision
Goals and Objectives
Management by Objective
Balanced Scorecard
Hoshin
Fundamental
September 9, 2004
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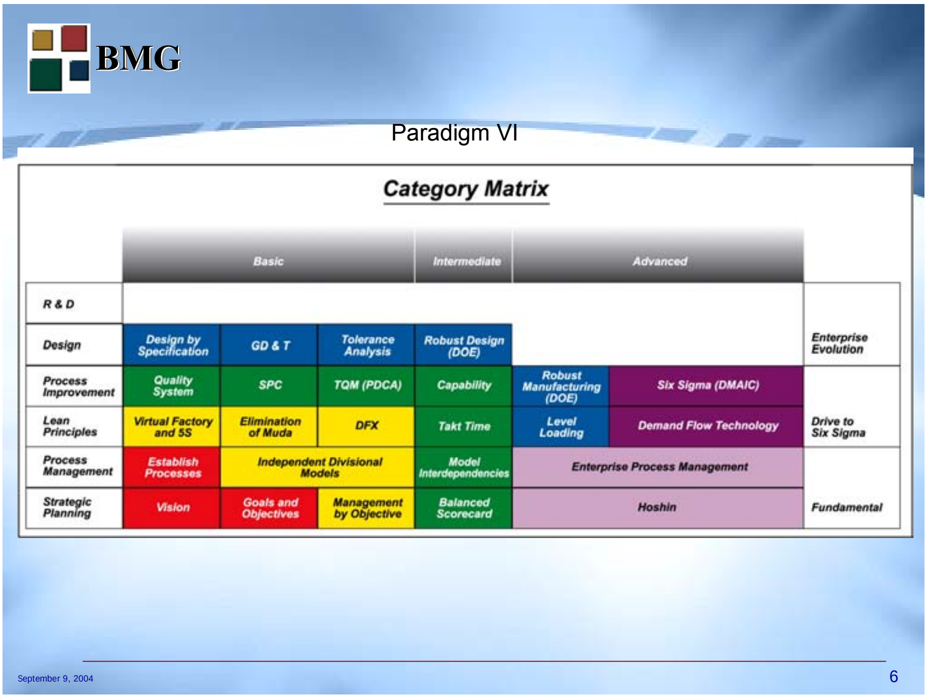
BMG
Paradigm VI
Category Matrix
Basic
Intermediate
Advanced
R & D
Design
Design by Specification
GD & T
Tolerance Analysis
Robust Design (DOE)
Enterprise Evolution
Process Improvement
Quality System
SPC
TQM (PDCA)
Capability
Robust Manufacturing (DOE)
Six Sigma (DMAIC)
Lean Principles
Virtual Factory and 5S
Elimination of Muda
DFX
Takt Time
Level Loading
Demand Flow Technology
Drive to Six Sigma
Process Management
Establish Processes
Independent Divisional Models
Model Interdependencies
Enterprise Process Management
Strategic Planning
Vision
Goals and Objectives
Management by Objective
Balanced Scorecard
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BMG

Paradigm VII

Category Matrix

	Basic			Intermediate	Advanced			
R & D								
Design	Design by Specification	GD & T	Tolerance Analysis	Robust Design (DOE)	DFSS (DMADV)			Enterprise Evolution
Process Improvement	Quality System	SPC	TQM (PDCA)	Capability	Robust Manufacturing (DOE)	Six Sigma (DMAIC)		
Lean Principles	Virtual Factory and 5S	Elimination of Muda	DFX	Takt Time	Level Loading	Demand Flow Technology		Drive to Six Sigma
Process Management	Establish Processes	Independent Divisional Models		Model Interdependencies	Enterprise Process Management			
Strategic Planning	Vision	Goals and Objectives	Management by Objective	Balanced Scorecard	Hoshin			Fundamental

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Paradigm VIII

Category Matrix

	Basic			Intermediate	Advanced			
R & D	Trial and Error	Derivative Development	Incremental Development	Closed Innovation	Open Innovation	Disruptive Technologies	Structured Innovation	
Design	Design by Specification	GD & T	Tolerance Analysis	Robust Design (DOE)	DFSS (DMADV)			Enterprise Evolution
Process Improvement	Quality System	SPC	TQM (PDCA)	Capability	Robust Manufacturing (DOE)	Six Sigma (DMAIC)		
Lean Principles	Virtual Factory and 5S	Elimination of Muda	DFX	Takt Time	Level Loading	Demand Flow Technology		Drive to Six Sigma
Process Management	Establish Processes	Independent Divisional Models		Model Interdependencies	Enterprise Process Management			
Strategic Planning	Vision	Goals and Objectives	Management by Objective	Balanced Scorecard	Hoshin			Fundamental

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THE INTEGRATION AND USE OF TRIZ WITH OTHER INNOVATION AND CREATIVITY TOOLS

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Abstract
Frequently, when TRIZ problem solving methodologies are brought into an organization, there is an existing infrastructure of problem-solving tools and methodologies. It is not uncommon to find that these methodologies have been used for some time, successfully, in the eyes of corporate management and those who are expert practitioners in these various tools. Examples of such tools include brainstorming, creative problem solving (CPS), Six Hats™ and Lateral Thinking™, and mind mapping. When TRIZ is introduced as a "breakthrough" problem solving process, debates and arguments can ensue regarding whose has the superior inventive process or tool kit. There are value in all inventive tools and processes and this paper attempts to show how the basic concepts of TRIZ can be "grafted" on to these existing processes to improve them. It is also possible to use some aspects of these other tools to improve TRIZ problem solving as well. This paper and presentation will review the basics of some of the more popularly used inventive tools and then discuss their connection with various tools in the TRIZ tool kit.
Keywords: TRIZ, innovation, inventive processes, inventive tools, creativity processes, Six Hats™, Lateral Thinking™, brainstorming, creative problem solving

1. Introduction

Innovation and creativity as individual and organizational processes have been in existence for centuries as both individuals and societies have coped with problems. These have been as simple as transporting food and as complex as the transmission of electromagnetic waves for communication. In the 18th and 19th centuries, great emphasis was placed on observational trial and error for breakthrough problem solving, especially in the fields of chemistry and physics. In the early 20th century, Thomas Edison perfected the concept of the mass production trial and error laboratory. In the mid 20th century Alex Osbourne suggested that idea generation was frequently hindered by the early judgment of ideas, limiting the desire of individuals to express new ideas for fear of being criticized. He suggested the separation of idea generation from idea judgment and this became the nucleus of what is now known as the creative problem solving process. Shortly thereafter, Edward DeBono, a renowned industrial psychologist, took these ideas a step further and suggested that segregating a group's thinking process into fixed modules would further improve this "brainstorming" process. A group's thinking module would be called a "hat" and different coloured hats would represent a different kind of thinking at that point in time and everyone within a group would think in the same way at the same time. These "hats" could be organized and used in certain orders, depending upon the type of problem being attacked. Continued develop of both methodologies resulted in certain stimulant words that proved successful in stimulating new ideas. DeBono's also developed another "break the mould" idea generation technique (provocation, or "po") known as Lateral Thinking™. This technique has many manifestations, but in many cases it involves reversing the problem situation, not dissimilar from the TRIZ problem solving principles, "do it in reverse".

Since these tools and processes have been in existence for quite some time, it is likely that a TRIZ practitioner is likely to encounter them and their use during the implementation of TRIZ problem solving techniques within an organization. Rather than debating the merits and potential superiority of TRIZ in many situations, it is sometimes more practical to incorporate important parts of the TRIZ tool kit within these other methods. It is the purpose of this paper and presentation to suggest methods for blending the various techniques together to maximize the useful output of the situation at hand.

2. The Uniqueness of TRIZ and its Tool Kit

Most everyone attending the ETRIA 4th Future TRIZ Conference is aware of the TRIZ process and its basis on the study of the patterns of invention. Compared to the more psychologically based tools mentioned previously, it offers a structured approach to problem solving using approaches that have been used by hundreds of thousands of inventors of the past, providing a model for future inventions. Though TRIZ experts might dispute a particular choice of TRIZ tools on which to focus, the following have been chosen by the author for further discussion as they are the easiest to integrate within these existing creativity and inventive tools. It is recognized that other TRIZ tools such as Lines and Patterns of Evolution, Smart Little People Modelling, etc. could also be integrated. However, the tools summarized below are the easiest to understand and explain to non-TRIZ practitioners.

2.1 TRIZ Tools

2.1.1 Ideal Final Result or IFR. This is the concept which forces a person or group to think seriously about a system or product they have and to eliminate all mental barriers to the achievement of an ideal functionality. As TRIZ practitioners are well aware, this concept is particularly difficult for experienced technical people, and yet can be one of the most powerful idea generating concepts. Defining the IFR is usually the first step in any TRIZ problem solving session.

2.1.2 Resource Use and Identification. This is the TRIZ concept that assumes that a system always has available resources that are unrecognized or underutilized. If a system's resources are truly exhausted, TRIZ points the way toward a replacement system through its patterns and lines of evolution.

2.1.3 Contradiction Analysis and Resolution. TRIZ recognizes that great inventions and problem solving comes through the identification and resolution of contradictions in product or system design and performance. Traditional problem-solving compromises around these contradictions, while TRIZ uses its contradiction table, 40 Principles, and separation principles to resolve these contradictions.

2.1.4 Patterns and Lines of Evolution. TRIZ recognizes that technology and systems evolve in predictable and known patterns that can be used to plan and forecast technical, management, and system evolution.

2.15 "Reverse" TRIZ for failure prediction. This is the concept of "reversing" the normal TRIZ thinking of ideal final result and resource utilization to identify failure routes or probabilities. Example: State the problem, invert the problem (i.e. we want to have the problem), exaggerate the problem (we want to have the problem to a severe degree at all times), search for causes and resources.

2.1.6 TRIZ Lines and Patterns of Technical and System Evolution. These are the patterns and lines of invention progression established through the study of the patent literature and the evolution of technical and non-technical systems.

2.1.7 TRIZ "9 Box" Analysis, shown in Figure 1. This is the concept of looking at TRIZ concepts above, below, present and past, for the problem, product or system of interest.

Past—above the current system	Current—above the current system	Future—above the current system
Past—current system	Present system	Future—present system
Past—supply to the current system	Supply to the current system	Future—supply to the current system

Figure 1. TRIZ Nine Box Diagram

3. The Creative Problem Solving Process (CPS)

3.1. Outline of the CPS Process

As mentioned previously, the art of brainstorming has evolved over the years to be much more than a technique for capturing ideas as fast as they are shouted out by a group of people. One of the formats in which CPS is practiced as follows, with the subheadings indicating some of the more specific tools used under each major segment:

A. Define the objective

    Ask the question "Why" five times
    Ask the universal questions: What? Where? When? Why? How? Who?

B. Determine facts required

C. Define the problem in detail

D. Generate ideas

Use triggering questions such as put to other uses? Adapt? Modify? Magnify? Minify? Substitute? Rearrange? Reverse? Combine?

E. Evaluate and prioritize ideas

F. Plan and implement

All of these steps can be run in both a divergent and convergent mode.

3.2 TRIZ Integration with this Process

First of all, use aspects of TRIZ in the problem definition phase (steps A-C). The CPS process asks the problem owner to define their problem, but not until basic facts, data, and opinions are gathered. Injecting the TRIZ concept of Ideal Final Result (IFR) at this point in time would cause the problem owners to ask if there is a more ideal way to achieve the result that they desire, as well as to cause a dramatic stretch in imagination to envision a totally idea system using no resources, etc. TRIZ practitioners know how difficult a thinking step this is and it would not be expected to be any easier for a CPS group. If the group is truly in a convergent phase of thinking and no group or management pressure is applied, using the IFR concept would produce valuable input at this point in the process. This would also be an excellent time to introduce the “9 Box” TRIZ concept and ask ideal for who? How does the problem look to the customer? Supplier? It would also be good at this stage to identify the key contradictions that are keeping the problem from being solved. The issues may not have been identified in this fact finding phase.

In the idea generation phase, the TRIZ 40 principles can be used in random order to generate ideas. If the problem has been phrased as a contradiction, the actual TRIZ contradiction table can be used. In both scenarios, the aggressive analysis of resource availability can be integrated into the problem solving session.

In the evaluation and implementation phase, the TRIZ patterns and lines of evolution can be used to stimulate second and third generation ideas beyond those originally generated.

The “reverse” TRIZ thinking can be used to analyze session output for possible negative concerns. A graphical summary of this integration is seen in Figure 2.

CPS Step	TRIZ Tool (s)
Define the Problem	Ideal Final Result, 9-Box Definition of Ideal Result (Ideal from Whose Perspective?)
Facts Required	Resource Availability, Define Contradictions
Define Problem in Detail	Further Definition of Resource Availability and Contradiction Analysis as a Function of Problem Detail
Generate Ideas	Use 40 Principles and Separation Principles as Appropriate; Parallel Industry Search for Awareness of Possible Solutions
Evaluate and Prioritize	Screen Ideas Generated by Closeness to IFR, Use of “reverse” TRIZ to Analyze for Potential Failure Mechanisms
Plan and Implement	Use Continuous Searching of Parallel Technologies for Assistance

Figure 2. Integration of TRIZ within CPS Process

4. DeBono’s Six Hats™ Process

4.1 Outline of the Six Hats™ Process

In order to make the group ideation process even more efficient, DeBono suggested dividing the group thinking process into parts, labelled “hats”. Each hat signifies a focused, different way of thinking and all participants thinking the same way at the same time. These hats are as follows:

Blue—Under this hat the meeting process itself (agenda, topics, etc.) are discussed.

Green—Under this hat, idea generation (similar to normal brainstorming ideation) is permitted, but no criticism of ideas allowed.

Black—Under this hat, criticism of ideas and possible negative consequences are permitted for discussion.

White—Under this hat, information that may be required for idea clarification, solution idea completion, etc. is permitted.

Red—Under this hat, participants express emotional, not necessarily fact based reaction or objection to an idea. "Gut feel" reactions are permitted.

Yellow—Under this hat, positive aspects and opinions regarding an idea are allowed.

The hats can also be applied in different order, depending upon the nature of the problem, time available, etc.

4.2 Use of TRIZ within the Six Hats™ Process

One can see a number of ways to fit various TRIZ tools under each of these "hats".

Blue—TRIZ would ask if all the appropriate tools and potential resources were available within the process itself. Is there a place within the process to stop and identify contradictions that need to be resolved? TRIZ would also ask if parallel industries, experts, etc. had been considered for inclusion into the process.

Green—Since this is the ideation phase, the 40 Principles, Contradiction Table, and the Separation Principles would all be used, the latter especially in the cases where the problem involves an inherent contradiction.

Black—If the issues raised under this hat involve are reasons why something "won't work", it may be possible to deal with those contradictions with the 40 Principles, Contradiction Table, and Separation Principles.

White—The TRIZ can be used here to ensure that all possible resources have been considered as part of the information resource bank available.

Red—There is not much that TRIZ can do under this hat except to use the "left brained" TRIZ tools to reduce the need for emotional, non-technical analysis and reaction.

Yellow—Using the concepts of Ideal Final Result, as well as some of the any of the contradiction resolution tools, ideas can be further improved and optimized.

Ways to integrate TRIZ into the Six Hats™ process are summarized in Figure 3.

"Hat"	TRIZ Tool (s)
Blue—the meeting process itself	Are all appropriate tools and expertise present? Has the process been set up to allow contradiction identification? Parallel industries been analyzed and studied?
White—Information, data, required, definition of problem in detail	Resource Availability, Define Contradictions Further definition of resource availability; Contradiction analysis vs. problem detail
Green--Generate Ideas	Use 40 Principles and Separation Principles as Appropriate; Parallel Industry Search for Awareness of Possible Solutions
Yellow—Augment good ideas	Accentuate the IFR concept and contradiction resolution to improve existing ideas
Black—What is negative about current ideas	Use contradiction table and TRIZ in "reverse" to potentially eliminate these issues

Figure 3. Integration of TRIZ with the Six Hats™ Process

5. Lateral Thinking

Lateral Thinking is another idea generation technique developed by Edward DeBono. It has within it a number of tools and discussing all of them is beyond the scope of this paper, but we will address the following in terms of TRIZ connections: Entry points, random stimulation, "do in reverse", parallel and analogies, and finally names and labels. Lateral Thinking, practiced in this formal way uses a number of techniques to stimulate the group or problem owner to think "outside the box". The goal here is no different than what is desired from the TRIZ tool kit. TRIZ concepts can be integrated into this structure as follows.

5.1 Entry points, random stimulation

DeBono suggest a number of clever ways of changing the thinking orientation of the problem solving group, including particular lists of words, "do it in reverse", changing the entry point. All of these are contained within the TRIZ methodology. "Do it in reverse" is in fact one of the basic TRIZ problem solving operators that has been used for decades, #13, “the other way around”. The use of the 40 principles in random order as stimulation is far superior to a random list of words as these principles have been validated to solve problems. Changing the entry point can be facilitated through the use of using the TRIZ 9-Box diagram at a different level.

5.2 Challenging Labels, Names, and Units

One of the basic TRIZ problem solving concepts is to get the problem owner to express their problem in generic terms without the use of special jargon and terminology unique to a particular industry or technology. Generalizing terms and phrases are proposed by both TRIZ and Lateral Thinkers. This allows the problem to be thought of in a more general way and allows the question of “how else might someone do this?” to be considered.

5.3 Parallel Universes

Again, a primary premise of TRIZ is to generalize the problem and look for parallels where this type of problem may have already been solved in a parallel universe of technology. The difference between Lateral Thinking and TRIZ is that TRIZ, sometimes through its many software products, allows this to be done in a systematic, structured way as opposed to guessing. As can be seen the integration of TRIZ principles within a Lateral Thinking session is almost seamless, as there is significant overlap between the philosophy and objectives of the techniques.

A summary of TRIZ integration with this process is shown in Figure 4.

Lateral Thinking Tool	**TRIZ Tool (s)**
Entry Points, Random Stimulation	Use 40 Principles in Random Order; Use TRIZ Separation Principles to Diversify entry Points
Challenging Names and Units	Generalize Terminology and Names in the same way as for a Normal TRIZ Session
Parallel Universes	Use Experience within the Group, TRIZ Software to Suggest Parallel Industries for Solutions and Applications Found

Figure 4. Using TRIZ to Improve Lateral Thinking

6. Conclusion

All ideation processes have value in providing mechanisms for both individuals and groups to create ideas that are new, novel, and useful. There are also many useful and productive creativity and innovations processes used by different individuals and organizations to create these new ideas. Any TRIZ practitioner is well aware of how useful and powerful the various TRIZ tools and techniques are when applied to practical problems.

When the occasion presents itself where TRIZ must be combined or serve as an addendum to an existing process or tool kit, it is easily possible to do this using the strategies and techniques outlined in this paper.

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THOUGHTS ABOUT THE DEVELOPMENT OF INDIVIDUAL ABILITIES OF HUMAN BEING IN THE CONTEXT OF TRIZ

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Dedicated to creating a world to which people want to belong

Abstract
Management of Human Risk and Development of Individual Abilities of Human Being as a matter of fact are an old subject by all standards. Unfortunately the subject did not receive very much attention in a variety of sectors in the past because many of us have been primarily busy with quantity and not quality. Only recently Development of Individual Abilities has been taken more seriously at many level of our societies. It is because the more one studies attempted solutions to current problems the more one has the impression of gifted people wearing out their ingenuity at the impossible and futile task of trying to get "water of life into neat and permanent packages".
Science and industry have increased both the speed and violence of living to an unprecedented level so that our packages of knowledge and experience are coming apart faster and faster day by day. In addition we have been exposed to a propaganda and disinformation creating ever stronger feeling of insecurity. Insecurity leads to compensation and overreactions with many manifestations.
To some this is a welcome release from the restraints of moral, social and other obligations and dogma. To others it is a dangerous and terrifying breach with reason and sanity. To most the immediate sense of release is followed by deep anxiety. But anxiety can lead to pathology, quite serious issue with high personal and social risk affecting innovation and creativity on purpose, the very idea of TRIZ..
Human beings appear to be happy just so long as they have a future to which they can look forward, be it tomorrow or in the future after death. Both are explored by many new religious and political movements using sophisticated brainwashing and other methods. They all have in return effect on individual performance and cooperation between selected parties. Hence there is a direct connection between Management of Human Risk and the Development of Individual Abilities of Human Being. The application of theories and methods like TRIZ, Quantum Mechanics, Psychology, Linguistics, Neuroscience form the base of what I have been calling SID(I)A – System of Intensive Development of Individual Abilities.
The paper would discuss an ecological, efficient and economical offer covering some of the above mentioned and proven tolls and technologies. In addition it would consider the ever growing importance for new philosophy when managing human risk within the context of innovation and creativity on purpose and the underlying process of life long learning..
Specifically it would refer to selected aspects of TRIZ, Biofeedback and Psychology including selected aspects of linguistics. Essential questions related to neurological levels,

the use of bio and neurofeedback for stress management, application of elements of quantum mechanics and brain functions including the use of English Prime all mixed with fascination for the law of reversed effort. A practical example from work completed by the author and dealing with improvements at processing plant belonging to one of the largest world franchise groups would complement the presentation.

1. Introduction

I feel that in the air is a victory of coffee and tea moving through smoke of tobacco of your cigarettes and cigars. I have therefore decided not offer anything, which from the language point of view would make the understanding of the topic difficult and which would spoil your time in this beautiful city.

At the same time I am asking you to be patient and relaxed if you wish to understand not only what has been printed or would be said, but also the not printed and not spell out.

Some of you, ladies and gentlemen in the auditorium's chairs may feel the same as many others in clubs and restaurants who wish to see the world of people and animals divided into two worlds: the good one and the bad one.

Some of you may be trying to find simple solutions similar to those of comics, artistic and intellectual work of people, who has been trying hard to replace in your mind the world "culture" for the word "civilization" and did not even hesitate some ten years ago to call this pain-and stressful process "the clash of civilizations".

Today's session may therefore not add to the comfort for those who subscribed to a simplistic view on the world and problems to be resolved with or without TRIZ because these are more complex and quite colourful.

What do I understand as colourful you may recognize when observing a simple rainbow, rain, clouds and sun. An analogy applies to the topic.

Because of time limit for presentation I cannot describe in detail all the elements of the process I have been calling SID(I)A – System for Intensive Development of (Individual) Abilities. But I would do my best and mix various elements of SID(I)A with pictures and graphs while talking, hoping at the same time that they and yourself would create an idea on how the key elements – the Bio and Neurofeedback (BNF), Theory of Inventive Problem Solving (TRIZ / TIPS), Neuro-linguistics, Psychology including extended psychology and some principles of Quantum mechanics are interlinked and functioning as a whole.

As the rainbow offers a beauty, sometimes also called aesthetic imprint by mixing five basic colours, so the five logical levels in their wholeness offer a lead to meta imprint in which both worlds, the one of natural sciences and the spiritual meet and unite. This is also one of another underlying ideas of SID(I)A.

2. Biofeedback

Motto: Paradigm is like a glass wall. You don't see it, but you can feel it when the change begins.

The experience to prevent, manage, treat stress and stress related disorders teaches how important is relaxation. The relaxation I have in mind is not a simple prayer, listening to music or mediation, during which the person does not know how or with what to fill the vacuum he or she is creating while praying, listening to music or meditating. The relaxation I have in mind is not a detachment from this world, not an exit from your body, the temple of Holy Spirit but an entry into it.

The grade of such a relaxation can be determined by the frequency of brain waves. In simple words: the lower the frequency the more relax is the person and vice versa. Higher frequency means stress.

3. Frequencies and biofeedback

In the context of bio and neurofeedback, which is used for prevention, management and treatment of stress and stress related disorders we are talking about Alpha, Beta, Delta and Theta waves and frequencies.

When talking about Beta brain waves I understand frequencies between 12 to 30 Hz. They indicate for high energetic load, concentration and stress. If Beta is high we encounter depression, fear and similar and some of you may know very well what I am talking about. There are approximately 20% of all children, students not included with syndrome of attention deficiency, known as ADD or ADHD (Attention Deficit Hyperactivity Disorder), which is usually accompanied by deficiency of certain neurotransmitter, in particular dopamine. The treatment focuses on electroencephalographic beta-stimulation of the thalamus and hypothalamus (diencephalons). The results shown on the screen give you an idea about the efficiency of this non invasive method allowing for training in the terms of ergotropia (15 to 18Hz) and trophotropia (12 to 15Hz called also SMR training) and changes in sympathetic and parasympathetic arousal. Nobel prize Laureate Sir Francis Crick and other scientists believe that the 40Hz beta frequency may be the key to the act of cognition.

When talking about Alpha brain waves I understand frequencies between 7 to 12 Hz. They indicate for a relax state like before you fall asleep or feel comfortable. It is a state in which endorphin is produced, the immunity system strengthens and all life functions regenerate as more and more neurons are recruited to this frequency and alpha waves cycle globally across the whole cortex. Alpha waves aid overall mental coordination, support calmness, alertness, inner awareness, mind and body integration and learning. They can propagate with frequency known as Schumann's resonance and people going into resonance with that Earth frequency naturally feel better, fresh and in tune, which may be also called the environmental synchronisation.

When talking about Theta brain waves I understand frequencies between 4 to 7 Hz. They lead to a mostly spontaneous state where vision, mystic states and thought, the gateway to learning and memory and similar can develop. In theta state our senses are focused on the mindscape – internally originating signals.

When talking about Delta brain waves I understand frequencies between 0,5 to 3 Hz. They allow "silence" most of functions, allow for full regeneration of organism and accumulation of energy during a sleep "without dreaming". Certain frequencies within the delta range trigger the release of a growth hormone, which is beneficial for healing and regeneration. This is why deep restorative sleep is so essential to any healing process.

Long term EEG training has the effect of exercising and expanding the brain's ability to move freely along the continuum of ergotropic and trophotropic dominance, which are mutually inhibitory. The brain intrinsic bias toward homeostasis dictates that any training, which evokes a brain response away from its the-prevailing equilibrium state will set in brain forces to restore the original state. Hence, even dis-equilibration can bring about improved equilibrium maintenance as a long-term consequence.

Beside the EEG training cardio-interval game based biofeedback training and own methodology both developed at IMBBP (Institute of Molecular Biology and Biophysics) of SB RAMS (Siberian Branch of Russian Academy of Medical Sciences) form a complementary, ecological, efficient and economical solution for managing stress and some forms of deficits caused by it.

4. Brain waves frequencies, Earth rotation and FFR

At this point of this discussion I wish to mention the frequency of Earth rotation, known to many of you as Schumann's resonance (SR), calculated at 7,8355 Hz and the FFR (Frequency Following Response) patented in 1975 by Dr. Robert Monroe. Monroe arrived at conclusion that certain vocal frequencies cause an adequate reaction of brain waves. When you bring say 107 Hz into one ear and 100 Hz into another, the brain's "acoustic computer" working on principle of binaural rhythm produces pulse tone at 7Hz frequency. Dr. Schumann's (Earth / cavity) resonance as calculated (in 1957) at 7, 8355 Hz is naturally circulation of rhythmic signals in the space between the surface of the Earth and the ionosphere. (The lower layer of the ionosphere is roughly 60 to 80 km from the crust and is known to reflect radio waves. Since the ionosphere is a highly charged layer, it forms a so-called capacitor with the Earth. This means that there is a difference in electrical potential between the two, leading at the same time to perceive it as a fundamental type of electrical generator. The solar wind interacting with the upper atmosphere rotation, act as the collector and brushes of a generator. The lower atmosphere can be seen as a storage battery for this potential. According to recent publications the frequency changed and increased to around 12 Hz. As Schumann's resonance forms a natural feedback lop with human / mind body and the human brain and human body developed in the biosphere the pulse acts as a "driver" of our brains and can potentially carry information. Functional processes may be altered and new patterns of behaviour facilitated through the brain's web of inhibitory and excitatory feedback networks.

To simplify the process of understanding of what I want to convey I am inviting you to recall your experience and imagine the percussion, Tibetian's plates or certain types of trumpets but also Gregorian choruses. They are hardly anytime playing or being used alone.

Each of you can probably make his or her conclusion of this simple fact.

5. Neuro-dynamics

It was Russian scientist Pavlov (1927) who first postulated the need for an optimal steady state of brain excitation in organized activity, characterized by a precise balance between excitation and inhibition and a high flexibility and variability of nervous-energy concentration so that it is easy to focus or shift focus from activity to activity, and from nervous-energy-concentration level to nervous-energy-concentration level. These optimal neuro-dynamics disappear in sleep or in defective waking mental states.

For those who know or wish to know more I recommend to consider some of the issues related to the brain like "the vestibular contribution to the "non-specific" nervous energy of RAS (Reticular Activating System), the contribution of the vestibular system and the cerebellum, upward and downward connectivity of RAS, specific function of RAS, metabolic and internal equilibrium processes and similar.

6. Brain theories

In this part of my presentation I wish to mention a few theories of brain functions only. Their simplified form aims to direct your attention to the need to look at so called obvious. This is another very important element of TRIZ.

These theories can be grouped in Generation of new connections, therefore sometimes also called Connections theory, including Cells assemblies, Causal loops, Digital Circuitry etc. The other theory is called Statistical Brain theory and the one preferred by myself is called the Cybernetic Brain theory.

The Connection theory claims that new connections are actually made by the growth of new nerve fibres between cells as sequences if actions or perceptions are learned or remembered.

Another theory claims that synaptic activity between two neurons is more readily generated if there is consistent activity between the two. This indicates that learning or memory would be a function of how much and how often these cells are fired in sequence together. This hypothesis would imply a degeneration or even loss of memory etc.

The Statistical brain theory, as formulated by E. Roy John in his final statement implies that" the memory of what is learned is not to be found in any specific brain region, but rather in its unique cell-firing rhythm…The brain's rhythms count for as much or more than the way it is put together." Although E. Roy John presents much new phenomena regarding neural function, and his statistical brain theory provides a much more elegant and intuitively satisfying explanation of memory than the connection theories, it still seems incomplete in many ways**.**

For these and many other reasons the Cybernetic brain theory offers not only me by anybody interested in the subject far more challenges and excitement.

I understand Cybernetics essentially as a meta model. This means model about modelling. Cybernetic models are different from statistical or linear in that they deal with the feedback of total systems, systems in which events at any positioning the system may be expected to have effect at all positions on the system at later times. In cybernetic models a particular cause or effect cannot be isolated from its context. Therefore each part must be considered and measured in terms of whole. Human behaviour and experiences are undoubtfully the results of such a system. Therefore any satisfactory model of human experience, behavioural, psychological or epistological must be cybernetic.

There are many cybernetic explanations, from which Gregory Bateson's is one of the most attractive to me (Steps to an Ecology of Mind, 1972). Causal explanation is usually positive. Cybernetic explanation is *always* negative (Theory of evolution under natural selection). In cybernetic language the course of events is said to be subject to restraints and it is assumed that, that apart from such restraints, the pathways of change would be governed only by equality of probability. Restraints of many different kinds may combine to generate this unique determination (pp 399-400)

The subject matter of cybernetics is not events and objects but the information "carried" by events and objects. We consider the objects or events only as proposing facts, propositions, messages, percepts and the like.

Therefore it is important to understand that the elementary unit of meaning in perception is difference. Our sense organs (eyes, ears, bodies, nose, tongue) all “perceive” by responding to changes or differences in our environment. Psychologically, sensory perception take place through differences in the location, firing pattern and inter connection of cortial neurons. Behaviourally we contrast the performance of the “good” and “less good”, or “bad”. The process of making comparisons is called contrastive analysis. The elementary meaning is information. In Bateson’s words information is ”a difference which makes a difference.” And as there are differences between differences we have to learn and apply their differentiation and classification.

For the purpose of this TRIZ conference *space and time are the basic dimensions of difference***.** Following three types of differences have to be considered in the context of SID(I)A:

Spatial difference (between two objects), temporal difference (change in that difference, like move of the eyes) and acceleration difference (delta in changing in the changing of the location of two objects).

Further consideration relates to classification of difference (hierarchy – transition from micro to macro – molecule-cell-tissue-organ-organization-society), which documents clearly qualitative difference between those that govern the microscopic interaction. In mathematics the numbers 8-16-24 form a subclass of all numbers divisible by 4, which in turn are subclass of all even numbers. In behavioural terms an eye movement is a subclass of facial expression, which in turn is a subclass of non-verbal communication. From this follows that each sub-unit is a part of the unit of the next larger scope and that certain different in the part of the unit must have informational effect upon the larger unit and vice versa.

Logical typing occurs where there is a discontinuity between levels of classification. In mathematics, by the restriction that a class cannot be a number of itself nor can be one of the numbers be the class. In logic, by the solution to the classic logical paradox: “This statement is false.” The actual value of the statement is of a differential logical type than the statement itself.

The Cybernetic brain model differs from the statistical brain model in that it does not separate the overall rhythms of neural firing from the structures by which they are propagated. Although I am not a specialist in developing or promoting any of the above theories I recognize that in the cybernetic brain the concept of the localization of perceptual representations is not discarded, nor the possibility of the equipotentiality of parts of the cortex for more than one kind of perceptual discrimination. These types of phenomena are considered in terms of the operation of the brain as a whole.

In more simple words I am arguing against the separation of mind and body, which is in my opinion another of key elements for a successful application of TRIZ

In fact, among behavioural scientists there has been a growing uneasiness with the requirement to exclude from description and experience the influence of the human agent, sometimes called Rosenthal experimenter effect.

Even in the physical sciences a framework attributed to Einstein’s relativistic model has dislodged the Newtonian theory of physical systems, which requires an exclusion of any reference to humans.

(Einstein said once: “I am not interested in this spectrum of light, or how much this molecule weighs, or what this particular atomic structure is. I want to know God’s thoughts. Everything else is details.”

I perceive this statement as a mission statement. So I think it is very important to accept to encounter in the process of implementation of any project a question like: “How can you answer questions concerning mission without addressing the issue of God in some way?”

As is implied in its name, the relativistic models demand an explicit representation of the perceptual position of the observer in describing certain space / time interaction.

The inclusion of the perceiver in descriptions of physical interactions represents a major increase in the descriptive power of the model thus introducing Heisenberg Uncertainty Principle, English Prime; and other elements into the process.

Before the consideration of linguistic aspects and their influence on person’s psychology and behaviour allow (me) for a short reflection in easily understandable words on neurons, living substance and beliefs.

7. The neuron, living substance and beliefs

In general, one might conclude that there are different hierarchies and levels of neural coding for different chunking and communications of sensory information or processing. Different types of coding can occur in the interactions between as the simple diagram shows:

a) a neuron to itself (that is, individual properties of a neuron size, shape, number of dendrites, firing threshold, degree of mylination, and so on),

b) a neuron to other neurons,

c) a neuron and its environment (location in cortex or body, chemical composition of immediate environment and so on),

d) different groups of neurons,

e) groups of neurons and their environment, and so on.

From what I have been saying follows that the living substance is comfortable with itself and has enough intelligence to offer happiness and richness not only by recognizing that time has not a begin and not an end but because of its existence in space and probably also the power to growth further.

For all the creation there is a reason and a belief. Beliefs have to do with the future; the function of beliefs has to do with the activation of capabilities and behaviours.

8. TRIZ , behaviour and biofeedback

Until bio and neurofeedback came along, nobody could believe that you could influence your heart rate or your blood pressure. Those involved in the application of bio and neurofeedback have believed in more. Nowadays we know that we can influence immune system, manage attention deficits, treat even drug addicts and much more. Those involved in Biofeedback could confirm that we can lead people to change their own beliefs. It is not up to me to change somebody else’s belief. The goal is to pace and lead persons into establishing a new belief (system), own virtual reality indicating to them following stages:

1. The first stage involves imprints at the level of biological intelligence, which has to do with survival. “Can I survive?” is usually the question.
2. The next stage involves emotional imprints. “With whom do I belong?” the two stages cover behaviour within logical levels.
3. The next stage involves the development of intellectual imprints. “Can I think?”

4. The next stage involves social imprints. “What is my role in relations to others?”
5. The next stage involves the development of an aesthetic imprint. You are beginning to be aware of things for what they are, and are finally able to perceive beauty and forms. “What is beautiful?”
6. Finally there is a stage in which you develop imprints on meta level, sometimes also called spiritual or identity level imprints. “Who am I?” “ In what ways can I evolve myself?”

For those in business I can recommend to apply the same, because I think that cultures and businesses go through the same stages. If there is a negative imprint in one of these stages it makes it difficult to go to the next level. The chain is not stronger than its weakest link. And if pressure is exerted onto the system it will often regress back to this particular stage. I think that there is no need for specific examples. Look please at many of the companies in your neighbourhood and their state and operation.

Such a look would probably remind you on the importance of the totality of levels mentioned at the beginning of this session. Some people are able to affect the world through their behaviours. Other people affect the world through their influence on people’s beliefs. Some people can affect the world purely through their identity, by who they were as a figurehead. The ones who really stand out are those ones who don’t’ only affect the environment and our day-to-day behaviours and our capabilities or knowledge or thinking or our beliefs and identities, but also our spiritual levels. The more levels something affects, the more complete the impact is. I very much hope that you have identified for yourself at least one personality if not more who really stands out.

9. Metaphor

Motto: How does one become a butterfly? You must want to fly so much that you are willing to give up being a caterpillar. (Pualos)

For those more advanced you can make a transition to your next belief change process with a metaphor about a group of people who lived far away in space.

These people are the opposite of us in how they live their lives. They watched us and decided we did it backwards; we’re born, grow up, work hard all our lives, and die at the end.

So these people lived their lives in reverse order. They die first and get it over with. They spend the first few years in old people’s home, tired and weary pf the world, seeming somehow distant from the people who are relatives and friends.

But as they grow older they actually grow younger. The more time they spend in the old people’s home, the more connected they seem to become with their fellows, the more excited and the more recognition they have with their family.

Finally they get older enough to get out of the old people’s home and somebody gives them a gold watch or mobile phone and they go to work. At first in their work they feel they have done everything that they could. There are not really any new directions; they get weary and tired of their work. But the more time they spend in their work, the younger they get; more creative ideas begin to come to them, the more interest they take, the more excited they get arriving at work every day.

Finally it seems like a wonderful adventure to go to work. When they reach that stage, they have to get out of work and go to college where they can spend time learning about themselves trying to find themselves.

In their world as students, they revolt, protest against the war, destroy, create, destroy…and continue to get younger towards their adolescence. They are not really sure of their identity. They have confusing experiences about who they are and their relationship to others. But since they have all their adult memories to remember forward to, they have resources than can help them through this time.

They can finally enter childhood, where each day their eyes open wider to the world around. Their sense of wonder and energy grows. Their beliefs seem to become broader, more open, more flexible each day. Then they spend the last nine month of their lives in a soft and warm environment where every need, every wish is taken care of for them. And they end it all up as the gleam in somebody's eye.

The story can go on and on. Indefinite time and indefinite space win over and the creator became a friend.

10. Goethe and the metaphor as a model for creativity

Motto: In the strictest sense, we cannot actually think about life and reality at all, because of the assumption that one would have to include thinking about thinking – ad infinitum. One can only attempt a rational, descriptive approach of the Universe on the assumption that one is totally separate from it; but if you and your thoughts are part of Universe, as a majority of the audience would probably agree including myself, you cannot be separated from it at the same time if you wish to describe it. To "know" reality you cannot stand outside it and define it; you must enter into it, BE it and feel it.

"Nature does not like jokes; it is always true, always serious, always strict; it is always true (that) mistakes and fallacy are generated by humans." I wish to add that felicities can also be generated by humans.

To generate them one should be creative. The metaphors I have been using today can serve as a model for creativity, because it can provide a basis for

a) Representation, b) Explanation and c) Prediction.

In this context I would like to stress, that metaphors serve as models of thinking:

a) Thinking is *perceiving,* b) Thinking is *moving* and c) Thinking *is object manipulation*.

Perceiving gives rise to a *representation model* that deals with issues of what and how information is considered.

Moving gives rise to *a search model* that deals with issues of sequencing of actions, end state, obstacles and alternatives.

Object manipulation gives rise to a *restructuring model* that deals with issues of combination and interaction of ideas.

(In short this means: Much of what we are doing is a question of changing the style of thinking. This includes the understanding that paradigm of the sciences is mechanics. If people imagine psychology, their ideal is a mechanics of the soul. But the problem for many lies in the fact that there are many laws of physics and hardly any laws of psychology).

This also include the need to understand and accept that DNA known to many as coming from the world of chemistry and genetics can also be perceived by many as an abbreviation related to Spirit: DNA as Divine Nature Attitude.

By putting the metaphoric correspondences into a formal system the three metaphors together form a powerful collection of models already suitable for creativity on purpose and implementation.

In regard to TRIZ and SID(I)A as defined at the beginning I add to the set of models also a proven method of solving contradictions. Contradiction means basically to say “No”. As you can see from the graph there are many types of contradictions and there is also TRIZ and software developed by Pavel Livotov for solving contradictions at conceptual level. At the same time I have to stress that TRIZ / TIPS is not a panacea and that it requires sophisticated educational and thinking background.

The combination of metaphor models, TRIZ / TIPS and extended psychology indicates for development of emotional state of a person and its ability to feel.

Feeling is an important as thought in stimulating creativity. Thought can be the slave of feeling, but it can be its master too.
(Vygotsky)

Therefore I sincerely believe that it is useful to be able change the way we perceive our lives; to learn from dreams and from both: the natural sciences and proven spiritual teachings.

Perhaps tonight your own unconsciousness mind can surprise and delight you with some special gift, pleasant memory or pleasant sensation. May be you can particularly enjoy somebody’s company, or sharing a feeling or belief with somebody with the innocence of a child. And with that childish innocence, which is a very precious thing, perhaps you can find yourself coming back to this conference room, coming back to this space with your eyes opened a little wider, with your senses a little more opened to both worlds, with your energy a bit higher as usual for the very few things that are important for you.

Working with feedback processes in various forms and during which the person turns from an object to a subject of the process requires also consideration of linguistic aspects and psychological inertia and awareness of what is called The Pathological science.

11. The language aspect

“The Sanskrit language, whatever may be its antiquity, is of wonderful structure; more perfect than the Greek, more copious than the Latin, and more exquisitely refined than either, yet bearing to both of them a stronger affinity, both of the roots of verbs and in the forms of grammar, than could possibly have been produced by accident; so strong indeed that no philologer could examine them all three without believing them to have sprung from some common source, which perhaps no longer exists; there is a similar reason, though not quite so forcible, for supposing that both the Gothic (Germanic) and the Celtic, though blended with a very different idiom, had the same origin as the Sanskrit; and the old Persian might be added to the same family…”

These are words written in 1786 by Sir William Jones, a British judge stationed in India, who did one of the most extraordinary discoveries in all scholarship. Jones had taken up the study of Sanskrit, a long-dead language, from which we may learn a lot when considering applications of ICT in teaching and learning using symbols, metaphors and when we consider some of the many aspects of new languages including those in genetic.

12. English and English Prime

There is also another linguistic aspect we should be aware of. The 4.000 to 6.000 languages of the planet do look impressively different from English and from another. What does the differences mean, you may find yourself. With the graph I am offering you look at the most conspicuous ways in which languages can differ from what we are used to in English.

1. English is an "isolating" language, which builds sentences by rearranging immutable word-sized units, like *Dog bites man* and *Man bites dog.*

2. English is "fixed - word – order" language where each phrase has a fixed position. "Free-word-order" languages allow phrase order to vary.

3. English is an "accusative" language, where the subject of an intransitive verb, like *she* in *She ran, is* treated identically to the subject of a transitive verb, like *she* in *She kissed Larry,* and different from the object of the transitive verb, like *her* in *Larry kissed her.*

4. English is a "subject-prominent" language in which all sentences must have a subject, even if there is nothing for the subject to refer to, as *It is raining or There is a unicorn in the garden.* In "topic-prominent" languages like Japanese, sentences have a special position that is filled by the current topic of the conversation, as in *California, climate is good.*

5. English is a "Subject-Verb-Object" language (dog bites man), Japanese SOV – dog man bites and modern Irish (Gaelic) is VSO –bites dog man.

6. In English a noun can name a thing in any construction: *a banana; two bananas; any banana; all the bananas.* In "classifier" languages, nouns fall into gender classes like human, animal and so on.

For further references please look at Chomsky's "Syntactic Structures" and Steven Pinker's "The language Instinct".

From the above you can easily deduct the influence on your brain functions and your ability to formulate tasks, or as many prefer to say problems. But as could be expected, there is at least one proven help available ready: it is English Prime, sometimes also called E-Prime.

The case for using E-Prime rests on the simple assumption that "isness" sets the brain into a medieval Aristotelian framework and makes it impossible to understand modern problems and opportunities. As with the computer, so it is with the brain, the first law of computers GIGO (garbage in – garbage out) is valid also in this consideration. Using E-Prime sets us in modern Universe in which the quantum theory of observed – created Universes has implications far wider than we can imagine now.

Despite many decades of availability I don't now of many educational facilities and training organizations which would say good-by to the belief that we can make statements about a "deep reality". Therefore you may wish to think about Niels Bohr statement: "If quantum mechanics hasn't profoundly shocked you, you haven't understand it yet."

13. Speech recognition and gathering of information

The human brain of course, is a high tech speech recogniser, but no one knows how it succeeds. Speech recognition may be so hard that there are only a few ways it could be solved in principle.

The history of artificial speech recognisers offers a valuable moral. In the 1970's a team of artificial intelligence researches at Carnegie Mellon University designed a computer program called HERSAY that interpreted spoken commands to move chess pieces.

Influenced by the top-down theory of speech perception, they designed the program as a "community" of "Expert" subprograms cooperating to give the most likely interpretation of the signal. According to one story, a general from the defence agency that was funding the research came up for demonstration. As the scientists sweated he was seated in front of a chessboard and a microphone hooked up to the computer. The general cleared his throat. The program printed "Pawn to King4".

But research in linguistics and speech structure offers an entertaining way and process for improving our way of thinking and of our creativity, both in need to know how to gather information.

14. Examples for information gathering

The minimal information to be gathered for decision making, problem solving, change or transition process to be properly engineered would consist – in linguistic terms only- of:

- *What do you want?* Indicating the desired and outcome state.
- *What is happening now?* Describing the present state.
- *What stops you from getting what you want?* Indicating the problem state.
- *What do you need in order to get what you want?* Indicating for resources needed.
- *How would you know if you were moving adequately towards your goal?* Indicating and providing feedback.
- *Have you ever got it before? What did you do then?* Indicating to resources.

At the level of extracting biological data we use sensors attached to the body as briefly described before. In addition to this we do conduct research using the principle of MIT (Magnetic Induction Tomography) and similar allowing for measurement(s) of conductivity without sensors attached to a body able to visualize the content.

There is also another research in progress dealing with terahertz frequencies, which are a curiously barren region of the electromagnetic spectrum. They lie, unexploited, between microwaves at long wavelength and infra-red at short. They are neglected because no one has developed a convenient source of terahertz radiation. Quantum cascade lasers developed at Bells Labs in America work by pumping up electrons and forming electron "cascades". They are tunable and working in the infra-red only at 30 degree of absolute zero. Because of the tremendous commercial potential terahertz frequencies have in medical imagining I have no doubts that further R&D would find easy money to proceed. Technically terahertz are strongly absorbed by large biological molecules and by water, and so promise to reveal tissues in astonishing detail and which is even more significant also for other purposes.

15. Psychological inertia

To embark on work as briefly described seconds ago, to understand and solve such complex problems there is a need to understand some of the principals of how human psychology functions. To this field belongs psychological inertia as formulated by Altshuller.

The principles of psychological inertia are well-known process you can check and prove it on yourself with or without any party involved, thus no "losing face", as the Asians are often so worry about.

Psychological inertia is a reactionary process related to the appearance of anything threatening, sudden or new. The process has six basic stages:

Denial – attack – anger – substitution – compromise- acceptance.

Having said that it seems to me necessary to accept for consideration what is needed by assessing a risk:

Pathological science

Scientists risk stumbling into a particular kind of pitfall when they encounter "the science of things that aren't so."
(Irwing Langmuir)

Before I close I wish you to note a few thoughts developed by Irwing Langmuir, Nobel Prize Laureate in chemistry (1932) during his professional career with GE Research Laboratory and elsewhere. He defined six symptoms of pathological science as follows:

1. The magnitude of the effect is substantially independent of the intensity of the causative agent;
2. The effect is of a magnitude that remains close to the limit of detectability or many measurements are necessary because of the very low statistical significance of the results;
3. Claims of great accuracy;
4. Phantastic theories contrary to experience;
5. Criticisms are met by ad hoc excuses thought up on the spur of the moment;
6. Ratio of supporters to critics rises up to somewhere near 50% and then falls gradually to oblivion;

Langmuir never published his investigations into the subject of Pathological Science.

The definition of symptoms of pathological science as presented by me comes from a microgroove disk transcription that was made from a tape found among Langmuir papers in the Library of Congress and which also include a reference to N-rays, Mitogenetic Rays as described by Gurwitch and other phenomena.

Some of the ideas and problems discussed today and to be discussed tomorrow may for a few or for many belong to this category. It is up to you what you want to believe or not. But the history offers a lot of examples proving that even such personalities as Langmuir can be wrong. Let's therefore forget who is or who may be right and let's end with three myths and relaxing meditation on love.

16. Myths

In all three myths – Adam and Eve, Prometheus and Faust - there is *a rejection of God prohibition to acquire new knowledge.*

Adam does not follow what he should do and eats from the tree of wisdom. Prometheus deceives Zeus and steals fire from which the human culture could develop. And Faust makes a deal with the Devil allowing him to access theological and cosmological secrets.

All three figures were punished for their actions: Adam had to go to exile from the paradise. Prometheus had been thrown into valley and suffers by eagles gnawing his liver until Heracles frees him. Faust had to stay in the hell forever.

In all three myths the woman is the sinner. Eve follows the advice of the snake and uses apple to attract Adam. Pandora brings the most beautiful in the world, the fire. And Helena,

the only woman Faust married is a very naughty incubus. Her lips suck and absorb the soul from Faust's body.
All three myths to which we can add more of modern myths, like Nathaniel Hawthorn's "The marble faun", Herman Hess's "Demian" and James Joyce's "Araby" to mention a few. All of them represent human boldness and human development capabilities which lead us to the secularization of sin and to the possibility to erase three major evils, misfortune and diseases of modern times:

- Boredom - Vice (wickedness) and Poverty.

This to say is not absolutely true, but it is what I think is true. The hanging on grey natural sciences without raising the issue of GOD lead to the separation of body and mind, lead to the separation of virtue and delight, lead to the separation of idea and life. It (has) caused the departure from the antic synthesis of beauty and goodness, to which we should return as soon as possible for its proven benefits to all. As a result of the above separations many of us suffer most of the time. Unless we unite all of them the Faust problem would not be resolved.

Before I end this presentation I wish invite you to reflect for the next five minutes on love. Without it even TRIZ would not have reached you here. You can do it in your own way or follow my suggestion formulated many years ago by one of my friends, Robert Dilts I did not meet for more than ten years.

The bond of love is never broken. It just shifts to different levels.

I would like you to close your eyes for a moment and think about some person that you care about but are not always with. It doesn't have to be somebody who is dying or who has passed on. It can be somebody that you have not been together with for a long period of time.

I would like you to notice how you think about that person. Where do you see that person in your mind? What do you hear in your mind? Is it a clear picture? Is it distant? Is it bright?

Then think of either a friend or an object; perhaps something from your past. Even though this person or this thing is no longer with you, you feel as though it is always there with you. It could be a toy that you had; when you remember it you treasure it without sadness. It could be a friend that you always feel that you are with, no matter where you are.

I would like you to notice how you visualize or hear this object, or this person, in your mind so that they can be with you all the time.

Take the memory of the person that you care about but can't be with, and change the qualities of that memory so that they match qualities of the memory of the person or the object that you feel always to be with you. Maybe you bring the image closer. Maybe instead of seeing it behind you or to your left, the location of that image is in your heart. May be there is a certain quality of colour, or brightness, that makes it seem closer or more present. Maybe there is a particular quality of voice, tone, tempo or depth.

As you continue to allow that memory of that person to find its place in your mind, in your values and beliefs, in your identity, remember for a moment a feeling of love, of pure love, a love that has no boundaries, it has not quantity, that kind of love that is neither giving nor taking, but just IS.

Notice where that love comes from. Does it come from somewhere deeply inside you? Is it from within your heart? Or is it all around you?

Begin to visualize that love as a pure, shining light. Let it brighten and shine within and around you. Then take that light. Make it into a shining silvery thread. And tie that thread from your heart to the heart of the person you care about – knowing that this thread of light can connect your heart to their hearts, no matter where they are, how far away, in which time.

It is a thread that you can take to any number of people, a thread that never breaks, a thread that never runs out of light. So as you see yourself sitting here you can see your heart connect with as many threads as those around you that you meet.

Feel the thread coming through now. Then the light of the thread begins to expand and glow, so it fills all the space around you. Know that it is a light that can fill the universe with its brightness.

Feel yourself in this room. Most important, make sure that you can feel that love for yourself. For a moment, feel your won heart as it beats within you.

Know also that you are a complete person, a complete being. Know that you can be an identity know that you can be an individual. Feel your own individuality, feel your uniqueness.

Perhaps tonight you might find or notice how others have attached those threads to your heart.

Just for a moment, BE in this room, so that your awareness is around nothing else. Just BE. Allow yourself to sense as fully as possible that being, the sound, your body, the air and light around you, the air that fills your lungs, brings oxygen and life to all your body. And become aware of the people around you, other beings, the individuals, special people. As your eyes open and sense the light that fills the room, bring that being completely here.

Acknowledgments

I thank you and wish you all a very pleasant stay in Florence.

And Many unique people dead and alive who did not or do not use to say “Give me” but always said or say “Take it.”

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TRIZ AS A LEAN THINKING TOOL

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Abstract
Lean Thinking is a highly evolved method of managing an organization to improve the productivity, efficiency and quality of its products or services. The core principle it uses is that no work should be done unless it is going to create customer value.
Traditionally Lean tools were Value Stream mapping, Quick Changeover/Setup Reduction, Single Minute Exchange of Dies (SMED), Kaizen, Flow Manufacturing, Visual Workplace/5S Good Housekeeping, Total Productive maintenance (TPM) and Pull/Kanban Systems. Companies and organizations employing these tools report significant gains in productivity and overall effectiveness within their specific entities.
TRIZ *Plus* can be effectively used a lean tool to support almost all lean principles as the experience of Kawasaki Steel Group clearly showed.
Keywords: TRIZ, Lean Thinking, Value, Value Stream, Wastes.

1. Introduction

The ideas behind what is now termed Lean thinking were originally developed in Toyota's manufacturing operations – known as the Toyota Production System – an spread through its supply base in the 1970's, and its distribution and sales operations in the 1980's. The term was popularized in the book "The Machine that Changed the World" which clearly illustrated the significant performance gap between the Japanese and western automotive industries. It described the key elements accounting for this superior performance as lean production – "lean" because Japanese business methods used less of everything – human effort, capital investments, facilities, inventories and time – in manufacturing, product development, parts supply and custom relations.

Lean Thinking is a highly evolved method of managing an organization to improve the productivity, efficiency and quality of its products or services. The core principle it uses is that no work should be done unless it is going to create customer value. Work should be performed in the simplest, most efficient way to maximize the smoothest throughput of product and services from you to the customer. Here is an example. A large truck manufacturing company inspected every returned part from its dealers against initial orders and inventory before a credit would be issued. Implementing this process cost the company millions of dollars each year. The dealers were irate because of the required justification, the time lag and their carrying cost.

The Lean Thinking project of this process showed that the value of 90% of returned parts was less than the cost of the whole process, without even considering the impact on dealer goodwill. The company changed its policy – no returns are checked unless the part exceeds a certain dollar value. As the result the process was dramatically simplified, weeks became days, dealers were happier and profitability increased for everyone .

The core principles of Lean Thinking are based on maximizing customer value and throughput. The faster you can process an order, build a product, or provide a service the less it costs to provide and the happier the customer. Lean Thinking focuses on streamlined work process, reduced inventory, no backlog, maximizing throughput, and eliminating bureaucracy.

Lean companies work to precisely define value in terms of specific products with identified capabilities offered at set prices through a dialogue with their customers. The process involves learning to adopt and employ a series of tools and techniques to achieve incremental improvements in an organization.. Above all, Lean Thinking methods are inclusive of all employees and involve a major change in the embedded attitudes of the individuals that make up the organizations.

Traditionally Lean tools were Value Stream mapping, Quick Changeover/Setup Reduction, Single Minute Exchange of Dies (SMED), Kaizen, Flow Manufacturing, Visual Workplace/5S Good Housekeeping, Total Productive maintenance (TPM) and Pull/Kanban Systems. Companies and organizations employing these tools report significant gains in productivity and overall effectiveness within their specific entities.

What about TRIZ? Is TRIZ a Lean tool? In what major principles of Lean could TRIZ help? Which of those 7 types of Muda (wastes) can TRIZ address?

TRIZ (Theory for Inventive Problem Solving) is one of the most powerful inventing methodologies, a scientifically-based and empirically-derived method that originated for the analysis of the world patent collection. Its strongest side is in the Conceptual Stage of design, while the Analytical Stage is not completely and effectively covered, at least in what is known as classical TRIZ.

Value Engineering Analysis (VEA), Root-Cause Analysis (RCA), Flow Analysis (FA) and several other engineering methods developed at different times offered exceptional analytical approaches, but lacked concept generation techniques. Merging these analytical methods with TRIZ gave birth to several integrated methodologies based on TRIZ : ITD, TRIZ *Plus,* I-TRIZ. An integrated method that intimately combined these analytical tools with the inventive power of TRIZ has a definite advantage and a potential

and can be effectively used in organizational methods like Lean, Six Sigma, TQM, etc.

So where exactly, at what stages of Lean could, say, TRIZ *Plus* be used? Womack and Jones (1996) describe the business environment within which they saw Lean techniques being successful . Five key principles emerged:

- Value
- Value Stream
- Flow
- Pull
- Perfection

2. Value

The customer is the only reason why businesses exist, therefore an understanding of what the customer actually requires is an essential element of the strategy of a lean organization. The value, defined from a customer's perspective, is then aligned within the organization and value-adding activities can be recognized as any activity that the customer is happy and prepared to pay for. A general estimate for a typical manufacturing firm is that value-adding accounts for less than 5% of the total time a material is at the factory. It is horrifying to think that remaining 95% of the time is spent adding costs (storage, delaying at queues within the factory, transportation between the stages of the process, etc.). Even more frightening still is the knowledge that such wastes are present at every supplier, customer and distribution point as the product moves towards the actual consumer and that many other types of "Muda" (wastes) have actually been "designed into" the internal and external material flow process.

In the practice of consulting projects, it is often necessary to adopt a product focus. Product focus enables a long-term dialogue to be started concerning the nature of value and how the product delivers it. More explicitly, the fact is that the client requires a product to suit his purpose and provide value for money. What the client is less concerned with is how the product is developed and how many people are involved in it. One rarely thinks about the suppliers to a production line when buying a car.

Now let us look at the approach to value in TRIZ *Plus.* Steps of its analytical stage - component analysis, function analysis, diagnostic analysis - in the long run have the same objective: to determine the value of different operations of the process or components of the product. The analysis results flag those functions that are of lower value ranking them accordingly.

The traditional Lean seven types of Muda are:

- Overproduction
- Inventory
- Extra Processing Steps
- Motion
- Defects
- Waiting
- Transportation

Using the terminology of TRIZ *Plus* analytical approach in our function model of a process we will have:

Lean	TRIZ *Plus*
• Overproduction	• Excessive Functions
• Inventory	• Corrective Functions
• Extra Processing Steps	• Providing & Corrective Functions
• Motion	• Providing & Corrective Functions
• Defects	• Insufficient, Excessive or Harmful Functions
• Waiting	• Insufficient Functions
• Transportation	• Providing Functions

The results of diagnostic analysis will clearly show the value landscape of the manufacturing process, fully supporting Lean Value Principle.

3. Value Stream

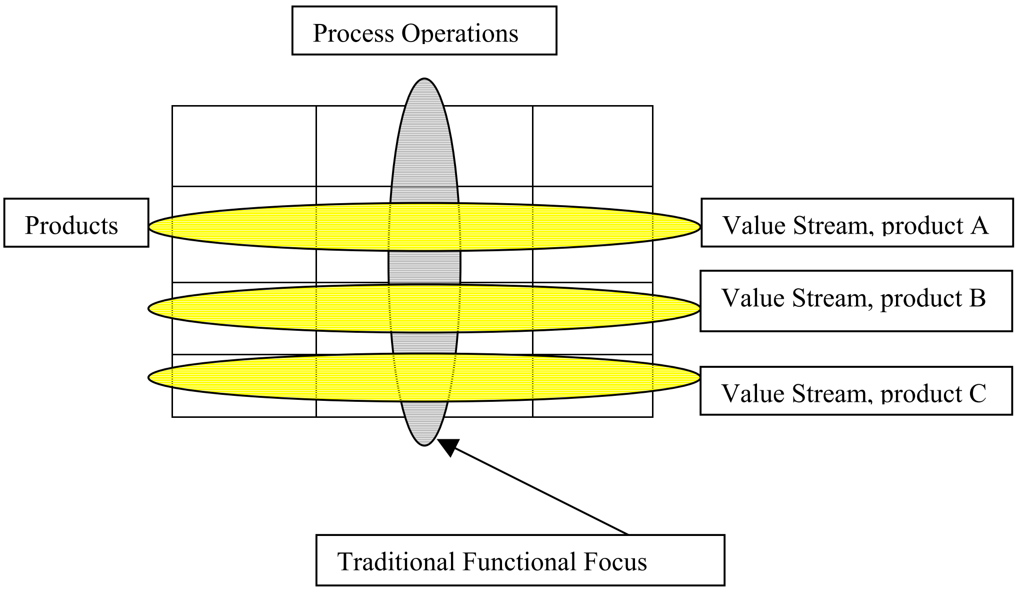
Once value has been specified, the next step is to identify the value stream. The value stream identifies all those steps required to make a product. The traditional key technique behind the value stream is that of process mapping. However, it is process mapping for a very specific reason – to understand how value is built into the product from the point of view of the client. At a strategic level it offers a perspective on defining what is to be done. At a more tactical level the value stream mapping can be used to identify where Muda lies in a particular operation and how the operation can be performed more effectively.

The value stream map is used to both illustrate the "current state" and the desired "future state" of the process. The map highlights the seven types of Muda mentioned above and is used to provide a basis for developing plans to implement lean tools and techniques.

Following the same analogous pattern, TRIZ *Plus* tools that can be used here:

Lean	TRIZ *Plus*
• Value Stream Map (current)	• Function Model of the Process
• Value Stream Map (future)	• Trimming, Cause-Effect Chain Analysis
• Value Stream Map (internal)	• Function Model of the Process
• Value Stream Map (internal)	• Function Model of the Supersytem
• Product Family Matrix	• Function Models of separate product lines

Product Family Matrix can be used to enable the organization to re-align its focus from functional to Value Stream.



4. Flow

Lean organizations are primarily concerned with making materials flow in the system with high levels of stock turn without allowing the material to idle in queues or stagnate at large stock points. The ability to ensure materials flow within a factory and derive value rather than cost, involves the eliminations all types of Muda. Flow is defined as producing a product from raw material to completion without unnecessary interruption or delay (that is, Muda). The goal is to achieve single-piece flow in each process, ensuring work flows smoothly from one stage to the next, one at a time, increasing flexibility. As a result, we will get reduction in work in progress, part movement, parts handling, quality defects and therefore, the lead time.

The key objective of Flow is to align the processes to suit the customer requirements, thus reducing waste in the system. The key tools for implementing Flow are:

- “Takt Time”
- Standardized Work
- 5S
- Work Balancing
- Leveled Production

Though there are traditional normative methods to apply these tools, a Lean project will get into a totally different perspective when a number of TRIZ concepts are used here:

Lean	TRIZ *Plus*
• “Takt Time”	• Rhythm Coordination approach
• Standardized Work:What, Who, How	• Inventive Principles, Standard Solutions
• 5 S	• Transition to Supersystem, Trimming, Standard Solutions (class 4)
• Work Balancing	• Function model , function re-allocation, new function architecture
• Leveled Production	• Transition to the Supersystem (different mechanisms), Trimming

5. Pull

At a strategic level Pull really identifies the need to be able to deliver the product to the customer as soon as he needs it. This principle derives from Toyota’s innovation, the Kanban. The Kanban is a tool that communicates specific production/withdrawal of parts information to the upstream process. The Kanban applies for the lean approach where Flow cannot be used to move materials between departments or processes. At these points it is important to have materials available when required and these key buffers effectively disconnect the internal (or external) customer and supplier operations. The supplier manages then is such a way that withdrawals of products by the customer trigger the manufacture of replenishments. Thus as products are taken to demand , the empty space left by withdrawal provides the “requirement” to replenish.

The traditional Kanban may take a form of a card, footprint, empty bin, etc. However Pull approach with be much more ideal if a number of TRIZ tools are used:

Lean	TRIZ *Plus*
• Production/Instruction Kanban	• Inventive Principles, Standard Solution (class 4), Trimming
• Withdrawal Kanban	• Inventive Principles, Standard Solutions (class 4), Trimming

6. Perfection

Once an improvement has been made, it must now become the standard for the process. Adhering to this standard will ensure that the problems experiences in the past do not occur now or in the future. It is important to understand that transformation to Lean is a continuous improvement process. This is a key concept at the strategic level, so TRIZ tools cannot be applied directly, however some Inventive Principles and Standard Solutions are appropriate here.

For business executives the implications of Lean approach are numerous and broad ranging. One of the first lessons of Lean Thinking is to understand the applications of five lean principles to your business, its key customers and suppliers. The application of the approach will be influenced by a number of factors. The implementation and deployment of

Lean Thinking within an organization will be more sustainable is the Lean approach is supported by an effective set of tools such as TRIZ *Plus*.

7. Conclusion

TRIZ *Plus* approach has been used in a multimillion dollar lean project at Kawasaki Steel Group, where at different stages of Lean a number of above-mentioned TRIZ *Plus* tools generated dramatic results including simplification of the process, considerable cost reduction, reliability and safety improvement.

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TRIZ APPLIED TO AXIOMATIC DESIGN AND CASE STUDY: IMPROVING TENSILE STRENGTH OF POLYMER INSULATOR

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Abstract
Since 2001, LG Cable has tried to improve R&D and manufacturing processes by applying TRIZ, and started to offer TRIZ education course for research engineer. Also Axiomatic Design is usually used for the initial problem modeling in the first stage of project. Some ideas of Axiomatic Design have similarities to concepts of TRIZ and they can make synergy effects if they are used in the different stage of developing process. Several successful results were made through this combined process in LG Cable. For example, the performance of Polymer Insulator or heat shrinkable tube was improved dramatically.
In this paper, the process of improving tensile strength of Polymer Insulator will be discussed, Axiomatic Design is used for defining design problem, and TRIZ is used for developing new design concept.
Keywords: TRIZ, Axiomatic Design, Polymer Insulator, Technical Contradiction, Independence Axiom, Crimping Process.

1. Introduction

The decision-making in the early stage of design affects the final product's quality and productivity. Many design failure examples show that the wrong decision of initial design results in high cost, recall or accident. Many designs are being done empirically or trial – error basis. Axiomatic Design is a design methodology to help designer define design structure and find design problems.

According to Axiomatic Design, good design is the design that satisfies Axiom 1 (Independence Axiom) and Axiom 2 (Information Axiom). Axiom 1 states that less interaction among functional requirements is better for final product's performance and cost reduction. Axiom 2 means that simpler design is better design.

From time to time, engineers are faced to design problem that violates Independence Axiom. In this case, the design should be changed to new design that satisfies Independence Axiom by defining new DPs (Design Parameter).

When changing DPs, engineers use their intuition and experience mostly. It can be time-consuming job, and sometimes engineers fail to find exact DPs that satisfy Independence Axiom. Concept generating method is needed to find new DPs.

TRIZ inventive processes like Contradiction Matrix and inventive principles can help finding new design parameter. If Contradiction Matrix is applied to Axiomatic Design, it needs a special mapping process. First of all, the design matrix's DPs are changed to standard parameters to apply it to Contradiction Matrix. Secondly, suitable inventive principles are selected in the Contradiction Matrix. Finally, uncoupling process is done by new DPs that are derived from the inventive principles.

Polymer Insulator (see Figure 8, 9) is a mechanical device that holds and insulates cable. Usually the 154kV type Polymer Insulator must keep over 24 tons but previous design couldn't satisfy the desired tensile strength. Through Axiomatic Design modeling and TRIZ methods, LG cable could be successful in increasing the tensile strength over 24 tons. The detail process is disclosed in this paper.

2. Axiomatic Design

Axiomatic Design is a kind of design theory created by Suh in 1970s. The main idea of Axiomatic Design is that there are general laws in design process and the design process is not empirical and intuitive process. Suh suggested two main axioms and several theorems and corollaries derived from lots of design cases.

As it is shown in Figure 1, design in the Axiomatic Design is defined as a mapping process that connects the requirements that the 4 areas of design require. The 4 design areas are 1) Customer Requirements: CRs; 2) Functional Requirements: FRs that actually realize CRs; 3) Design Parameter: DPs that are related to the FRs; 4) Process Variable: PVs, the variable that is needed in the actual process.

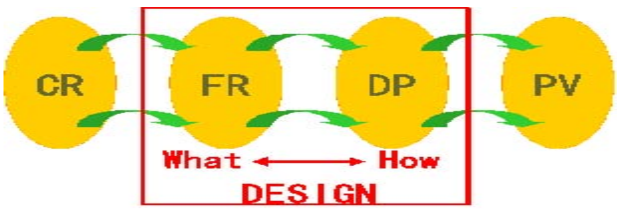

Figure 1. Design process

The Axiom 1 is about the relationship between the design components. In other words, it means that a component of design had better not affect another component of design. If the design is coupled design, it may cause many problems after the product development is finished.

The relation between the FR and the design variables is expressed by the design matrix method. X means that DP influences FR, and O means that there is no relationship.

The design matrix that satisfies Independence Axiom can be shown in either diagonal matrix or triangular matrix. The diagonal matrix is uncoupled design that satisfies

Independence Axiom perfectly. In this case each FR is affected by one design variable and the any DP can change its parameter easily. The triangular matrix is decoupled design matrix. The DP should be changed according to a specific order, from top to bottom in case of decoupled design, the DPs can be altered without influence on other FRs.

$$\begin{pmatrix} FR_1 \\ FR_2 \\ FR_3 \end{pmatrix} = \begin{bmatrix} X & O & O \\ O & X & O \\ O & O & X \end{bmatrix} \begin{pmatrix} DP_1 \\ DP_2 \\ DP_3 \end{pmatrix} \quad \begin{pmatrix} FR_1 \\ FR_2 \\ FR_3 \end{pmatrix} = \begin{bmatrix} X & O & O \\ X & X & O \\ X & X & X \end{bmatrix} \begin{pmatrix} DP_1 \\ DP_2 \\ DP_3 \end{pmatrix} \quad \begin{pmatrix} FR_1 \\ FR_2 \\ FR_3 \end{pmatrix} = \begin{bmatrix} X & X & O \\ X & X & X \\ X & O & X \end{bmatrix} \begin{pmatrix} DP_1 \\ DP_2 \\ DP_3 \end{pmatrix}$$

Uncoupled Design *Decoupled Design* *Coupled Design*

Figure 2 shows the structure of FR called Design Hierarchy. The FR in Functional Domain has their sub FR. The structure of FRs and DPs is same. The higher level FR is abstractive than the lower level FR that contains more detail description.

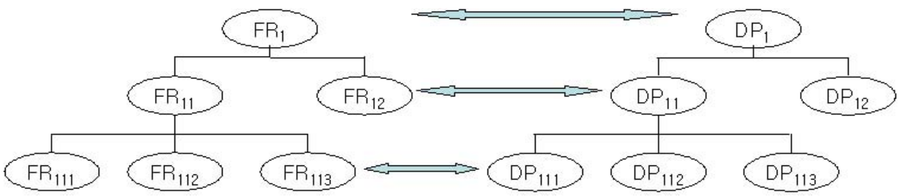

Figure 2. Design Hierarchy

3. TRIZ

Today the innovations are the most important point for companies to survive at present society. If the company fails to innovate, it will be weeded out. Therefore the modern companies try to find effective methods for innovation and inventive problem solving.

There are a lot of different creativity methods which are based on Trial and Error approach and give possibility to generate a lot of ideas in short period (see Figure 3). For example, Brainstorming, Focal Objects method, Gordon Synectics, Check Lists, Zwicky Morphological analysis etc. But these methods are not effective because they have not criterions for selecting the best ideas and cannot control psychological inertia. And it takes a lot of time in order to consider every idea.

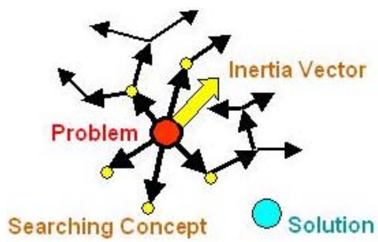

Figure 3. Methods are based on Trial and Error approach

A new methodology is required to solve problems systematically. That methodology is TRIZ. TRIZ is Russian acronym for The Theory of Inventive Problem Solving. TRIZ was created and developed in former USSR by Russian engineer and inventor G.S.Altshuller and his followers. TRIZ is a science that studies Evolution of Technical Systems to develop methods for inventive problem solving.

The main distinction of TRIZ from creativity methods that are based on Trial and Error approach is that the TRIZ offers directed and algorithmic searching of solution instead of chaotic generation of ideas (see Figure 4).

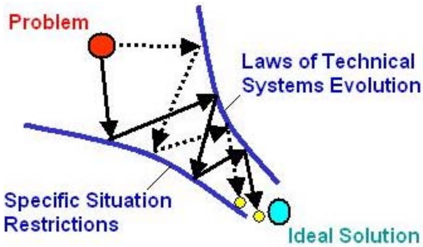

Figure 4. TRIZ directs a problem solving process to Ideal Solution.

The first main idea of TRIZ is that the technical systems develop in concordance with the objective Laws of Technical Systems Evolution. These Laws can be studied and applied to inventive problem solving without a lot of trails and errors. Laws of Technical Systems Evolution were discovered through analysis of more than 1 500 000 patents and evolution histories of different technical systems.

The main Law of Technical Systems Evolution is increasing Ideality of System. Ideal System is a System in which Quantity of Material, Volume, Power consumption and other expenditures tend to zero, but its functionality increases.

The second main idea of TRIZ is that the technical systems evolve through appearance, intensification and overcoming contradictions. Solving problem is a step in the development of System. Problem is difficult through existing hidden and explicit contradictions. Special algorithmic tools based on Law of Technical Systems Evolution were developed to work with unclear problem description and to transfer it into problem formulation in contradiction view step by step and after that to a new ideas and concepts. There are Algorithm of Inventive Problem Solving (ARIZ), Inventive Standards System, Altshuller Contradiction Matrix, Scientific Effects pointers.

Steps and rules of these TRIZ tools direct of problem solving process to a strong solutions area which is situated near from Ideal Solution through overcoming contradictions and using existence resources (see Figure 4).

TRIZ is a method for developing technology, which can be adapted to all the area that possess problems, it can be used for improving the conventional system, proving a causal relationship and developing new concept products, process, strategy of R&D.

3.1 Contradictions and contradiction Matrix

Contradiction is one of the main concepts of TRIZ. From TRIZ viewpoint, every difficult problem contains contradiction. In order to solve a problem it is necessary to find and resolve contradiction. TRIZ classifies Administrative, Technical and Physical contradictions.

Administrative Contradiction shows that problem has appeared but does not show the problem reason and does not suggest the ways for solving this problem.

To solve problem it is necessary to carry out analysis of problem and formulate Technical Contradiction when an improving one parameter of technical system causes a worsening another parameter of one. For example, thick steel sheet makes a car more safe, but the weight of car increases.

Physical Contradiction is a situation when two opposite properties are required from physical condition of the one element of technical system. For example, steel sheet for car must be thick in order to make car more safety and must be thin in order to make car lighter.

Altshuller tried to collect ways of resolving contradictions - inventive principles that were used by engineers and inventers in during their practice. For that target Altshuller selected and investigated strong solutions from patents descriptions. As a result he collected 40 different inventive principles that were used for resolving contradictions from different engineering fields.

But the most important Altshuller's discovery was that the same technical contradiction from different engineering fields might be resolved by using the same inventive principles.

Using 40 inventive principles and 39 universal engineering parameters Altshuller built Contradiction Matrix for resolving 1250 typical technical contradiction (see Figure 5.).

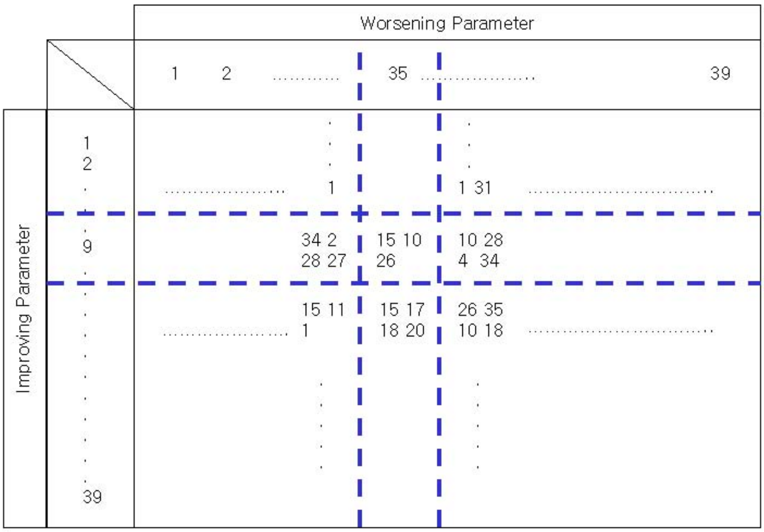

Figure 5. Altshuller Contradiction Matrix

The process of problem solving by using Altshuller Contradiction Matrix is presented on Figure 6.

According this process, at first, it is necessary to select interactive objects (Tool – Product) that create undesirable effect as a result its interaction. After that, to determine what Tool or Product's parameter must be improved - (A parameter) by applying one of the known and suitable ways.

Then it is necessary to find what parameter of another object will be worsened after applying this way – (B parameter) and to formulate Initial Contradictions between improving and worsening parameters.

But in order to use Contradiction Matrix we have to reformulate Initial Contradictions into Typical Contradiction using 39 standards parameters from Altshuller Matrix instead of real engineering parameters.

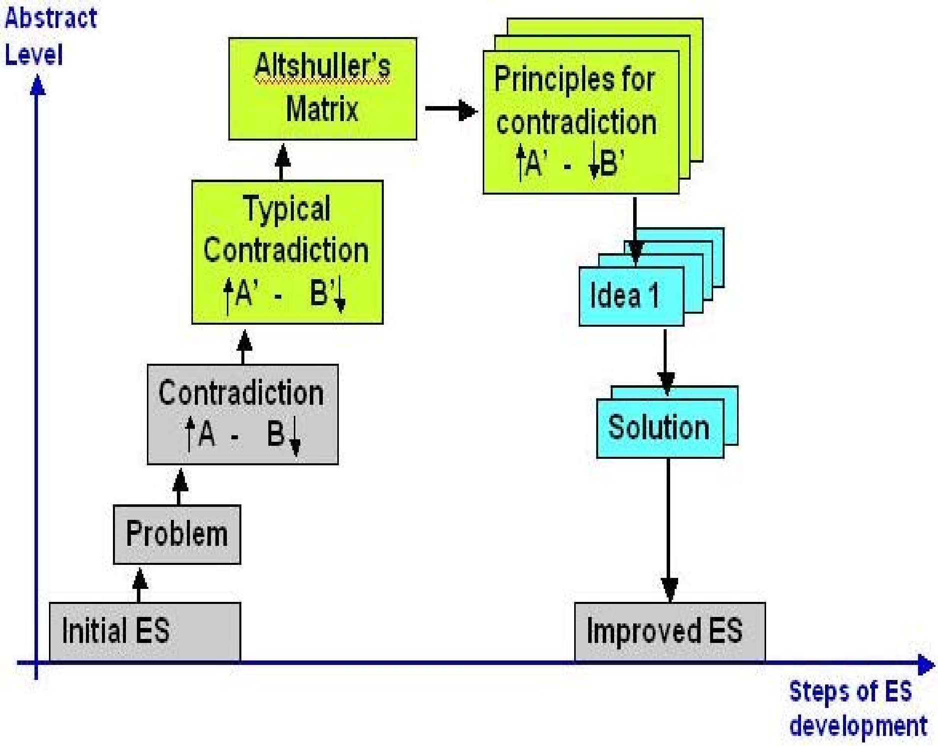

Figure 6. The process of problem solving by Altshuller Contradiction Matrix

After that Contradiction Matrix can give some Inventive Principles for resolving this typical contradiction. Applying recommendations from these Inventive Principles to Tool and Product we may find some ides how change interactive objects in order to resolve contradiction and formulate new concept of technical system.

The contradiction concept is very similar to the coupling in Axiomatic Design approach.

4. Finding new DPs by using Contradiction Matrix

To change coupled design or decoupled design to uncoupled design, Contradiction Matrix can be applied to Axiomatic Design. A specific mapping process is required because DPs is expressed by common words.

Firstly, the proper standard parameter is selected. Design matrix's DPs should be changed to standard parameters. Secondly, suitable inventive principles are found in the Contradiction Matrix. Finally, new DPs are derived from the inventive principles and the design matrix is uncoupled.

A lot of design problem result from coupled design that violates Independence Axiom. In coupled design, it is hard to control DPs because some DPs of design matrix affect more than two FRs. Therefore engineers try to change the coupled design into uncoupled or decoupled design by finding new DPs.

Finding new DPs is usually done intuitively or empirically. If the engineer doesn't have much experience and knowledge, it can be time-consuming job. To generate new DPs, TRIZ methods that resolve contradiction can be used. It is true that coupled design contains technical contradiction or physical contradiction.

TRIZ offers two tools for resolving contradictions:

- Altshuller Contradiction Matrix which is used for resolving technical contradiction mainly;
- Set of 11 Principles from ARIZ for resolving physical contradiction.

In this paper, Uncoupling Method with Altshuller Contradiction Matrix is considered only. The flow chart of uncoupling process from Axiomatic Design with Altshuller Contradiction Matrix application is shown on Figure 7.

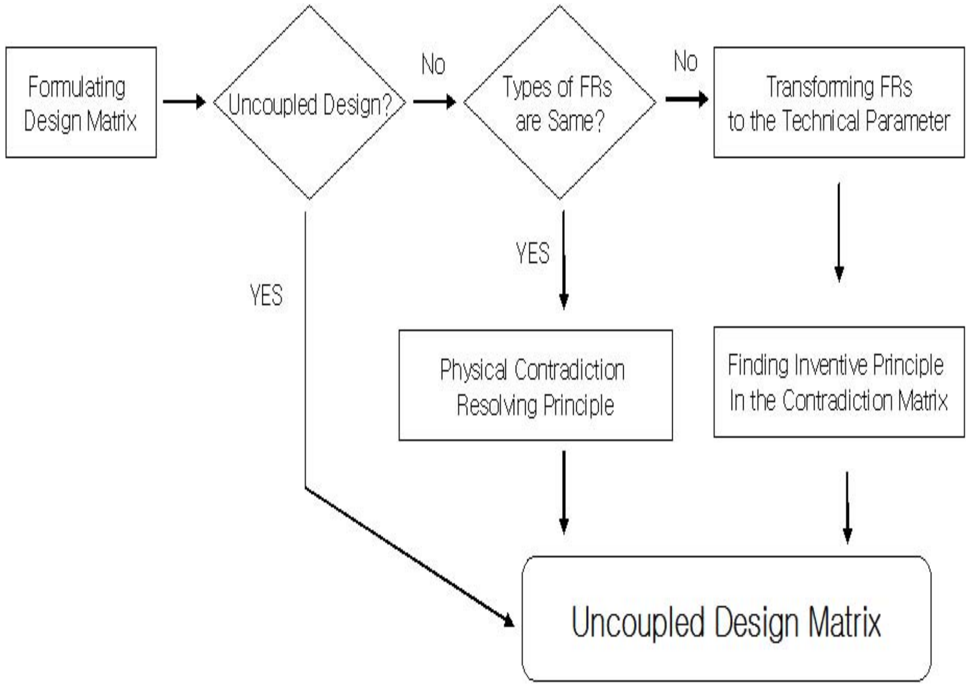

Figure 7. Flow chart of uncoupling process

STEP 1 : Formulating designing problem

Most of customers notice the problem, but usually it is hard for them to define the nature of problem. First of all, the designer should make hierarchical structure and design matrix by using Axiomatic Design.

STEP 2 : Determining the type of contradiction

The type of contradiction must be analyzed to select proper contradiction resolving method. In case that one FR requires high temperature and the other FR requires low temperature at the same time, it is a Physical Contradiction. Physical Contradictions Resolving Principles may be used to solve this kind of design problem.

In case that the type of coupled FRs is different, for example, the rotational speed of CD-ROM increases while the noise of CD-ROM becomes louder. It is technical contradiction problem and the Altshuller Contradiction Matrix may be used to make uncoupled design.

STEP 3 : Changing coupled FRs into standard parameters

In order to generate new DPs through Altshuller Contradiction Matrix, each coupled FRs should be converted to one of the 39 standard parameters.

STEP 4 : Finding Inventive Principles in the Altshuller Contradiction Matrix

Using standard parameters found in Step 3, Inventive Principles can be chosen in the Altshuller Contradiction Matrix.

STEP 5 : Generating new DPs which make design uncoupled

To generate new DPs that satisfy Axiom 1, the process shown in Figure 6 is carried out, because the preliminary ideas from Contradiction Matrix are very abstractive like Segmentation, Prior Action, etc.

Each Inventive Principle has a lot of examples based on patents. From time to time, applying the Examples of the Inventive Principles to the design problems can derive solutions.

Using these processes, the new concept of DPs that satisfy Axiom 1 is generated. And the design matrix is changed into uncoupled design.

5. Improving tensile strength of polymer insulator

LG Cable produces a mechanical device called Polymer Insulator, which is a component for holding cable and insulate tower from cable. Figure 8 shows the Polymer Insulator and its interaction with cable and tower.

In 2003, LG Cable decided to improve the performance of Polymer Insulator because the customers want Polymer Insulator that can endure tensile strength over 24tons. At that time the maximum tensile load of LG Cable’s product was 22tons. Also LG Cable planned to develop new type of 345kV Polymer Insulator. In order to avoid same problem, it was necessary to find new design concept of 154kV type Polymer Insulator.

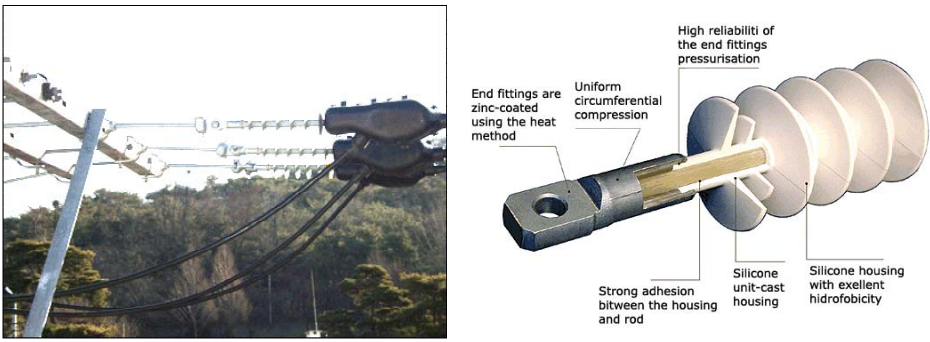

Figure 8. Polymer Insulator

Figure 9 shows conventional crimping process of Polymer Insulator. In case of 154KV cable, the Polymer Insulator must hold over 24ton tensile load. In order to increase tensile load of Polymer Insulator, Fitting Metal should be compressed more.

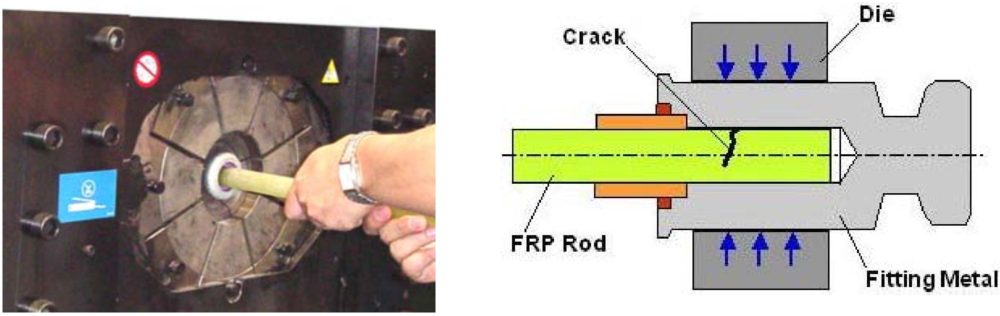

Figure 9. Compressing of Fitting Metal and Crack in FRP Rod

Higher compressing force will generate stress concentration in Fiber Reinforced Plastic Rod (FRP Rod), and it will make crack on FRP rod. New design solutions that increase tensile strength without breakage of FRP Rod are required.

In order to assemble polymer insulator, they put FRP rod inside of fitting metal. After that, fitting metal is compressed and strong bonding force is generated between fitting metal and FRP rod. During compressing fitting metal, stress concentration is occurred on the FRP rod. It restricts maximum compressing force. This situation can be expressed by design matrix in STEP 1.

The process discussed previously in Figure 7 is used to develop new design. Let's consider how we can use step of offered flow chart of uncoupling process in order to develop a new design of Polymer Insulator.

STEP 1: Formulating designing problem

The design matrix can be formulated as follows

FR_1 : Improving Tensile Strength of Polymer Insulator over 24tons
FR_2 : Preventing the breakage of FRP Rod

DP_1: The compressing force applied to the fitting metal
DP_2: The solidity of the FRP Rod

$$\begin{bmatrix} FR_1 \\ FR_2 \end{bmatrix} = \begin{pmatrix} X & O \\ X & X \end{pmatrix} \begin{bmatrix} DP_1 \\ DP_2 \end{bmatrix}$$

If high compressing force is applied at the Fitting Metal of Polymer Insulator to hold the FRP Rod tightly, it will also destroy the FRP Rod. If the force is reduced in order to protect FRP Rod, the tensile strength cannot be increased over 24tons.

STEP 2 : Determining the type of contradiction

The tensile strength and the safety of FRP rod are different type of parameter. The design problem has a technical contradiction. The Contradiction Matrix is applied to resolve that kind of contradiction.

STEP 3 : Changing coupled FRs into standard parameters

The FRs of this design matrix is now converted to standard parameters.

FR_1 : Improving parameter:
Tensile Strength of Polymer Insulator over 24ton - 10. Force

FR_2 : Worsening parameter:
Preventing the breakage of FRP Rod - 30. Object-affected Harmful Factor

STEP 4 : Finding Inventive Principles in the Altshuller Contradiction Matrix

In the Contradiction Matrix these Inventive Principles are found:

N1 – Segmentation
N35 – Parameter Changes
N40 – Composite materials
N18 – Mechanical Vibration

STEP 5 : Generating new DPs which make design uncoupled

Usually the Inventive Principles do not give a ready for use solutions but they guide a searching process in perspective directions and give general recommendations how to change interacting components of TS in order to resolve contradiction.

Complex problems are resolved by applying a combination of Inventive Principles or combination of Principles with Physical Effects.

So for Polymer Insulator the “Segmentation” Inventive Principle gives partial idea that inner surface of Fitting Metal may be divided on some part in order to distribute compressing force to FRP Rod more uniformly and prevent cracking.

And the next recommendation from Segmentation Principle shows how to develop this idea by increasing degree of segmentation from a solid to a Loose Body or a Liquid.

According “Parameter Changes” Inventive Principle it is necessary to make inner surface of Fitting Metal more flexible in order to distribute compressing force to FRP Rod more uniformly. This recommendation supports ideas from “Segmentation” Principle because Loose Body is more flexible then solid metal but can distribute compressing force more uniformly and holds FRP Rod safely.

As a result of using mentioned Inventive Principles and physical and geometrical properties of Loose Body the new concept of Polymer Insulator design was developed (see Figure 10).

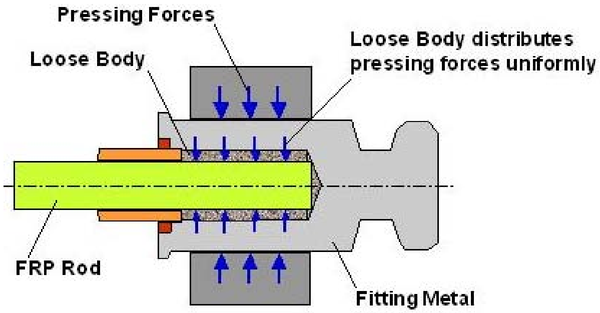

Figure 10. Putting Loose Body between Fitting Metal and FRP Rod

It is proposed to place a Loose Body (for example, metal or abrasive powder) between Fitting Metal and FRP Rod. In during pressing operation Loose Body will distribute pressing force more uniformly along the surface of FRP Rod and prevents its breakage.

Compressed Loose Body has the similar property as a solid material and can hold FRP Rod safely in during loading period

Finally the new FRs and DPs are selected and the design matrix becomes uncoupled.

FR_1 : Improving parameter: Tensile Strength of Polymer Insulator;
FR_2 : Worsening parameter: Preventing the breakage of FRP rod

DP_1: The pressing force applied to the metal fitting
DP_2: The loose material between fitting metal and the FRP rod

$$\begin{bmatrix} FR_1 \\ FR_2 \end{bmatrix} = \begin{pmatrix} X & O \\ O & X \end{pmatrix} \begin{bmatrix} DP_1 \\ DP_2 \end{bmatrix}$$

Experiment has been done to verify the new design concept. Al oxide and Silica Carbide (C) and Glass Silica Carbide (GC) powder from 5㎛ to 100㎛is used as loose material.

Loose material distributes the stress concentration, and the crimping force could be increased by 10bar without any crack. As a result, the tensile strength is increased to 24tons.

Table 1 shows the result of experiment. Every loose material satisfies need tensile strength. The quality of Polymer Insulator is improved.

No.	Inner Diameter of Fitting Metal (mm)	Result		Loose Material	Tensile Strength (kg)
		Ball	Socket		
1	Φ 23	Good	Good	Al oxide	24,000
2	Φ 23	Good	Good	C 1000	24,000
3	Φ 24	Good	Good	G/C 600	24,000

* Good means no breakage in metal fitting

Table 1. Experiment Result of Tensile Strength Test

6. Conclusion

In order to avoid final product's cost and failure problems, satisfying Axiom 1 in design process is important, and the design matrix should be uncoupled.

To change coupled design to uncoupled one and develop the new concept of design, intuition and inspiration is not enough. More logical and algorithmic process is needed. The main idea of coupled design is similar to the Contradiction concept from TRIZ. The uncoupling process can be done more effectively through the Contradiction Matrix.

The design matrix of Polymer Insulator was decoupled design in the first time, but the design matrix was changed into uncoupled design through these STEPs.

These steps are used to apply contradiction-resolving process to Axiomatic Design:

1. Formulating problem;
2. Determining the type of contradiction;
3. Changing FRs to standard parameters;
4. Finding inventive principles in the Contradiction Matrix;
5. Generating new DPs that make design uncoupled.

Originally the tensile strength of Polymer Insulator was 22tons. According to the suggested algorithm and steps, the “Segmentation” inventive principle is applied to the system. Loose material is used to segment the surface of FRP rod.

As a result, the required tensile strength of new Polymer Insulator is achieved. The new design matrix that satisfies Axiom 1 is generated. This example shows that it is very useful way to apply Contradiction Resolving Principles to Axiomatic Design.

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KNOWLEDGE AND INTELLECTUAL PROPERTY MANAGEMENT

TRIZ EDUCATION WITH COMPUTER BASED TRAINING SYSTEM

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Abstract
After reviewing the State-of-the-art of TRIZ diffusion and education, the idea of TRIZ educational principles in computer based training system is proposed, and the optimal way to deliver the idea of TRIZ to mass people via computer based training system, CBT/NOVA^{TM}, is presented.
The computer based training system provides capability for people who wish to improve their innovation skills and to solve complex engineering problem by learning in deep TRIZ and its applications. Basic and Advanced TRIZ courses introduce the Laws of technical system evolutions, Algorithm to solve inventive tasks (ARIZ), Principles and Standards for resolving technical / physical contradictions in technical systems, and tools to activate creative thinking.
The computer based training system is built on client-server technology, and its scalable software architecture allows education professionals to create and manage different multimedia based education courses, control education process and communicate with each learner. Powerful features for test generation support teachers to create certifications programs of different level complexity.
The computer based training system supports daily education process in corporations, universities and colleges to support TRIZ diffusion on a large scale.
Keywords: TRIZ, Computer-based Training.

1. State-of-the-art of TRIZ diffusion and education

During last 10 years, TRIZ-based systematic innovation has penetrated all major industries. World leading companies use TRIZ to solve both long-term and short-term problems and generate new concepts of products and services. Based on 50 years of scientific studies, TRIZ helps to drastically accelerate innovation process by offering tools and techniques for systematic situation analysis, problem solving and new ideas development by combining system thinking and creativity.

But the difficulties to diffuse TRIZ on a large scale, such as within universities, enterprises, even nationwide, in Occident and Asia-Pacific are also appearing. Reviewing the

State-of-the-art of TRIZ diffusion and education, following three styles or paradigms of TRIZ diffusion and education are observed.

1.1 Seminar and/or training with TRIZ specialists

Typical case of this style is the success and hurdle of TRIZ in Boeing.

From 2000 to 2003, Mr. Royzen's 5-days TRIZ workshop provided more than 500 of Boeing's engineers with the ability to solve their real problem with TRIZ. Using TRIZ, substantial internal cost savings and new contract awards have been realized. [TRIZ Consulting Inc, 2003]

But according to [Masingale, 2003], due to the limited training that has taken place thus far in Boeing (500 out of approximately 100,000 technical persons in Boeing is not a high overall percentage) TRIZ has only marginal acceptance throughout the very large Boeing Enterprise. The optimal way to deliver the "initial introduction" of Basic TRIZ to tens of thousands of people is via web-based e-learning/training, followed up by at least a few hours, if not a few days, of coached practice working real problems. Its creation and implementation is paramount to having TRIZ widely accepted and fully implemented in major industrial institutions, as well as for the needed Global expansion of TRIZ.

Therefore, the short-term (3 or 5 days) TRIZ seminar/training make possible the introduction to TRIZ, but unfortunately, it is not enough to allow students or trainees to use TRIZ in practice.

1.2 Combination of TRIZ specialists and on-line training system

Typical case of this style is the success of TRIZ application in Samsung. [Shpakovsky, 2002]

The scheme of a three-stage TRIZ training was proposed at Samsung: (1) Teaching all employees by on-line training system "TRIZ-Trainer", (2) Teaching by seminars with teacher, and (3) Teaching by real consulting.

From 2000 to 2002, TRIZ training had done for more than 2000 employees at Samsung with the help of internal "TRIZ-trainer" developed by TRIZ experts from Belarus and Samsung engineers. The R&D cost savings is the equivalent of US$ 91.2m.

1.3 Distance TRIZ education via Internet

TRIZExperts [Sorkina] proposed distance TRIZ education via Internet, i.e., students can obtain the lectures of TRIZ specialists and individual tasks to be solved in time convenient for them.

This is an effective and efficient way to educate TRIZ for individuals. But as for TRIZ education in universities or enterprises, this style has difficulties to integrate with existing curriculum or training program.

1.4 TRIZ diffusion suggestions of Keynote speach [Cavallucci, 2003] in TRIZCON2003

Directions for successful diffusion & durable development of TRIZ:

- ✓ Robust & efficient industrial practices and reliable consulting actions is a must, but we need to understand that corporate cultural changes are necessary;
- ✓ Academic world must be involved to structure research effort around TRIZ integration & development;

- ✓ Worldwide recognition and aura of TRIZ must be cultivated by testimonies and success stories;
- ✓ Individual competences and skills must be disclosed and taught at all ages to guarantee industrial survival & uses.

Directions for successful nationwide diffusion:

- ✓ Convince the highest authorities in the nation (state) about the necessity to modify curriculums and skills definition;
- ✓ Teach the teacher's teachers (several per academia) with advanced trainings and disclose the pedagogical way they will be introduced into curriculum.

1.5 TRIZ educational methodology by Homenko and Altshuller

TRIZ objectives and theoretical issues of the TRIZ educational process were outlined in details [Homenko, 2002]. The theoretical and educational methodology is not only for engineers but also for young students. People who studied TRIZ through this approach can analyze various kinds of problems, not only engineering.

2. TRIZ education with computer based training system

After reviewing the State-of-the-art of TRIZ diffusion and education, a full range of training services, CBT/NOVA^{TM}, which helps engineers and students to learn a unified and structured approach to Systematic Innovation and master practical skills with its tools and methods, is presented. Our principal trainers have at least 15 years of experience with training Systematic Innovation worldwide. Both public and in-company training are supported.

2.1 Principles and objectives of CBT/NOVA^{TM}

Among various creative abilities at which TRIZ is aimed to develop and motivate system thinking. Overcoming of the intellectual and psychological inertia is one of the main objectives of the training. In this context, it's suggested to apply the system vision of the problem and to model the problem using the natural language without using domain-specific terms. The problem solver looks at the problem beyond the situation, where the problem occurs. This broadens the field of problem investigation thus looking for the solutions from other technical domains. The application of ARIZ is aimed at mastering of the following abilities: formulating of the technical contradictions, analysis of the resources and IFR, formulating of the physical contradictions at the Macro- and Microlevels, inventive rules based reasoning with TRIZ Principles and Standards.

ARIZ is a powerful tool that allows the problem solver to discover all the sides of the problem thus working out strong and effective solutions. To achive strong solutions, ARIZ supposes to use biological, physical, chemical knowledge, knowledgebase TRIZ Standards and the strong analogous solutions derived from the patents.

The main objective of TRIZ in CBT/NOVATM is to learn to handle the problem using the algorithmic approach. The learner is stimulated to develop and use creative thinking when analysing the problems and searching for the solutions.

2.2 Functions and structure of CBT/NOVA^{TM}

There are two TRIZ courses in CBT/NOVATM:

Basic TRIZ:
- ✓ Methods for Creative Imagination
- ✓ Laws of technical system evolution
- ✓ Technical and physical contradiction
- ✓ Conversion of technical contradiction into physical contradictions
- ✓ Principles for resolving of technical and physical contradictions.
- ✓ Principles of innovation knowledge base creation
- ✓ Concept evaluation principles

Advanced TRIZ:
- ✓ Introduction in Su-field analysis
- ✓ Standard Rules to Solve Inventive Tasks (TRIZ Standards)
- ✓ Algorithm for Inventive Problem Solving (ARIZ 85C)

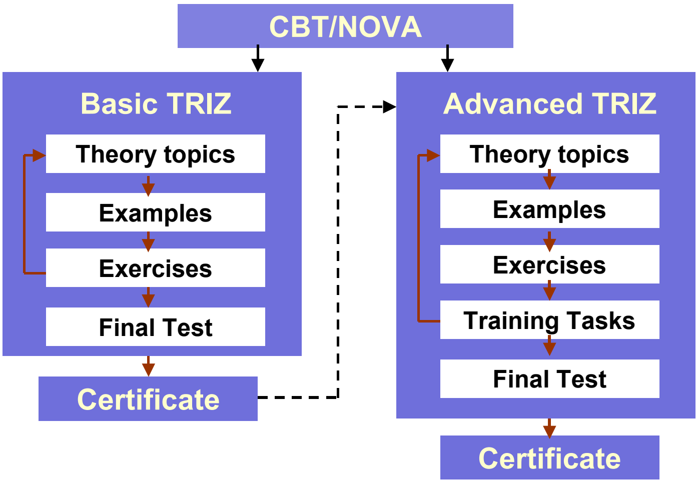

Figure 1. CBT/NOVA™ functional workflow for Learner

Theory topics introduce the fundamentals of the TRIZ theory.

Examples illustrate a practical embedding of the TRIZ methodology for problem solving according to the selected topic/subtopic.

Exercises allow nailing down acquired theoretical knowledge thus practicing problem sensitivity.

Training Tasks are special tasks needed interaction between Learner and Teacher. Training Tasks are aimed at mastering the skills for identifying the right problem solution according to the passed theoretical material. They are composed in the Advanced TRIZ course only.

Question Base contains the collection of training tasks and exercises. Teacher selects appropriate practical tasks, stored in the question base, and in such a way composes the final test (the question base is not shown on the figure1).

Final Test contains the practical tasks covering the material of the overall training course. This test is meant for final evaluation of learner’s success.

Certificate is a document in electronic form, which states that learner successfully passed the training course.

CBT/NOVA™ supports also the possibility to create additional courses and compose their contents.

There are no strict limitations on the quantity of exercises, final tests and training tasks to examine learner's knowledge. The concept is that practical tasks do not over-saturate the course and meet the requirements of the teaching-learning methods.

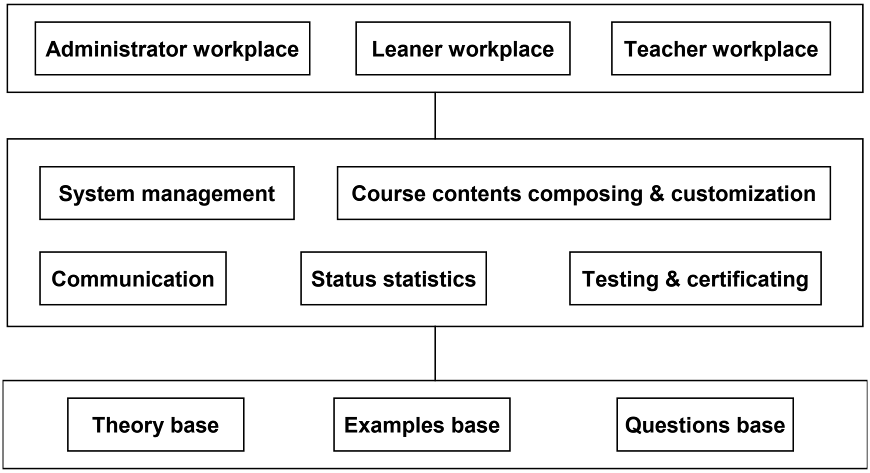

Figure 2. CBT/NOVA™ structure and services

2.3 Benefits of CBT/NOVA™

Benefits of CBT/NOVA™ are:

- ✓ Education management can easily organize and manage courses, teachers, students and students group.
- ✓ Knowledge composer provides publishing of texts and multimedia for Theory explanation articles, Examples of theory application, Tests and Training Tasks.
- ✓ Powerful features for test generation support teachers to create certifications programs of different level of complexity.
- ✓ Statistics tools allow teachers and students to trace education process (number of passed topics and tests)
- ✓ Teacher can state the creativity level of every student and communicate with person to help in resolving difficulties.
- ✓ Communication feature supports student in communication with teacher if the first completed Training Task or has questions to teacher.
- ✓ Basic and Advanced TRIZ courses introduce the Laws of technical system evolutions, Algorithm to solve inventive tasks, Principles and Standards to resolve technical / physical contradictions in technical systems and tools to activate creative thinking.
- ✓ All examples and exercises explaining TRIZ applications are original, based on real-life or industries-oriented cases, and have not been published in TRIZ literature.
- ✓ Custom Basic and Advanced courses can be supplemented domain oriented examples, tests and Training Tasks.

CBT/NOVA™ can be helpful in supporting innovation educational and training process for:

- ✓ Professors, teachers, students of engineering specialties
- ✓ Consultants in the field of innovation design and technology
- ✓ Organization of vocation qualifications
- ✓ Engineers of R&D department
- ✓ Engineers of Patent application department
- ✓ Quality engineers
- ✓ Chief Engineers of R&D department
- ✓ Senior Engineers of R&D department
- ✓ Production managers

3. Conclusion and future works

Goal of CBT/NOVA™ is to teach more and more young generations in order to build the foundation of TRIZ pyramid outside former Soviet Union. In the near future, following potential enhancements and perspectives of CBT/NOVA™ will be considered:

- ✓ New courses will be developed to support DFSS workflow:
  - ✧ Combination of technical systems.
  - ✧ Basic and Advanced QFD. QFD and TRIZ integration procedures.
  - ✧ FMEA. FMEA and TRIZ integration procedures.
- ✓ New courses will be developed to support TRIZ education for middle school students.
- ✓ New creativity assessment system based on TRIZ will be developed to support TRIZ diffusion on a large scale.

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KNOWLEDGE MANAGEMENT AND TRIZ: A MODEL FOR KNOWLEDGE CAPITALIZATION AND INNOVATION

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Abstract
The aim of this article is to propose a model in order to create an organizational network. The development of this network, in which the main postulates of Knowledge Management (KM), Theory of Inventive Problem Solving (TRIZ) and Case-Based Reasoning (CBR) approach are combined, will produce a system and a database of solutions, ideas, models. In this database every organization member's expertise could be stored, indexed, maintained and consulted. The main objective of this network is to create a support for the innovation and knowledge capitalization process in the context of a technological-social environment.
Keywords: Knowledge Management, TRIZ, CBR, Innovation.

1. Introduction

Our industrial environment could be described in terms like complexity, ferocity, competition and "extremely". In this environment, the innovation is regarded as the most important factor for permanency and sustainability for an enterprise.

In the simplest model, innovation is represented like an addition between theoretical conception (creativity), technological invention, manufacturing and marketing for finally obtain a commercial product [Cortes 2003]. Under this approach, it is possible to establish that a firm could be seen as a "*coordinated collection of capabilities*" where *"The main building block of these capabilities… is knowledge*" [Prusak 2001]. Consequently, innovation is a technological-social process where individual and organizational knowledge are exposed, assimilated, shared and transformed to create new knowledge and for these reasons, a complex and elusive process to manage [Gurteen 1998; Harkema 2003].

Therefore in the present industrial context, the challenge to face is the localization, capitalization, exploitation and evolution of the knowledge embedded in an organization, in order to create new knowledge that will be transformed to innovation. These requirements have been covered by a new discipline : Knowledge Management (KM). KM "*is emerging* *as a new discipline that provides the mechanisms for systematically managing the knowledge that evolves with the enterprise*" [Abdullah *et al*., 2002].

The scope of this article is to describe a methodology capable to fulfill these requirements. To accomplish these objectives, a synergy between TRIZ, Case-Based Reasoning and Knowledge Management will be created. In first place, KM makes available the methodological requirements for identify, localize and outline critical processes, knowledge and the associated problems. Second, TRIZ brings into action, a several set of techniques and tools for modeling and solving problems. Then CBR provides the mechanisms for capture, index, reuse, make accessible and maintain in a case database, the knowledge deployed when a person or team solves one problem. A fundamental basis in this work is that knowledge is revealed, when a solving problems activities are deployed and thus the application of TRIZ - CBR will be useful as a tool for building a KM System.

This paper is organized as follows: Section 2 offers a succinct overview of Knowledge Management, here will be emphasized the importance of the knowledge's localization process. Section 3 describe briefly the process followed in the Case-Based Reasoning (CBR) process, then the Theory of Inventive Problem Solving (TRIZ) will be introduced in section 4, for finally lead to the methodology which is the core of this work.

2. Knowledge Management

Offer a definition of Knowledge Management is a difficult task, for example:

- "KM is the formalization of and access to experience, knowledge, and expertise that create new capabilities, enable superior performance, encourage innovation and enhance customer value - Beckman ". - " KM is the art of creating value from organization's intangible assets". [Sveiby 2003]. - "KM is the collection of processes that govern the creation, dissemination, and utilization of knowledge - Brian Newman ". [Pachulski 2001]

However, it is possible to find consistent features between many definitions. KM is a process or environment where knowledge is transformed with a goal : capitalize, reuse, create and make accessible the knowledge inside an organization. Finally, KM makes from this knowledge transformation a competitive advantage, usually using an Information Technology System [O'Leary 1998]. The knowledge management approach has been influenced by disciplines like : Economy and Management, Artificial Intelligence and Information Technology. The integration of these disciplines gives birth to many different platforms and approaches to manage the knowledge inside an enterprise. The selection and design of the system (computational tool and network-intranet) that should support our methodology, is for the moment out of the scope of this article. This system will be the object of future work.

Knowledge and the general process of KM

Knowledge in the context of this article represents the mobilization of *explicit* and *tacit* knowledge as a whole, by the members of an organization as part of their activities. This implies that knowledge could be seen from two different perspectives : tangibility and sense. Tangibility means that knowledge is only tangible if is applied, second means that knowledge possesses a special meaning or sense only for whom is producing and using it [Tounkara 2002]. The continuous and dynamic interaction between tacit and explicit knowledge is the source of organizational knowledge. ***Explicit knowledge*** is the knowledge than can be formalized in a structural and systematic way, generally by some means or artifacts (documents, images, digital means, etc.), with the objective to communicate with someone else. ***Tacit knowledge*** is a personal attribute, is the knowledge produced by the experiences, values and perspectives of a person in a particular context, and for that reason, hard to formalize and share. This kind of knowledge is "actionable knowledge" and the most important foundation for the creation of new knowledge: "*the key to knowledge creation lies in the mobilization and conversion of tacit knowledge*" [Nonaka & Takeuchi 1995 ; Marwick 2001]. According to Nonaka and Takeuchi this process of transformation is constituted by four different stages. Figure 1 shows this interaction:

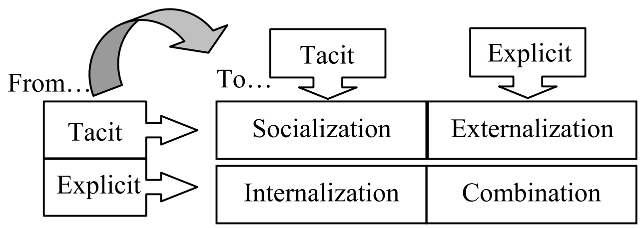

Figure 1. The cycle of knowledge transformation [Nonaka & Takeuchi 1995]

Nowadays the enterprise is searching the way to capitalize their intellectual resources. In order to do it, those resources must be defined, measured and controlled with a view to enhance their application and use [Amidon 2001]. The capitalization process means to make the knowledge productive. This process is according to Grundstein a four-stage process integrated by : the localization, actualization, valorization, and preservation of knowledge [Pachulski 2001].

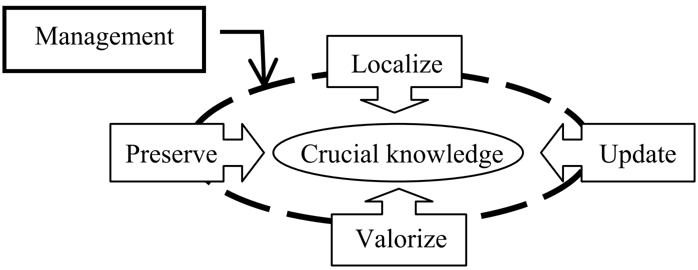

Figure 2. The knowledge capitalization's process by Grundstein [Pachulski 2001]

This four-stage process has been embraced by two different methodologies. The localization of knowledge was covered in [Pachulski 2001], and the three remainder by the Case-Based Reasoning approach (CBR).

The CBR process has proved to be an efficient tool for developing Knowledge Management Systems (KMS) [Limam *et al.* 2003]. This advantage is founded in the facility to the user or reasoner to understand, utilize and apply the concrete examples provided by this kind of systems. This empathy is based in the process followed in a CBR system, which is the same process used by humans while solving problems. A CBR system compares the current problem with cases (a *case* is usually a specific problem that has been previously identified, solved, and indexed), encountered in the past to determine if one of the earlier experiences can provide a solution. If a similar case or set of cases exists, their solutions must be evaluated and adapted to find a satisfactory one [Leake 1996; Gallagher & Bierker 2002; Terninko *et al.*1998]. Finally, the CBR process provides a framework for learning from experiences and the acquisition of knowledge [Aamodt & Plaza 1994; López & Plaza 1996; Watson & Farhi 1994]. Next section offers a succinct description of this approach.

3. Case-Based Reasoning

Cased-Based Reasoning is a process where the reuse of passed experiences is the core. This approach has been used in many fields like Cognitive Scientists, Artificial Intelligence Research, Expert Systems, and Information Technology, among others [Aha 1997]. For the purpose of this work, the approach of Case-Based Reasoning for solving problems in Artificial Intelligence field will be adopted. In this approach, the reasoner searches to solve a new problem by recognizing the similarities to previous solved problems or *cases*. Then the knowledge and information collected from this passed experiences (and what has been *captured and learned* in a way), is transformed and tested to obtain a new solution, which will be incorporated in a memory for future utilization [Aamodt & Plaza 1994; López & Plaza 1996].

The evolution of CBR began with the work of Schank R. in a document published in 1982 titled *Dynamic Memory: A theory of learning in computers and people* that described the memory-based approach to reasoning [Schank 1982]. This means that human memory is dynamic because it is continuously changing according to the new problems or situations (*cases)* faced. These new experiences include some lessons learned in a particular context, which can be employed to face new ones. The CYRUS system developed in 1983 by Kolodner, was the first computer implementation of many of the schemes exposed in Schank's work. After that, too many systems had been implemented in fields such as medicine, law, nutrition, cooking, and design, among others [López & Plaza 1996; Liao *et al.* 2000; Watson & Farhi 1994; Restrepo *et al.* 2004].

3.1 CBR as a tool for solving problems

Case-Based Reasoning is often divide in two classes according to the process detected : interpretive CBR and problem solving CBR. In the context of *interpretative CBR*, the primary goal is to determine if a new situation should be treated like a previous one and establish a reference line for classify and characterize the new situation [Leake 1996].

In *problem solving CBR*, the goal is to create a solution to a new case based on the adaptation and evaluation of solutions stored in a past case's memory. It is important to note that in practice, an effective CBR system must have both processes [López & Plaza 1996].

Case-Based Reasoning as a problem-solving tool, is a mix between a pragmatic and cognitive approaches [Leake 1996]. From the cognitive field, the analogical thinking (and learning), which is one on the main bases of the CBR process is the most common process of human's problem solving [Aamodt & Plaza 1994; Sifonis *et al.* 2003; Terninko *et al.* 1998].

From a pragmatic point of view, the development of a knowledge based systems using CBR, will comprise less knowledge engineering effort than others techniques [Cunningham 1998]. Briefly, psychology provides a guide to identify the useful components for AI systems, which subsequently could implement these characteristics in a system. Figure 3 represents the CBR's process, called the "Four R's" for Retrieve, Reuse, Revise and Retain :

1) *Retrieve :* the problem solving process begins with an initial description of a problem or new case This new case is used to *retrieve* a case or set of cases stored and indexed in a collection of previous solved problems.
2) *Reuse :* if one or various stored cases match with the problem situation, the most similar case is selected to *reuse* its solutions by any way known within the new case.
3) *Revise :* the obtained solution has to be evaluate, tested and repaired if it is necessary for success.
4) *Retain :* finally, the new experiences are retained for future utilization and the collection of solved cases is updated. It is important to remember that mistakes, special processes or other special features in a case, are retained with the goal to facility the future solution of a new case.

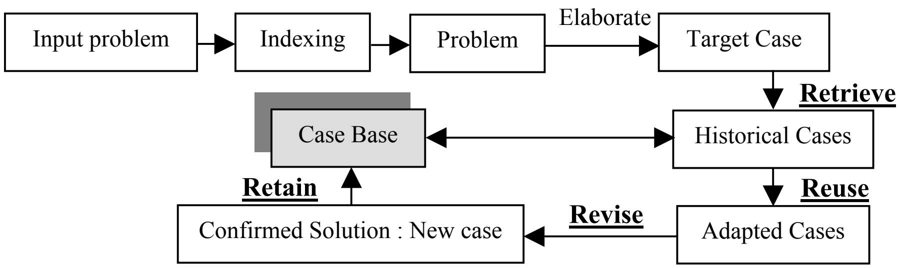

Figure 3. The CBR Cycle [Limam *et al.* 2003]

It is important to notice that in the core of this process, exists a case memory, which contains all the accumulated knowledge (general and specific), extracted from the cases previously encountered and which will support the solving process in a particular domain or industry.

3.2 Learning as inherent process behind the Case-Based Reasoning

Learning is a very important product of the CBR process, maybe the most important. [López & Plaza 1996] emphasize: "*Learning is in fact inherent to any case-based reasoner not only because it induces generalizations based on the detected similarities between cases but mostly because it accumulates and indexes cases in a case memory for later use*" [López & Plaza 1996]. According to [Leake 1996], "*reasoning and learning are intimately connected*" and reasoning from analogies is the fundament of the CBR process, besides the retain phase or memorization process is an excellent support for sharing and acquisition of knowledge. Briefly, the approach of the CBR process has proved to be an efficient tool for the implementation of Knowledge Management Systems (KMS).

4. TRIZ: The Theory of Inventive Problem Solving

TRIZ, the Russian acronym for the Theory of Inventive Problem Solving, is the product of a Man who refused to embrace the paradigms of creativity, a Man who will find the postulates to systematize the creativity: Genrich Saulovich Altshuller. The forge of TRIZ began in 1940 at the patent department of the Soviet navy [Ideation 2004]. The development of TRIZ was initially an Altshuller's personal search about principles, which could help him in his inventing practice. But soon the goal of this research changed to a more ambitious objective: "Invent methods of inventing" [Altshuller 1999, p. 31]. The aim of this research was to find some techniques or tools that will help inventors to solve problems during the innovation process. Altshuller began to study creativity under a psychological approach without satisfactory results. Consequently he thought that creativity could be analyzed from a different point of view : the creativity's evidences (inventions) which are contained, indexed and maintained in the patents databases. Thus *"TRIZ is based on technology rather than psychology*" [Zlotin & Zusman 1999]. At the end of the 80's, more than 2 millions of patents had been investigated [Mann 2003, Ideation 2004].

Altshuller found in the patents database, that the same elemental problem had been pointed out by different invention in different areas of technology, more important yet, he noticed that the same solutions were repeatedly used and implemented, sometimes separated by many years. Altshuller thought that if those solutions were available to inventors by some means, the innovation process will be more efficient (this approach is shared by the CBR process in Leake 1996) [Terninko *et al.* 1998]. Development of TRIZ was not limited to patent analysis, Altshuller extended his research to other domains like inventor's behavior, techniques and tools for solving problems, and a wide analysis of scientific literature [Cavallucci 1999]. This research leaded to the creation of TRIZ where are contained the creations of the best inventive minds. As a consequence, TRIZ is an extensive body of knowledge and its application is not restricted to a single science domain [Sushkov *et al* 1995].

Based on this research Altshuller exposed the cornerstones of TRIZ: (1) The evolution of all technical systems is governed by objective laws; (2) Ideality is a goal; (3) The concept of inventive problems and contradictions as an effective way to solve problems; (4)The innovative process can be systematically structured. As a result, TRIZ had adapted and assimilated in its structure a set of techniques for modeling and solving problems, overcoming psychological inertia and a set of laws that could be used to foretell the evolution of technological systems.

For the purpose of this article, another Altshuller's discovery has a capital importance: knowledge is transferable outside of the domain where it has been conceived. While analyzing the patent's database, Altshuller classified the solutions to a problem accordingly to five levels, depending on patent's degree of inventiveness (table 1) :

Level	Description	%
1	Apparent solution	32
2	Small improvement	45
3	Invention inside paradigm	18
4	Invention outside paradigm	4
5	Discovery	<1

Table 1. Altshuller's Innovation Levels [Zlotin & Zusman 1999]

According to [Terninko *et al.*1998], inventions involving levels 1, 2 and 3 "*are usually transferable from one discipline to another*", this expression means that 95% of inventive problems in any domain have already been addressed and solved in some other field. Those levels are the axis of the present methodology.

5. The methodology

The present methodology is based on Grundstein's knowledge capitalization process (figure 2), which forms a four-stage process : to localize, update, valorize and preserve. This section will be devote to the localization phase which had been covered in [Pachulski 2001]. In this Ph.D. thesis, an analyze between different tools and methodologies of KM was made. The main conclusion is that only the GAMETH methodology [Grundstein 2000a] embrace the identification of key knowledge for an enterprise. Key knowledge means in the context of Pachulski's work, the existing knowledge intended to maintain and enhance the performance of an enterprise.

Consequently, the proposed methodology is founded in the same methodological approach of the Global Analysis Methodology (GAMETH). This approach presents some important characteristics for our methodology: (1) GAMETH is directed by problems. Problems are identified and also their knowledge requirements. (2) GAMETH is focus on processes and for that reason, connecting intimately knowledge and action. (3) Modeling knowledge is a social process, where individual knowledge is revealed by action [Grundstein 2000b].

5.1 The localization of knowledge

The application of this first section combines eight activities to localize knowledge at two different levels: decisional and operational. Decisional is all knowledge that allows somebody to build up an internal representation of a problem. Operational means all knowledge that enables somebody to take action in a situation perceived as a problem. Figure 4, shows the stages involved only at operational level.

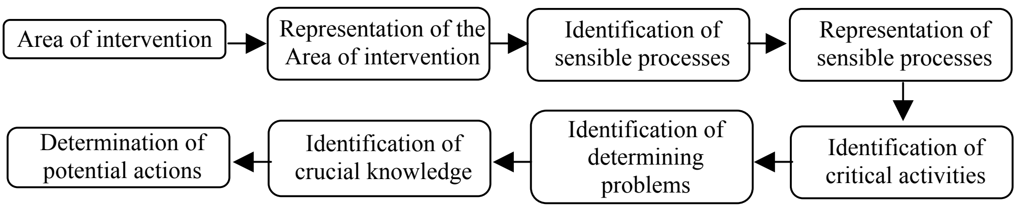

Figure 4. Steps involved in knowledge localization [Pachulski 2001]

This is a simplification of Pachulski's work. This process embraces the application of several techniques and tools like interview, process's graphic representation, the Failure Modes and Effects Analysis (FMEA), analytical grids among others. Some TRIZ tools could be useful in this methodological section, principally at the "Identification of critical activities" and "Identification of determining problems" steps. The Innovation Situation Questionnaire (ISQ), developed by Ideation International makes explicit all the needed information for the individual working with innovative problems [Terninko *et al.* 1998] and the Anticipatory Failure Determination (AFD) technique, which search the real cause of a problem by looking the failure as an intended consequence and concentrate on how to make the failure happen [Clarke 2000].

Between the most important results of this first methodological section are accordingly to [Pachulski 2001]: (1) the name of all processes collectively considered as a fundamental; (2) a graphic model of all processes previously identified; (3) a list containing the critical activities and the associated problems; (4) a list of determining problems; (5) a crucial knowledge's cartography; (6) Creation of knowledge about the knowledge (meta-knowledge) within the organization and (7) a list of zones to implement the rest of this methodology for knowledge capitalization.

The showed methodology's section had been successfully tested and implemented, also is the base for a computational tool named GAMETH-Station. Products of this first section are a well-defined structure about where knowledge are, where it is needed and who possesses it. The information produced will be the raw material to next section where TRIZ and CBR can be applied.

5.2 TRIZ and CBR

The reasoning process of TRIZ is what [Aamodt & Plaza 1994] call it "Analogy-Based Reasoning" used to "*characterize methods that solve new problems based on past cases from a different domain*", while typical case-based methods search to index solved problems for single-domain cases [Aamodt & Plaza 1994]. Therefore CBR's approach could be adapted into TRIZ. The resulting synergy is represented in Figure 5:

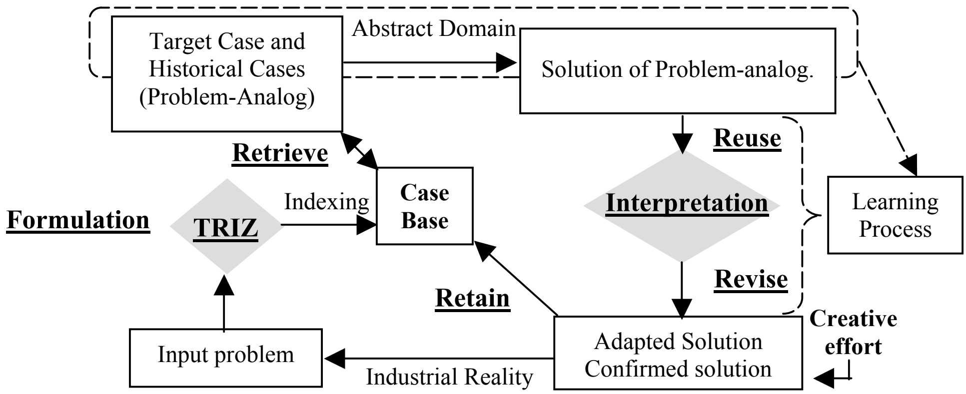

Figure 5. TRIZ-CBR approach.

This structure is useful for: (1) to memorize the knowledge and experience developed while using TRIZ as a solving problems tool, (2) provide a framework to analyze, solve problems and capture knowledge already detected in an organization.

The implementation of TRIZ-CBR needs as initial requirements, to know where is the knowledge, who possesses it, how is interacting and why it is necessary to implement this tool. All this requirements are covered at the knowledge localization phase. Another presupposed element is a previous training program about TRIZ philosophy ant tools. It is important to note that a fundamental concept in this methodology is what knowledge (explicit and tacit) is revealed during action and, actionable knowledge is the knowledge mobilized when a problem is detected and solved. This *process* and *knowledge* must be captured, with the aim to capitalize.

5.3 TRIZ-CBR: a briefly description

The case memory

The efficiency of a CBR process is intimately related to the structure and content of its stored cases (case memory). Different models had been used to explain this complex process like Schank's Dynamic Memory Model (DMM) or Bareiss & Porter's Category and Exemplar Model (CEM), among others.

These models have in common a three elements structure. The DMM model, is a hierarchic structure of Episodic Memory Organization Packets also referred as Generalized Episodes (GE). The basic idea is to organize specific cases, which share similar properties under a Generalized Episode (GE). A GE is integrated by three elements : norms, cases and indices. A norm is a common feature in all the cases stored under a GE. Indices are features that discriminate between a GE's cases and indices are a pointing element to a more specific GE or cases.

In the CEM model, the case memory is a network structure of categories, cases and index pointers. Each case is associated with a category, an index may point to a case or category and, an index pointer could be associate to problem features, case or categories, differences between cases, among other functions [Aamodt & Plaza 1994].

Both structures make reference to an abstract generalization, which will play the role of root-directory in order to, store and index the cases in the memory. Some TRIZ concepts were developed as a generic tool [Mann 2001], specially the 39 Generic Parameters and the 40 Inventive Principles[1] and could serve as a guide to accomplish this abstraction.

The 39 Generic Parameters and the 40 Inventive Principles

The 39 Generic Parameters and the 40 Inventive Principles, were identified by Altshuller between 1940s and 1970s [Savransky 2000; Altshuller 2001]. These two TRIZ elements allows the resolution of *technical contradictions* (the condition in which improvement of one system characteristic results in the degradation of another). Technical contradictions (a problem) could be expressed as a combination of two between the 39 parameters and the solution with one or a set of principles.

Hence, this 39 initial general domains which are in fact an "*analogous standard problem*" and the 40 Inventive principles an "a*ssociated standard solution",* could serve as a reference for solve and indexing a case[Terninko *et al.* 1998, p. 68]. The 39 parameters as an index for problems and the 40 inventive Principles for the solutions.

The interrelation between the 39 Generic Parameters and the 40 Inventive Principles is contained in the Contradiction Matrix[2] (Figure 6). This is a 39*39 matrix where the first column and row are the 39 Generic Parameters and each cell represent a particular technical contradiction and their associated solutions (represented as a number), corresponding to the inventive principle that has been successfully applied to resolve it.

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[1] For a more extensive analysis and definitions about the 39 Parameters and the 40 Principles, it is recommended to consult the TRIZ Journal web site at http://www.triz-journal.com.

[2] Is possible to find a Contradiction Matrix exemplar at the TRIZ Journal Web Site.

Undesired Result (Conflict) / Feature to Improve		1…	9	10..39
		Weight of moving object	Speed	Force
1	Weight of moving object		2, 8, 15, 38	8, 10, 18, 37
2... 39	Weight of stationary object			8, 10, 19, 35

Figure 6. the Contradiction Matrix [Cortes 2003]

This memory configuration, will be used as a way to index a problem and could be used including the case where a problem cannot be stated by a contradiction. If a case cannot be indexed under one of this 39, a new root directory could be created, idem for the solutions.

The 40 Inventive Principles had proved a very flexible application, it is possible to find their interpretation in fields like : business, education, social examples, architecture, food industry, Service Operations Management, software, microelectronics, quality management, public health, among others. Consequently, the 39 Parameters and the 40 Principles could be used as an index ontologies in this methodology. Finally any case memory based on analogies, could utilize this TRIZ concepts as a guide for index a case.

Case content: A case in TRIZ-CBR is a problem already identified, solved and indexed. One case is generally constituted by three components *: Problem description, Solution and Implementation*. All this steps are supported by diagrams, videos, analogies or another (usually digital) way to explain a particular step embedded in the process. These elements will be part of the problem description, solution and implementation. A *problem description* usually contains : (1) Information about the environment, system or condition where problem[3] exists; (2) Information about the problem situation which means (improvement or eliminate a disadvantage, causes within the problem situation); (3) Attributes describing the problem and her interaction (Relationship between the elements which are leading to the problem, their mechanisms of occurrence and related problems). A *solution description* commonly contains: (1) the steps leading to the solution and criteria for selection; (2) the solutions obtained; (3) justifications about taken decisions; (4) final solution. Another capital point to include in a case are all vestiges about how a solution was derived (which is different to replay a solving sequence, this is a psychological process), by identifying and repeating the reasoning process involved.

Implementation of the final solution include (1) success or failure; (2) if a failed solution occurs, the strategy for repaired must be recorded; (3) when a successfully solution occurs, the propositions expressed by users to : use new solution in a new way, future derivations,

[3] A problem is defined as anything that is undesirable in the system or the opportunity for improvement [Terninko *et al.* 1998]

applications or relationships with some other problems must be remembered and included in the case [Aamodt & Plaza 1994, Terninko *et al.* 1998; Lopéz & Plaza 1996].

Based in this information all the labels and important features for case characterization will be obtained. The application of another TRIZ tools and concepts are under analysis. Tools like :

- The Substance-Field Analysis (Su-Field Analysis) and the System of Standard Solutions. The Substance-Field Model used as a problem's feature and the Standard Solutions as an Associated Standard Solution. Besides the utilization of Su-Field empower ideas transfer in a way that could be understand by everybody, who is familiar to the Su-Field concepts.
- A fundamental TRIZ concept says : all systems evolve towards the increase of degree of ideality. Ideality is the fundamental basis for a tool named "The Ideal Final Result (IFR)". This concept express an imaginary result where an element(s) of the system or environment eliminates an undesirable effect, preserving the capacity to produce a useful effect all by itself [Salamatov 1999]. This tool is an excellent criterion for the best solution.

5.5 The rest of the process

Rest of the CBR process takes place in the usual way. These activities are represented in Figure 7.

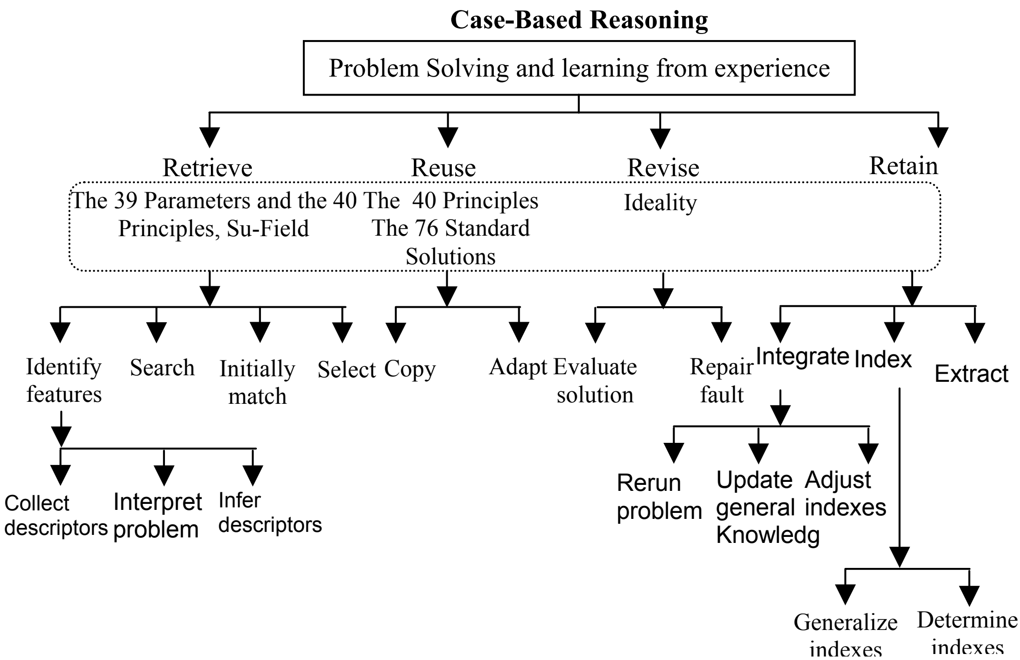


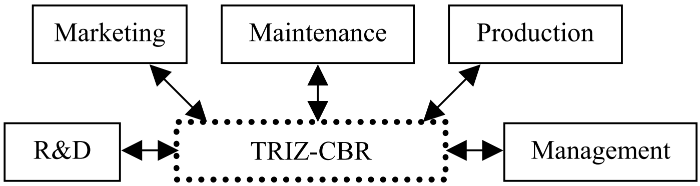
Figura 7 A general view of the TRIZ-CBR Process

6. Conclusions

The benefits of the synergy created between TRIZ and the CBR process could be described from different points of view. The most important are:

- The presented model has some advantage over traditional models to knowledge management. This is mainly because TRIZ-CBR offers a way to transfer the solution from an identified analogue problem to a new target problem, reducing effort and time in solving problems. TRIZ had proved that knowledge could be extracted and applied outside of the domain where it was conceived [Zlotin & Zusman 1999], thus TRIZ offers in the CBR process an initial database of the most efficient solutions for solving problems (stated or not as a contradiction). Which means to have an initial (analogous) case and solution to compare a target case, even if a similar case had not be faced. At the same time, the CBR process offers to TRIZ, a structure to memorize and the technical support for sharing and adopting knowledge and the best practices embedded during problem resolution.

- This memorization process is an unsatisfied TRIZ necessity. Accordingly to [Campbell 2002], " *TRIZ does not leave fingerprints*". This is due to the generic nature of some TRIZ methods and techniques, that have been used longtime ago. Thus the efficacy of TRIZ is hard to prove. TRIZ-CBR could offer in an industrial environment, the evidences about its efficacy. An additional benefit is the personalization of TRIZ, accordingly to detected requirements in a specific enterprise's department.



- From a technical point of view, the transfer of the experience and knowledge collected by the CBR process is more efficient than a rule- or model-based approach, because is easier for users to understand and apply the specific (and generalized) examples provided by cases [Limam *et al.* 2003]. This simplification consent several benefits like: largely volumes of information can be managed (more than in a rule-based approach) and the knowledge as case memory can be maintained and updated automatically with the use of the system. Another determining factor it is time. Users of this kind of computational tools (corporate intranets, internet or communication system) becomes more competent over time [Leake 1996].

- "*Learning is in fact inherent to any case-based reasoner not only because it induces generalizations based on the detected similarities between cases but mostly because it accumulates and indexes cases in a case memory for later use"* [López & Plaza 1996]. Hence TRIZ-CBR could provide a framework for learning from experience and enable an acquisition knowledge process. This interaction is the source of knowledge transformation and this new knowledge, represent a competitive advantage in a firm.

TRIZ-CBR is an approach where psychology and technology are combined, thus a sensitization process is needed in order to overcome psychological obstacles like fear and insecurity, which is in fact the main obstacle [Tounkara 2002].

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MULTILANGUAGE PATENTS ANALYSIS AND CLASSIFICATION

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Abstract
The availability of huge amount of data from a bewildering variety of sources leads to the well-identified nowadays paradox: an overload of information means no usable knowledge. Text Mining and Knowledge Management technologies are therefore assuming a key role for many organizations: in order to propose competitive products or services it is necessary to minimize the resources dedicated to the accomplishment of repetitive tasks and to focus on "creative" activities. Moreover, innovation is basically limited by psychological inertia on one hand, and by lacks of knowledge on the other. This paper presents a set of tools developed by the authors for increasing knowledge extraction from patents. A proposal for a Patent Mining suite is therefore discussed.
Keywords: Natural Language Processing, Functional Analysis, Patent Analysis, Text Mining, Clustering

1. Introduction

Analyses of emerging technologies and their implications are vital to today's economies, societies, and companies. Such analyses inform critical choices ranging from the multinational level to the individual organization. Decisions that need to be well-informed concern setting priorities for research and development efforts, understanding and managing the risks of technological innovation, exploiting intellectual property, and enhancing technological competitiveness of products, processes, and services [1].

In this context, information retrieval, documents classification, business intelligence, technology forecasting, competitors monitoring etc. are crucial activities requiring advanced tools capable to face the dramatic paradox: an overload of information means no usable knowledge. Such a contradiction between the width of the information source and the low usability of a large amount of documents is typically met in patent search activities: monitoring competitors, checking the novelty of an invention or looking for technical solutions in other fields of application require big efforts even for skilled researchers. Performing a text analysis for constructing design representation has been approached by several authors, as in [2], by means of techniques mainly based on statistics (i.e. counting terms frequencies, identifying specific words etc.). The same approach is followed by tools specifically dedicated to patents analyses as [3], but their main limit is that they cannot distinguish the role of a component in a technical system.

The commercial availability of software capable of analyzing documents with semantic processing algorithms offers a revolutionary way to search, summarize and classify information. Linguistic Analysis tools allow the identification of the key elements of a document, by combining morphological, syntactic and semantic analyses.

Major results can be obtained by processing structured documents whose format is strictly related to the content. This characteristic is typical of several forms of technical documentation, and allows "low-cost" linguistic analysis techniques and tools to be adopted. Patents are a typical example, with distinguished sections for claims, background of the invention, description of the preferred embodiment etc.

In this context the authors have developed several tools for supporting any kind of patent analysis, from detailed searches of inventions peculiarities [4-6] to multi-language patents unsupervised classification [7-9].

In this paper, first available technologies for patent mining are briefly surveyed; then the functionalities of the systems developed so far by the authors are summarized. Eventually, the last chapter presents a work still in progress about the implementation of an integrated suite for multi level patent analyses and classification.

2. Patent analysis: available technologies

Patent analysis has applications to many different tactical and strategic company assessments, from those dealing directly with patents, such as intellectual property management, to those related to company valuation and competitive intelligence. Companies gain a strategic advantage over their competitors through "technology watch" activities, which provide the best way of keeping updated with cutting-edge technology developments. Information can be drawn from patent databases, which can be precious sources of technical knowledge. Nevertheless, these databases are large and complex and cannot simply be "watched". In fact, each patent is identified by specific codes that describe its application areas, inventor and similar data, as well as by other free textual fields, which are rarely used for classification purposes. The alphanumerical codes are always partially overlapping and redundant, the free textual fields contain instead the true valuable information. Thus, it is not easy, even for an experienced researcher, to recognize the importance of a patent and its relationship with other patents, especially when the corpus consists of hundreds of documents, potentially heterogeneous for language used.

Commercially available patent databases provide basic means for information retrieval and citations tracking, but patents searches are still time consuming and require big efforts for being accomplished. In facts, citation analyses are the most used techniques for identifying within a company's patent portfolio the small number of valuable, high-impact patents against the large number of patents of marginal importance [10]. It is believed that a statistical analysis of the rate of publication of patents pertaining to a certain field or assigned to a certain company, provides information about technology maturity and corporate technology strategies. Typically, the analysis is performed by counting in an online database the number of patents issued annually in a set of calendar years [11]. Besides, it normally takes five or more years from publication before a patent begins to be cited to any great extent. In general, 70% of all patents are either never cited, or cited only once or twice, so that even five citations place a patent in the top few percent of cited patents [12].

Therefore, the analysis of the free textual description is assuming a greater relevance for getting major advantages from disclosed inventions.

Text Mining applications provide effective means for content searches in the textual fields of patent databases, but they are typically not tailored for patent analyses and too often require a deep expertise about how to gain major advantages from this technology. Some special features are available in Invention Machine Goldfire platform [13] mainly related to the application of syntactic parsing capabilities so that from each sentence a SAO triad (Subject, Action, Object) is extracted. Indeed, such an analysis allows a much more powerful classification of the concepts contained in a patent description; nevertheless, as well as for more traditional keywords based tools, no systems are available on the market for capturing the role of a component in an invention or for grouping patents according to the claimed functionalities apart from their fields of application.

More specifically the following features aimed at speeding-up patent analysts activity still lack on the market:

- identifying the architecture of the claimed invention, distinguishing the functional (semantic) role of each component;
- identifying invention peculiarities as a means for providing an automatic extraction of the core of the patent; (it is worth to mention that too often the patent abstract is very low informative);
- clustering technical solutions according to the way a function is accomplished apart from the field of application (therefore providing proper means for technology transfer);
- allowing easy and effective queries by means of a multi-language taxonomic knowledge base so that search results do not depend on patent language and/or the use of synonyms, hyperonyms, meronymes etc.

3. Tools for efficient patent analysis

On the base of the above discussed limitations of traditional tools for patent analyses, the authors have carried on complementary experiences that can be integrated with the aim of providing a comprehensive platform for any kind of intellectual property related tasks.

In this chapter a survey of these works is presented.

3.1 Automatic patent functional analysis

Functional analysis is a powerful tool for conceptual design both for problem identification and innovative solutions generation: the functional description of a product is a description at an abstract level, so that different design solutions can be explored by developing functional variants. At the same time, functional analysis helps the designer in following a systematic approach also in the study of complex systems, by breaking up functions into simpler sub-functions and subdividing the problem into more manageable tasks.

According to these assumptions in [4, 5] a system for translating automatically the description of an invention into a functional diagram has been proposed. The methodology has been implemented in a prototype software tool, PAT-Analyzer, capable to identify the components of the patented system, perform a hierarchical classification of those components subdividing them in different abstraction levels, draw a functional diagram of the complete system and of the detailed subassemblies, therefore providing a graphical representation of the invention described in a patent. An exemplary diagram obtained by processing the US Patent 5,406,868 “Open End Wrench” is shown in Figure 1, where:

1) each identified component of the system is represented by a rectangle labeled with its reference number and the representative name defined in the Components Recognition phase; each identified component or subject external to the system is represented by a grey rectangle labeled with a representative name;
2) the detail level hierarchy is represented nesting the components at a deeper detail level inside the components at a more abstract level;
3) the functional interactions between the identified components are represented with straight arrows pointing from the Tool to the Artifact, labeled with the Field;
4) the positional interactions between the identified components are represented with dashed arrows pointing from the Tool to the Artifact, labeled with the Field.

By means of several types of score ranks it is possible to highlight the core of the invention, the most peculiar components and performed functions:

1) Detail Level Chart: on the basis of the components hierarchical classification performed in the text analysis phase, it is possible to assign a Detail Level (DL) to each TFA triad and/or to each paragraph: a DL is assigned to each component so that the maximum abstraction level is represented by a DL=0 and the DL of each subsystem is one level greater than the DL of the corresponding supersystem. The detail level of a basic sentence (TFA) is estimated as the average DL of Tool and Artifact; the detail level of a paragraph is the average DL of all the TFAs belonging to that paragraph. By analyzing the DL run along the description it is easy to identify the most relevant paragraphs and concepts of the inventions (it is worth to notice that if the patent description is focused on specific details of the proposed system, it means that such a part of the description is strictly related to the peculiarities of the invention).

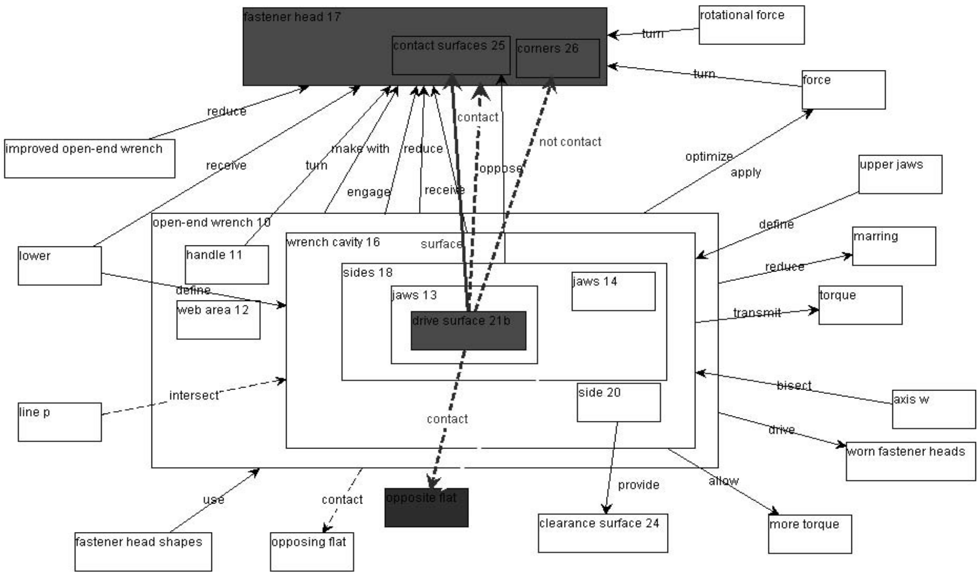

Figure 1: Functional diagram extracted from the US Patent 5,406,868 ‘Open End Wrench’. The color map highlights the sub-functions accomplished at a more detailed level.

2) Components Occurrence Analysis: by counting the citations of each component of the proposed invention (of course taking into account of the automatically extracted synonymous) it is possible to determine a relevance score of the components themselves; in order to improve the quality of such an estimation, different weights are assigned to the citations found in the title, abstract, independent claims, dependent claims (first level, second level, others), summary, description of the preferred embodiment.
3) TFA Occurrence Analysis: by means of the same technique adopted for the Component Recurrence Analysis, it is useful to assign a score to the functional and positional triads TFA. Also partial pairs of the triads (TF, FA, TA) are counted by means of the same set of weights. Therefore a rank of the most relevant sub-functions performed by the invention is determined, again in order to focus the attention of the user to the patent peculiarities.

3.2 Concepts mapping

The results of a patent analysis accomplished by means of the tool mentioned in the previous paragraph, can be further processed in order to extract a contents map of the patent itself. In facts, if the above described analysis allow to identify the core topics of the invention, for example by looking for the paragraph with the highest detail level of the description, further useful information can be found also in other sentences with a lower detail score, but still treating the same concepts.

By means of a TFA-based content analysis as described in [6], it is possible to create a map of the concepts disclosed in a patent. Basically, the technique consists in calculating for a given TFA identified as relevant for the examined invention, a TFA score for each paragraph, by weighting differently the occurrences of the Tool, the Field and the Artifact.

An exemplary application of this technique is shown in Figure 2, where the three top score concepts in terms of detail level of the US Patent 6,097,012 (Induction-heating bender) are mapped through all the patent text.

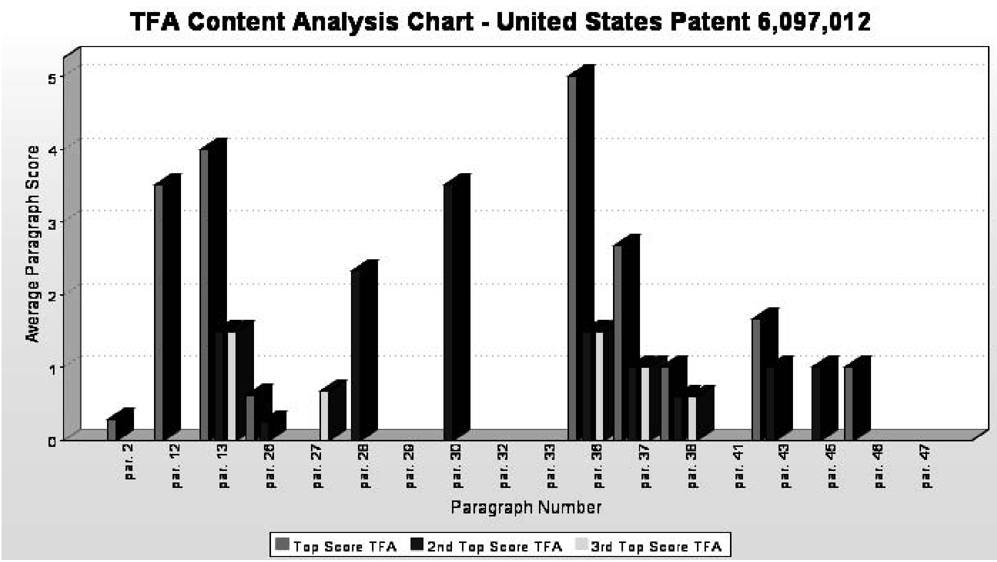

Figure 2. Content Analysis of the top score concepts identified by the analysis of the US Patent 6,097,012: heating and cooling system for non-uniform temperature distribution in the beam section (top score); rotating gripper head for variable bending radius (2nd top score); feeding mechanism (3rd top score).

Par. #	Text	Score
12	An induction-heating bender according to claim 1 wherein the heating-and-cooling mechanism comprises a heating coil encircling the workpiece to be bent and a plurality of cool compartments placed inside of the heating coil.	3.5
13	An induction-heating bender according to claim 6 wherein the heating-and-cooling mechanism further comprises at least one circular aperture and at least one elongate slot to cool the temperatures of the plurality of cool compartments independently.	7
28	As described above, the gripper 21 is rotatably fixed to the free end of the pivot arm 20 for gripping the workpiece M. At the opposite end, the pivot arm 20 is rotatably fixed to the square arm support 30 via an associated arm holder 37, as later described.	2.3
30	The pivot arm 20 is inserted in the square holder 37 by loosening fastening bolts 37a, and then, it can be fastened to the square holder 37 by tightening the fastening bolts 37a, thereby permitting the pivot arm to be set at a desired pivot-to-gripper distance. As shown in the drawing, the upright axle or pivot 36 of the square holder 37 is offset from the longitudinal axis of the pivot arm 20 horizontally in the direction in which the workpiece travels.	3.5
36	These coolant ejection nozzles 48 can eject different coolants at different flow rates, as for instance, follows: water may be ejected from one of these coolant ejection nozzles 48 at the temperature of 40.degree. C., and at the same time, air may be ejected from the other coolant ejection nozzle 48 below the temperature of 40.degree. C., preventing the hardening of the workpiece.	7.8
37	Referring to FIGS. 6A to 6D, coolant slots may be formed in place of the ejection nozzles 48 as shown in FIG. 5. These coolant slots are of different shapes and sizes for controlling the flow rate of the coolant. A linear arrangement of relatively small circular apertures 48a is appropriate for ejecting the coolant at a decreased flow rate (see FIG. 6A). A linear arrangement of elongated slots 48b is appropriate for ejecting the coolant at an increased flow rate (see FIG. 6B). An alternate, linear arrangement of circular apertures and elongated slots may be used for ejecting the coolant at controlled flow rate (see FIGS. 6C and D).	4.7
38	Referring to FIG. 4 again, the divisional sections 42i, 42f and 42h of the heating-and-cooling coil sub-unit 41 for heating and cooling the inner flange of the H-steel have circular apertures 48a and elongated slots 48b made for rapid cooling whereas the divisional sections 42a, 42b and 42c of the heating-and-cooling coil sub-unit 41 for heating and cooling the outer flange of the H-steel have circular apertures 48a made for slow cooling. The cooling of each flange at different temperatures permits the wrinkle-free bending of the H-steel.	2.2
43	Referring to FIG. 10, the manner in which the subsequent two meter-long section is bent at two meter-long radial distance is described. First, the pivot arm 20 is returned to the initial position in which the pivot arm 20 is parallel to the arm support 30, and the fastening bolts 37a of the square holder 37 are loosened. Then, the motor 34 is made to start rotating, thereby moving the carrier 33 two meters apart from the center of the heating-and-cooling mechanism 41. The turntable 25 of the gripper 21 is inclined at the angle .alpha. with respect to the longitudinal axis of the pivot arm 20 to be in conformity with the precedent, one meter-long section already bent (see FIG. 3). The fastening bolts 37a of the square holder 37 are tightened to hold firmly the pivot arm 20. While the workpiece is heated by the heating-and-cooling mechanism 41, the beam-like workpiece is fed forward by the conveyor 11, thereby allowing the beam-like workpiece to be bent. The turning of the turntable 25 in conformity with the precedent curved section of workpiece assures the smooth transition from the precedent to subsequent curved sections, which smooth transition cannot be attained simply by bending at different radial distances as is the case with the conventional bender.	2.7

Tab. 1: Summary of the US Patent 6,097,012 obtained by collecting the top score paragraphs, according to the analysis shown in Figure 2. The paragraph score is evaluated by summing the content score of the three more relevant TFAs.

By selecting the paragraphs with a score greater than a threshold value it is possible to identify a meaningful subset of sentences that constitute an efficient synthesis of the patent content, as shown in Tab. 1. It is worth to note that compared with standard linguistic summarization techniques, such an approach is strictly based on the contents of the invention description, therefore it is very well focused and no irrelevant concepts are included.

3.3 Patent clustering

In the previous two paragraphs the attention has been focused on the detailed examination of a single document; besides, while approaching the analysis of several dozens or even several hundreds patents first it is necessary to classify their content apart of the invention field of application.

As detailed in [7, 8], such a text mining task can be accomplished following a two step process: the Linguistic Analysis of documents allows to recognize the relevant descriptors of the content, whilst the Statistical Analysis uses those descriptors to dynamically discover the thematic groups that best describe the document categories.

The automatic Linguistic Analysis is based on Parsing, Morphological and Statistical rules [14, 15]. The Parsing analysis is based on a set of pre-defined rules, which specify the most relevant fields in patents and their main features: the label identifying the field of interest, or the masks that need to be applied to extract the main information included in the field (i.e. inventor name, assignee name etc.).

The automatic linguistic analysis of free textual fields is based on Morphological and Statistical criteria. This phase is intended to identify only the significant expressions from the whole raw text. This analysis recognizes as relevant terminology only those terms or phrases that comply with a set of pre-defined morphological patterns (i.e.: noun+noun, noun+preposition+noun sequences etc.) and whose frequency exceeds a threshold of significance [16]. The detected terms and phrases are then extracted, reduced to their Part Of Speech tagged base form. Once referred to their language independent entry inside a multilingual dictionary, they are used as descriptors for documents.

Indexation based on terminology detection is extremely reliable for managing any type of documentation, especially if it is technical and scientific.

Once the documents have been linguistically structured, they are clustered into thematic groups by using the Relational Data Analysis (RDA) method [17], whose greater advantage is that the resource consumption (process time and memory) is linear vs. the number of analyzed documents. The clustering process is carried on by linguistic and statistical criteria by using:

– grammatical categories as descriptors for documents (i.e.: proper names are the most valuable items for subject detection, adverbs are obviously not so important);
– semantic categories as descriptors too;
– filters for descriptors, assigning different weights to them and their values;
– an upper and a lower thresholds for descriptors values, so as to avoid considering noisy words (i.e.: an item, whose occurrence is systematically or relatively rare in the corpus, can be discarded, giving no additional information);
– a threshold for similarity.

An absence/presence table, describing the cross connection between the documents and the words they contain, produces the Similarity table: documents sharing lemmatas are then grouped into thematic clusters by the quasi-seriation of this table, each group identifying a topic, respecting the similarity criterion. The "weighted Condorcet criterion" is normally used to detect similarities among all the documents.

As an example, let's consider a study performed on more than 200 patents and scientific articles related to airbag and car crash tests. The selected data illustrates the classification problem, being each document characterized by a number of items which describe its contents: title and abstract lemmas, time/date, document type, classification codes which are partly overlapping and partly redundant, due to the fact that documents have been taken from different data banks.

The Text Mining analysis automatically detects nine groups of documents, each with highly distinctive characteristics. The results shown in Figure 3 are similar to what everyone would expect from reading these type of documents: the group of documents which deals with whiplash injuries is strictly linked to documents related to seat characteristics, head restraint, seat belt and cervical spine/vertebra.

It is worth to note that side impact documents, instead, are completely isolated from the others: it is intuitive to think that seat characteristics, head restraint, seat belt have a very low influence in limiting neck injures in lateral car crashes. Therefore, a simple reading grid is given to the analyst, who is able to access documents by contents and find out any hidden relationship among them.

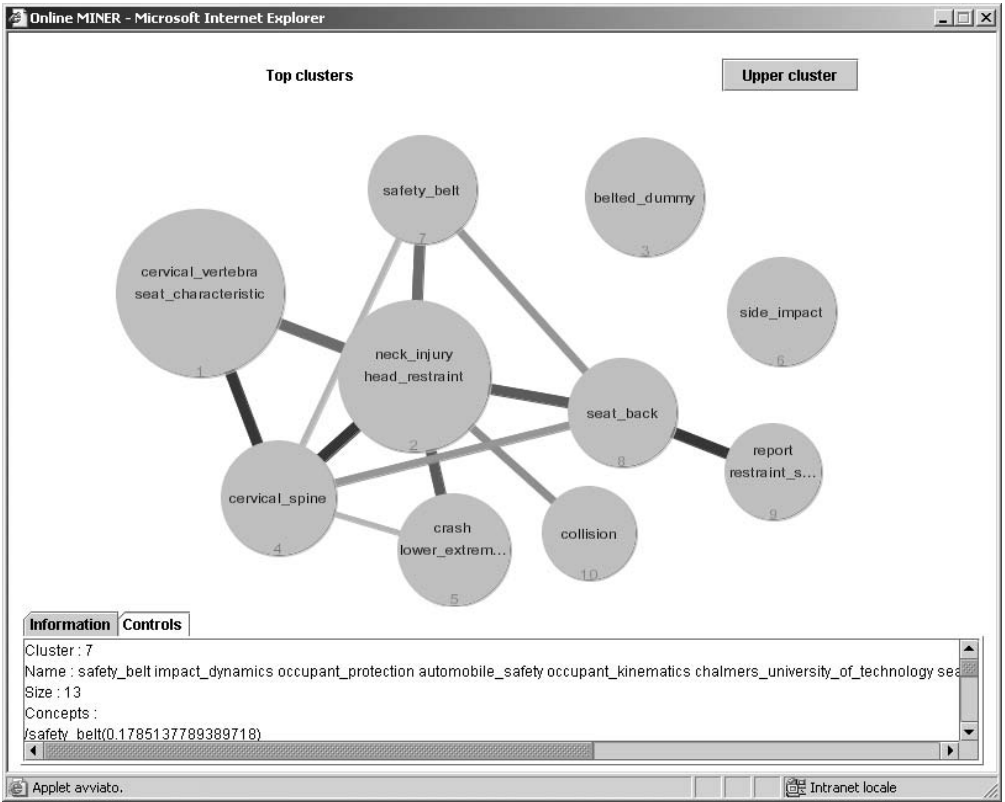

Figure 3: Automatic classification by clustering more than 200 patents related to whiplash injuries.

3.4 Multilingual searches

While big companies are usually familiar with patent searches both for strategic and technical activities, just a small number of small and medium enterprises make use of patent databases for improving their competitive means. Very often a big obstacle is constituted by linguistic barriers, therefore limiting the efficiency of free databases like esp@cenet.

In order to encourage SME participation in patenting and technology transfer opportunities the Wisper project (Worldwide Intelligent Semantic Patent Extraction and Retrieval [9]) has been developed with the aim of:

– providing customized content of publicly held patent data;
– employing techniques of deep level data mining and developing partial ontologies of the patent domain;
– developing techniques for search on figures, drawings, and images, opening up a whole new realm of web-based semantic information in patents;
– supporting Natural Language Information Retrieval, producing results in native language from texts in different languages;
– maintaining a user profile of previous searches, preferred language and areas of interest.

The prototype automatically recognizes sentences written in five natural languages (English, French, German, Italian and Spanish) basing on wide monolingual dictionaries and grammars. Synthema monolingual lexicons have the following sizes:

– English 100.000 lemmas,
– German 70.000 lemmas,
– French 55.000 lemmas,
– Italian 62.000 lemmas,
– Spanish 42.000 lemmas.

The prototype also uses a multilingual lexicon specifically created starting from the English catchwords retrieved from the IPC 7 version. Each English catchword is tagged with class information and translated into the other four supported languages. The translation work, which has started from the B class, is still in progress.

The user can enter a query phrase in his/her own natural language. The prototype performs a morphosyntactic analysis of the query and identifies the user language and relevant terms, then looking for those terms in the local DB shows the query results in the IPC List and relevant catchwords in the homonymous panel (Fig. 4, above).

It is now possible to tune the query in 2 ways: by class or by catchword. The panel IPC List shows the list of relevant IPC codes with their description in the user language. Choosing one or more classes in the IPC List window, it is possible to obtain all the patents of the selected classes from local DB (Fig. 4, middle).

The catchwords panel shows the relevant terms extracted in the user language, the related IPC code and the corresponding terms in all supported languages. To retrieve patents, the interface lets the user check the language he is interested in.

While browsing the results of the query, the user can ask for an automatic translation of the patent into his language (Fig. 4, below); it is clear that the quality of machine translation is not high. Anyway, even if not all sentences may be linguistically correct, the translated abstract may absolutely help a user in understanding the content of the invention.

At the present stage of the project, all the (38) B62B catchwords are correctly recognized in all the five languages. A test performed on other 100 catchwords of the B CLASS revealed the following coverage: all the English catchwords are recognized; about 70% of them are recognized in French and Italian; about 40% of them are recognized in Spanish and German.

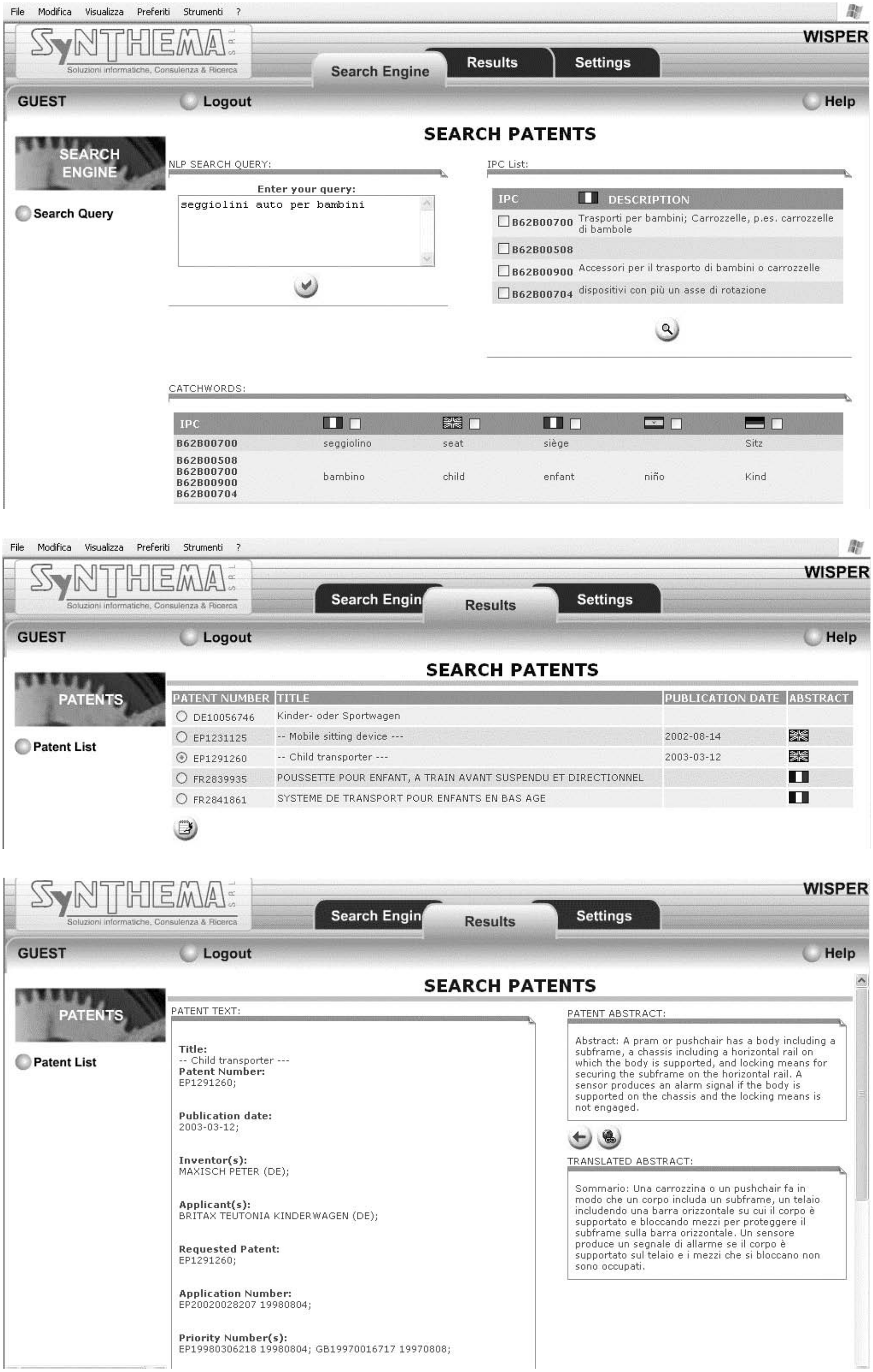

Figure 4: Wisper multilingual portal for intelligent access to massive patent databases.

4. Towards a multi-language multi-level Patent Mining platform

On the basis of the complementary competences experienced by the authors, University of Florence and Synthema srl have established a collaboration aimed at integrating the patent mining capabilities presented so far.

By combining the functionalities described in the section 3 of the paper, it is possible to implement a platform to be tailored according to specific customers requirements with the following general characteristics:

– multi-language queries for patent retrieval;
– patent classification based on the free textual description of the inventions and identification of not evident conceptual links among patent clusters;
– graphical representation of inventions functional architecture;
– identification of the core concepts disclosed in each patent and pertinent paragraph extraction for patent summarization.

Furthermore new opportunities arise from this integration, once more confirming that a proper collaboration is more effective than a trivial sum of capabilities.

First, the clustering algorithms can be applied not just to the descriptors extracted following the approach presented in par. 3.3, but to the outputs of the functional analysis described in par. 3.1, i.e. to the list of components of an invention or to their functional relationships. Otherwise, the standard descriptors extraction can be applied not to the whole patent text, but just to the most relevant paragraphs identified according to the par.3.2 methodology. Both these original techniques are very promising in terms of capturing inventions peculiarities and semantic relationships. In facts, it is worth to notice that compared with available “semantic” technologies merely based on text syntactic parsing, in this case e real semantic analysis is performed by associating components, functionalities and roles.

The preliminary tests aimed at checking the efficiency of the proposed technique were very encouraging even if accomplished on a restricted number of patents in the field of medical diagnosis x-ray apparatuses. A more careful validation is in progress in the high-tech textile field and will be detailed in a next publication.

Another relevant novelty is constituted by the capability of providing an even rough translation of the summary of an invention, not based on the abstract written by the inventors, but on the paragraphs selected according to their relevance score.

5. Conclusions

In order to face the unmanageable size of technological information sources, means for speeding up reading capabilities are necessary for any product development activity.

It has been proven that the application of linguistic analysis techniques to patent documents allows efficient information retrieval and classification, but still a lot of opportunities for improving patent mining efficiency can be exploited.

In this paper, after surveying commercially available systems, the patent mining capabilities of the technologies developed by the authors have been presented. The complementarities of these experiences have suggested the integration of such functionalities in a patent mining platform capable of providing an useful support to any level patent management activity, both to expert analysts and sporadic users (as for example designers in SMEs).

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INNOVATION STRATEGIES: FROM SMEs TO WORLD WIDE CORPORATES

TRIZ IN SMALL BUSINESS-COMPETITIVE ADVANTAGE

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"Theory of solving inventive problems may be considered as a prototype of effective thinking which excludes significant mistakes. More precisely - general principles of strong thinking that are used in TRIZ".
Altshuller G.S., Rubin M.S. (1987)

Abstract
TRIZ mechanisms can be used not only for solving technical problems but for business problems as well. TRIZ is most effective for small business development. TRIZ methods can be used together with other known methods of business analysis such as SWOT-analysis, Boston matrix, etc. Enlargement of the field of TRIZ use requires changing and adapting some TRIZ mechanisms. There are common laws of material systems development – techniques, business, nations, etc. Due to these laws it is possible to use single mechanisms of development, to form an effective thinking which is essential for taking strong decisions.

In recent years one of the main issues of developing TRIZ as a theory has been the following: does TRIZ belong only to technical field or the range of its application is rather broader. Altshuller G.S. and many other TRIZ authors wrote that TRIZ methods can be applied to a wide range of other fields of human activity.

In the past natural resources were considered as the main basis of economical development. At present the basis is technology while in future this basis would become technologies of creating technologies, creativity technologies and strong thinking technologies. First of all this relates to the use of TRIZ in business.

TRIZ can be widely used together with other methods not only when solving inventive problems but at all stages of development and activity of business. Special significance TRIZ has got in the sphere of small business where rapid situation change, highly competitive environment, limited resources and many other factors provoke many problems. Experience of TRIZ application has shown the effectiveness of TRIZ methods for solving different problems of a small company: evaluation of business ideas, drawing out strategy and tactics of the development, drawing out marketing plan and carrying out marketing studies, pricing, business-planning, management, staff administering, holding negotiations, competitive struggle, establishing partner ties, market stimulation, financial management, etc.

First of all the peculiarity of small business is its need for rapid adaptation to changing environment. The staff is quite small, so employees should be universal specialists able to take bearings in new fields, take decisions with lack of information, etc. Small companies often can not turn to outside advisers because of limited resources. Small companies can't afford serious mistakes in business since their activity is connected with high risks. All this shows the importance of the use of TRIZ methods in small business for developing technologies and solving management, marketing and other business problems. TRIZ use is most significant for small innovation enterprises in which typical problems of small business (risks, lack of resources, etc.) are very acute.

1. Profitability tends to infinity.

At one of the seminars we have discussed a typical business problem.

Producer of patties finds out that price of flour and some other products has been increased. He must also advance the price to keep profitability of business. Here a contradiction appears: if he increases sale price then he keeps profitability but the demand becomes lower.

Usually the following methods are suggested to keep the price in such a situation: to buy stuffs of lower quality, make half-empty patties to keep the size and so on. Anyway loss of quality leads to another contradiction. In order to settle the initial contradiction the producer must increase the price so that the demand would not decrease.

One of TRIZ principles is transition from mono-system to bi-system. In this case it means transition from one to two sorts of patties. One of them should be small and cost less than it did before the rise in prices. Another sort should be bigger but its price should be higher also. But for all that the price should be changed not in accordance with the patties' size but so as to keep or even increase the initial profitability in spite of rise in prices of ingredients. Two products instead of one give additional consumer qualities and allow learning more about the demand. Such method of diversification may be used in many other situations.

All known methods of business analysis are aimed at improvement of the existing situation. It is possible to compare sales volumes of different products, take a decision of stopping sales in time. Only TRIZ suggests methods of creating new products which provide qualitative change of price/costs ratio.

Another example from consulting practice.

When carrying out TRIZ analysis of hydroelectric power stations cascade (Murmansk region) the electric boiler-house was determined as a problem area. It was the less economically effective subdivision: electricity costs, heating systems repairs and other costs exceeded the income. At the same time it was impossible to deprive the settlement of electric energy. It was revealed that profitability of this subdivision was much lower than one.

After TRIZ analysis a decision was suggested. It allowed to get rid of the problem of pipes corrosion, to stop spending money on the electric boiler-house including salaries, to avoid heat loss when transmitting it form the boiler-house to flats, to make the service profitable for the enterprise.

Ideally according to TRIZ methods the function (heating of houses, buildings) should be maximal while expenditures should be minimal or even equal to zero. In this case profitability really tends to infinity. Our suggestion lied in liquidation of electric boiler-houses and installation of individual heating systems in the houses and buildings. At the same time there was no need to reconstruct power grids since the capacity was enough.

One more example from small business practice of the Republic of Karelia.

A few years ago Petrozavodsk administration has set very high dues and fees for licenses for sale and fast food organization on the city embankment – one of citizens' most favorite places for spending their free time especially on holidays. The action was aimed at replenishment of the treasury. Businessmen could do nothing to change the situation.

A well-known for his original ideas businessman has bought an old barge, moored it to the embankment and established fast food points on it. The barge does not belong to the city administration so it can't make the businessman to pay dues… At the same time an additional consumer effect appears since cafe on the water attracts many visitors.

New ideas, which increase the degree of business-system ideality, increase profitability of this business as well. TRIZ is able to create the ideas which can be converted into additional income.

2. TRIZ methods for business

The sphere of TRIZ application mainly deals not with some fields of civilization activity (development of technologies, industry, business, science, art, etc.) but with technology of creating something new, inventing methods which had been unknown before.

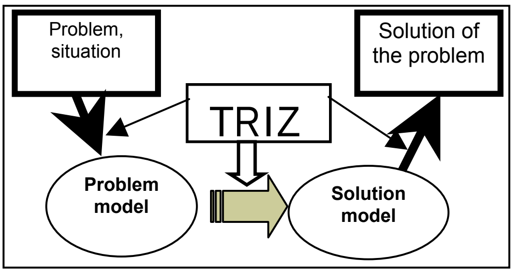
Since ancient times civilization has developed on the basis of trial method according to the system of natural selection. For example, bad boats or ships have never come back; carts which could be broken easily have been never built again. This method is widely used in business till now – ineffective solutions lead to bankruptcy. At present models of large-scale objects are used to test some strategies. This method is rather cheaper and safer. A well-known method is modeling of business in business-plans. The next step is transition from real models to mental modeling on the basis of trial method again. TRIZ allows humanity to make another step forward in projection development. The idea lies in the use of manageable thinking (instead of trial method), qualitative change of business model on the basis of overcoming contradictions and coming closer to an ideal end result by means of the most effective use of resources.

In TRIZ two main groups of methods can be marked out:

- methods based on revelation, analysis and overcoming of contradictions in the examined system (Algorithm of inventive problem solving, contradiction matrix, etc.);
- methods based on revelation of laws and tendencies of development common for systems (lines of technical systems development, system analysis technique, su-field, etc.).

There are methods which unite both approaches for example these are the standards for solving inventive problems.

In TRIZ as well as in chemistry, physics, mathematics and other sciences, various models for the initial inventive situation representation are used. Process of solving inventive problem may be figured as a scheme: transition from description of a real situation or problem to model of the problem, then to the solution model (using TRIZ methods), and finally to a real solution. At that both methods based on revelation and solving contradictions and methods based on the known rules of systems development may be used.



All basic TRIZ mechanisms which have been first created for solving technical problems can be applied to other fields including the one of business. For example, formulation of the *contradiction of demands (CD)* can be an analogue of formulation of technical contradiction. If speaking about the problem of opening fast food points in Petrozavodsk the following contradiction took place: it is good to set up these points on the embankment since there is an opportunity to increase profitability of business and it is bad as the administration makes businessmen pay high dues for the permit.

As about analogue of physical contradiction in business it can be *contradiction of characteristics (CC).* In the situation mentioned above this contradiction may be formulated in the following way: fast food points should be placed on the embankment to increase the income; at the same time they should not in order to avoid paying high tax.

Business-systems as well as technical systems are based on realization of some functions. That is why formulation of *an ideal end result (IER)* is applicable: function of the system is being realized while there is no holder of the function; number of the functions increases while costs of their realization tend to zero.

It is a well-known fact that many *principles and methods* of solving technical contradictions can be applied to resolving contradictions of demands: division of conflicting objectives in space and time; principles of Blessing in disguise, “The other way around”, Dynamics, Merging, etc.

Analysis and application of substance-field resources (SFR) is an important instrument for solving business problems. In business as well as in technical problems it is necessary to find a conflicting pair, determine easy-changeable and difficult-changeable elements, operation time of the conflict, etc.

System analysis technique, su-field analysis as well as most of other TRIZ methods can be used when analyzing business problems taking into account peculiarities of this activity field. For example, when solving business problems various resources and effects can be used: economical, financial, administrative, social, psychological, etc.

When working on business problems some TRIZ methods should be changed, some should be added to the existing tool kit. This issue will be discussed in section “How business changes TRIZ”.

In business lots of different methods are used for analysis. Among them: SWOT-analysis, Boston matrix, FAB-analysis, etc. The use of these methods together with TRIZ allows us not only to analyze the development of business and evaluate a certain situation but also find absolutely new solutions.

3. SWOT-analysis on the basis of TRIZ

One of TRIZ methods’ peculiarities lies in their ability to be combined with other methods of analysis. SWOT-analysis is a well-known method of business analysis and development strategies selection. It is simple and universal; however there are some disadvantages. Among them are the following: quite often not specific characteristics and weaknesses which are not attached to a certain object are formulated; there are no instruments for solving problems revealed by the analysis as well as reliable criteria for quick evaluation of the proposed solutions quality. An improved SWOT-analysis is suggested. Within this refined analysis these disadvantages as well as some others are partly removed due to the use of TRIZ methods.

The method consists of 7 stages:

1. Working out a list of the examined system (situation) elements.
2. Working out SWOT-table, determining connections between the elements over the period under view.
3. Choosing two clashing elements (conflicting pair).
4. Formulating contradiction of demands.

5. Analyzing contradictions and searching for solutions with use of TRIZ methods.
6. Formulating suggestions on development (resolution) of the initial situation.
7. Testing efficiency of the selected solution.
It is better to present the method by a concrete example.

Example. Description of the initial situation.

A well-known international program chooses the main executor of a large-scale consulting contract. Two companies pretend to perform the contract. One of them is a recently established small company ("Business development agency"). The other one is a strong and influential rival company which has got stable international contacts; however its activity field does not quite match the project. The rival company suggests companies uniting in order to use advantages of both of them. The one should analyze the situation and make "Business development agency" to get the contract. Otherwise small company which has just started working may go out of business.

1. Working out a list of the examined system (situation) elements.

It is necessary to point out all the basic elements (parts) of your organization, activity or situation as well as main elements of the super-system to which they belong. Number of elements should be enough to represent it correctly. Secondary elements should not be listed. Abbreviations and symbolic notations may be used for marking elements.

	External environment	Internal environment
Positive	**Strengths**: - name and mission of the "Comp" do not fit technical task "In-Cont" best; - "ADB-founders" – if the decision of "In" is evidently groundless, the founders would defend interests of the Agency;	**Opportunities**: - "ADB" and "ADB-mission" – name and mission fit technical task of the contract ("In-Cont"); - "ADB-Qualify" – high-qualified staff of the Agency;
Negative	**Weaknesses**: - "In" prefers "Comp"; - in fact merging of two companies means absorption and failure of "ADB" agency since it has no assets; - "ADB" agency has not got such great experience of international connections as "Comp";	**Threats**: - "ADB" agency has not got premises and equipment of its own; - rejection of merging with the competitor would be taken as rejection of cooperation with an experienced partner, inability to work in team. This would lead to the refusal of the contract.

Example. Important elements of the system (shorthand notation is in brackets): name ("ADB"), mission and company profile ("ADB-mission"), founders ("ADB-founders"), qualification of staff and governing body ("ADB-Qualify").

Important elements of the super-system: international program ("In"), technical task of the contract ("In-Cont"), competitor ("Comp"), current legislation and environment ("Leg").

2. Working out SWOT-table, determining connections between the elements over the period under view.

It is necessary to keep to the elements pointed out at the 1st stage when formulating statements. Some elements of the initial situation may be its advantages and disadvantages at the same time.

3. Choosing two clashing elements (conflicting pair).

It is essential to pay special attention to the elements which belong to both positive and negative sections of SWOT-table. It is possible to find and analyze a few conflicting pairs.

Example.

- "ADB" agency clashes with "Comp".
- "ADB" agency clashes with representatives of the international program "In".

4. Formulating contradiction of demands.

Contradiction of demands should be formulated for one of the conflicting pairs which were pointed out at stage 3. Preference should be given to the conflicting pairs which include elements that you can manage from your position. Contradiction formulation should include opposite demands of the same element. If it is impossible to formulate contradiction on the chosen level then subsystems should be analyzed: of which of them the opposite demands are made.

Example. The first pair is selected as it includes more manageable elements – it is easier to control "Comp" than international program "In".

"ADB" agency should agree to merge with "Comp" in order not to conflict with "In" representatives. At the same time it should not agree to be able to control negotiations when making the contract.

5. Analyzing contradictions and searching for solutions with use of TRIZ methods.

All basic TRIZ mechanisms applicable to social and business systems must be used. Among them: determination and analysis of operational zone and operation time of the conflict, formulation and analysis of characteristics' contradictions, revelation and analysis of resources, determination of an ideal end result, use of principles and methods of resolving contradictions, etc.

Example. In the present situation changeable (manageable) elements are "ADB" agency itself and partly "Comp". "ADB" has almost no resources of its own; main part of resources belongs to the competitor. Ideally "Comp" should act so that "In" representatives dismiss "Comp" and prefer "ADB" agency as executor of the contract. "Comp" presses toward union. If "ADB" resists it then it certainly loses the game. The striving of "Comp" for merging is the main resource for problem solving. Analysis of subsystems shows that the merging itself consists of a number of elements: agreement, terms, decision-making procedure, etc.

6. Formulating suggestions on development (resolution) of the initial situation.

Now it is necessary to go on from hints and ideas to working out some concrete suggestions which meet best the formulations got at stage 5.

Example. It is necessary to work out such form of merging which would suit interests of "ADB". There are two possible ways: first, "Comp" itself provides for entire transparency of merging and makes "ADB" a full partner, second, "Comp" acts as a conflict and incapable for cooperation organization and this makes "In" dismiss it.

Agreement on joint activity of the companies is chosen to become an instrument for realization of this strategy.

Strategy which implies that "ADB" agrees to unite with "Comp" was suggested. At the same time work on the unification should be divided into two parts. This means that "ADB" drafts an agreement on joint activity while "Comp" works out all basic clauses.

7. Testing efficiency of the selected solution.

Was the contradiction resolved? How close the solution is to an ideal one? How SWOT-table will change? If necessary repeat the analysis starting with stage 1. It is recommended to analyze the initial situation from the point of the opposite party. What strategies can be used against you? What can be done to be prepared to face them?

Example. The described situation is a real fact. After “ADB” agreed to merge the situation became less tense. “ADB” did not have much to do since there are samples of joint activity agreements in all law reference books. “Comp” felt sure that the situation would be settled successfully. That is why it did not take any steps, neither attracted additional resources. At the same time acuteness of the conflict moved to it. “Comp” could not work out clauses of the agreement as it did not want to declare its aggressive intentions or because of inability (there was not enough competence) to depict future allocation of functions, responsibilities and expenses of the parties to the agreement. Several months passed “Comp” started irritating representatives of “In” with inactivity. They did not have enough time to continue the talks. “Comp” failed to fulfill its part of work. “In” representatives had to give preference to “ADB” agency since there was no agreement on merging.

There is another example of effective and successful strategy in the situation which seemed to be desperate.

Two years ago one of organizations of Russian holding company was attacked. The act of aggression was well prepared, lots of resources were used. If the holding company started defending this organization it would lose other subdivisions one by one. Here was a contradiction since the company had to protect this organization to keep the holding company in one piece and at the same time it had to leave the organization alone in order to keep resources for future development and not to give a chance to the aggressor to use actions of the holding company against it.

The situation was analyzed with use of TRIZ instruments. This allowed developing an appropriate strategy. It was decided to leave the weakest subdivision of the company. The aggressor was unprepared for such a step. Since the resources were quite limited an IER was used: one of the strongest subdivisions of the aggressor was invited to become a partner to the rest of holding company. The attack stopped, company remained safe and sound and continued developing. The lost organization was set up and became part of the company again (it is a well-known TRIZ principle of reject and regeneration of system’s parts).

These examples show that even small companies with lack of resources always have an opportunity to win competitive struggle if they use correct strategy and all possible resources even those ones which first were against them. TRIZ gives competitive advantage in business even if there is a minimum of resources.

4. Application of TRIZ methods together with “Boston matrix” and other methods of business strategy planning.

Matrix by “Boston consulting group” allows to determine prospects of goods (services) which a company sells, to analyze assortment of portfolio and prospects of this or that good (service) of the company. This method is well-known and widely used for planning strategies of business development.

Vertical axis shows market share of each product; horizontal axis reflects tendencies of the rate of market share growth in this market:

- “Difficult children” – huge investments are needed to turn the product into “Stars”

Market share	High	Low	**Rate of market growth**
Big	“Milkers”	“Star”	
Small	“Dogs”	“Difficult children”	

- “Stars” – the product can bring enough profit to maintain its own existence; however some financial difficulties may take place
- “Milkers” – the product brings lots of money which may be used to turn “difficult children” into “stars” but in the near-term outlook only
- “Dogs” – demands great attention from administration, a decision to stop producing these goods may be made. “Dogs” can turn into “difficult children”.

“Boston matrix” has some disadvantages: only two indicators of the product’s market position are used; there are no mechanisms for working out qualitative changes of the product/service or promotion strategy, etc.

The method can become more effective if used together with TRIZ mechanisms. Each point of “Boston matrix” has typical contradictions which are connected with either keeping present market share or necessity to move to another position.

As an example one of the most complicated situations will be used. It is characterized by small market share and low rate of development (segment “Dogs”).

The development of Karelian Leasing Company (Russia) may serve such an example. KLK started its operations in 2002. The basic service is leasing equipment and cars for small companies. Owned and debt capital was not enough for stable functioning of the company. Some other leasing companies worked in Karelia. They were attached to banks and disposed of cheap credit resources. KLK was close to the bankruptcy because of low turnover and yield. Such problems are typical for this position of “Boston matrix”.

A contradiction appeared. On the one hand, KLK needed to attract additional means to the authorized capital stock, for example the company could invite some bank or financial corporation to become a new founder. On the other hand, this could lead to great difficulties in future. If a new founder comes to the company, acting owners lose control and possible benefit.

At the same time KLK may be deprived of a quite unique service. Usually banks lay down additional conditions for clients of leasing companies attached to these banks. According to the demands clients of the leasing companies can establish accounts only in these banks. Such a situation can frighten many people away and especially representatives of small business. This way KLK may lose many of its clients.

Finally, it may happen that the bank, having a large share in the leasing company, starts establishing special conditions of credit granting; it can also limit use of financial resources of other banks or introduce some other limitations.

Contradiction of demands: KLK needs to attract additional investments in order to increase turnover of the company; at the same time it should not do this because otherwise KLK may become totally dependent on the investor. Ideally it should be leasing services of KLK that would make financial resources increase and this way help the company to avoid attracting investors. Thus an absolutely special idea appeared – to make micro-leasing the core service of KLK. This means leasing of very cheap equipment. The leasing companies which are attached to banks are not interested in such services since they are not profitable, they strive for large-scale expensive deals. So, KLK entered a rather free market of small business. Representatives of small business usually do not turn to big leasing companies as they can not afford this or find it inconvenient. Micro-leasing allowed the company to increase ratio of capital turnover and profitability of deals. For the last year sales volume of the company increased 323%, profitability grew up. This means that the new market strategy and service allowed the company to move to the next segment of "Boston matrix" – "difficult children".

This example shows that the use of "Boston matrix" as well many other well-known methods of business analysis together with TRIZ methods allows not only to reveal business problems but also to work out absolutely new and effective development strategies.

5. How business changes TRIZ

TRIZ mechanisms can be effectively used not only together with SWOT-analysis and Boston matrix but also with many other methods of business analysis. The way cinematography has turned static photography into permanent motion, TRIZ turns methods of business analysis into methods of analyzing the development of business.

Enlargement of the field of TRIZ use requires broader understanding of its basic mechanisms. The word "invention" should be taken not only as some technical invention but also as an administrative invention, business invention and so on. Sometimes it is impossible to determine the field to which the initial situation belongs: it may be techniques, economy, law, interpersonal relationships, etc.

When using TRIZ methods in business it is necessary to take into consideration a number of peculiarities. We will list just a few of them.

When solving business problems one should understand that elements of the initial situation are subjective. It is essential to find out from whose point of view you solve the problem from the very outset. Sometimes this division between "we" and "they" promote significant progress. In some situations carrying out such an analysis is an inventive problem itself. For example in the problem of "ADB" agency the selected tactics allowed to determine if another company is a partner or a competitor which is incapable of cooperation. Of course, such situation can't appear in technical systems.

The term "field" in business-systems differs from the one in technical systems. Any interaction between elements (psychological, juridical, functional, etc.) of the system involved can be the field. Typical example of field in business-systems is a set of consumer qualities of some good or service. That is why when selling a washing machine sometimes in fact such its quality as "silence" is being sold; speaking about sale of a car the producer may sell its "status level". In business determining quality of such a business field can be an independent problem. For example, at FAB-analysis (Feature; Advantages; Boon), which allows determining consumer characteristics of a good or service.

Nature of the interaction field in business-systems predetermines different characteristics of conflict space and zone. It is not a physical space like in technical systems but rather a topological space which is comprised of conflicting elements and connections between them.

In business it is very important to determine the rank of the problem in time (century, long-term, momentary) and space (world, state, city, district, company) properly. The level of the used resources and tools must correspond level of the problem.

One of the most important business resources is time. In some cases simple inactivity can be a solution even in the most conflict situations.

In financial systems we can see that ideality level is increased not by means of reduction of costs but by means of gradual increase of the number of the functions performed. For example, in the course of time a simple bill of debt turned into a bill of exchange - one of the main elements of the modern financial system. The same situation we find in leasing - common rent became a financial instrument with many economical and financial functions and effects. It is typical for non-technical systems that ideality is increased first of all by means of enlarging the number of functions.

In contrast to techniques, there are no invention databases in business. Not all methods which are applied in technical field can be applied in business. Some other effects can be used: not only technical and physical but also psychological, social and some others. In technical sphere there is often a plenty of time for solving some problem while in business time is limited and there are only some hours or minutes to take a decision. There is also a difference between the notion "novelty" in business and in techniques. Some other differences and peculiarities can be mentioned which should be taken into consideration when developing TRIZ in business.

Transition from technical analysis to analyzing the initial situation from various points of view (economical, legal, financial, administrative, etc.) enlarges the number of possible search directions and resources for solving the initial problem. This may be compared with transition from search in one-dimensional space to search in multidimensional space.

Here is an example. In 1992 we faced the problem of control of coal quality at Apatity heating and power plant (Murmansk region, Russia).

The main expenditures of heating stations lie in acquisition of coal. The amount of produced heat depends on quality of coal: the worse its quality, the more coal is needed.

Control was based on technology approved by state standard (all-Union State Standard). This technology provided for a rather complicated procedure in order to ensure objectivity of coal quality evaluation. The procedure required lots of descriptions, regulations, schemes, etc. It took three days to perform the whole procedure. For this time stock of coal is usually already burnt in fire-chambers and so it is impossible to assert a claim to the supplier. The heating station gets into great mischief. The problem was settled: the technology must be improved so that quality of coal could be determined in at least two days. The problem was very difficult since we had only one day to solve it because the Board of Directors needed an idea of the existing technology modernization.

After specification of coal quality control technology we found out that there was an instrument in chemical workshop which could evaluate the quality of coal in short time (about several hours). The result was not absolutely precise and did not meet the state standard so it could not be used for asserting a claim to the supplier. Merging of two technologies could become a solution, but there was not enough time for analysis.

Next day we presented an ideal solution of the problem to the Board of Directors. It was suggested changing the supply agreement and adding a clause of using the technology of express-analysis for evaluation of coal quality instead of referring to the state standard. The station would not conclude treaties with those suppliers who resist this new clause. This alteration of agreement saved large sums of money for the heating station.

This example shows that initial situations which are formulated like technical problems may have solutions on different levels: in this case on the legal one. Some other situations may take place when an organizational or business problem may have a technical solution.

6. About the unity of business-systems and technical systems development

It is obvious that it is not just an occasion that TRIZ methods which have been worked out on the basis of technical systems analysis, can be effectively applied when solving business problems. There are some laws of development that are more general if comparing with techniques and business. The author has carried out research in this field in the context of developing Theory of Material Systems Development (TMSD).

Most of TMSD concepts can be easily applied to business development. For example, in TMSD "substance" is regarded as any system, which is represented as a single unit (substance) with a certain characteristics set, in the model involved. So, the substance can be: an employee, subdivision of a company, single companies or even a number of companies united by common functions and characteristics. Such unified substance can be an element of the model in the analyzed development process.

Such TMSD terms as system ontogenesis (development of an individual concrete system) and system phylogenesis (development of generalized abstract systems) can also be important for business. For example, when analyzing some business problem it is necessary to determine the level to which it belongs. If the problem relates to a certain type of business generally (all trade organizations, all grocery stores, all stores of the city or a certain street, etc.) then it is a problem of the system phylogenesis. Vice versa if the problem relates only to your business then it belongs to the system ontogenesis. After determining the level of the problem it is necessary to find a method for solving it. One should keep in mind that instruments for solving the problem and the problem should belong to the same class. For example, if the problem of fast food points was related to problems of all Petrozavodsk companies working on the embankment then it would be a complicated social problem. At the same time if the problem is formulated as an individual problem (mini-problem) then it is easier to solve it.

The main TMSD laws allow examining rules of systems development in various spheres of human activity from a single point of view. So the law of tendency to seizure of surrounding and keeping of own resources (substance – energy – space – information - time) can be used for business systems analysis directly. In the situation dealing with holding company seizure (section 3 of the article) processes of seizure through different resources were analyzed.

Another law of simultaneous development on a few system levels is necessary for business analysis as well. For example in the problem of cascade electric boiler-house it is important to see several system levels at once. These are: level of all electric boiler-houses of the world; level of a single subdivision of hydroelectric power stations cascade of Tulomsk; level of the boiler-house as an independent organization, etc. There are certain rules on each level. Sometimes they may be adjusted with each other; sometimes there may be some contradictions between them.

General laws of material systems development form single principles of creative thinking for different activity fields of the human being. For example, the main principle lies in the statement that any thinking is the process of creation and changing (development) of mental models. One should understand that any business starts with its mental model, a so-called business idea. General principles of thinking of a businessman, engineer, scholar, artist or housewife are common. They are always based on mental models transforming.

Any mental model is comprised of its elements, connections between them, aims and/or functions of the system involved. One should strive for creating the simplest models which reflect the system best. It often happens that there is the need for two or more models at once (principle of two-model or multi-model) for representing the same system or process in order to provide deep understanding of processes and decisions. For example, when developing strategy of interaction with business partner one can proceed from two different models at the same time: the partner is really willing to cooperate and build a joint company or he just uses the mask of partner to seize and destroy your business. This took place in the situation involving "ADB" agency: the situation was created in which the competitor could not show itself as a real partner and thus lost the game.

In the most complicated and conflict situations of your business development it is essential to be able to conceive the situation as an independent and, if possible, simple model which can clarify the problem. You can do whatever you like with this model even most terrible and reckless things such as to make friends with competitors, fire irreplaceable employees, produce unprofitable goods, etc. Experience shows that such style of thinking allows drawing out tactics for escape from deadlock and thus creating business development strategy for the next years. TRIZ promotes strong model decision which is essential for taking effective business decisions.

When developing mechanisms of business-systems development and solving creative problems different laws and principles, which have been discovered while researching various spheres of material world development (techniques, biology, economy, ecology, sociology, etc.), can be used.

7. TRIZ as an element of business-education

Taking into consideration the effectiveness of TRIZ methods and their ability to be combined with methods of business analysis it seems very important to introduce some TRIZ elements into training programs for businessmen and business advisers. The author started working on TRIZ training program for businessmen in 1992. Representatives of different spheres of business have underwent these course – bankers, insurance companies employees, exchange employees, managers, representatives of small business. Training courses for 40-60 hours have been worked out. They include basic TRIZ elements, simplified version of ARIZ, independent tasks. Such seminars are in popular demand among representatives of small business. Since 2000 TRIZ seminars are being organized for the representatives of small business of the Republic of Karelia in the framework of the state program of small business support. TRIZ becomes an important instrument not only for engineers but also for businessmen.

The use of TRIZ in various spheres of human activity (techniques, business, science) makes it an essential part of thinking and culture of the human being.

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INNOVATIVE ENTERPRISE INFRASTRUCTURE

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Abstract
This paper discusses why automation still fails to increase innovative capabilities of organizations and proposes infrastructure based on Systematic Innovation to improve innovation management and increase innovative productivity. We discuss four major components of the innovation infrastructure: core systematic innovation team; knowledge sources, innovation management, and relevant IT support. We believe that it is necessary to focus on even development of these elements inside an organization to achieve maximum of success and provide long-lasting effect on enterprise-wide innovative effectiveness.
Keywords: Systematic Innovation, TRIZ, innovation infrastructure, innovation management.

1. Introduction

Efficiency of innovation depends on our capabilities to produce successful ideas that can be realized in form of viable products and technologies. Thus we deal with the issue of productivity: once an enterprise is willing to stay competitive, it must be capable of permanently raising and maintaining innovative productivity. Today, any enterprise involved to the development of new products and technologies increases its productivity via growing 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, while being busy with Systematic Innovation, 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 four key elements of modern innovation structure and their relationships: methodology, knowledge, IT support, and management.

2. Creativity vs. Automation

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 trigger it nevertheless.

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.

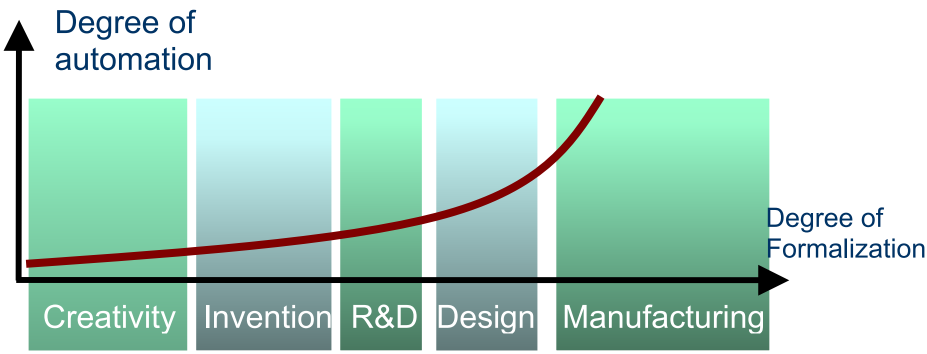

Figure 1. Formalization vs. automation during product development

It is not a coincidence that modern software development efforts are focused on information management, 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.

3. 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 [Altshuller, 1999]. A key idea behind TRIZ is that those contradictions that drive technology or product evolution should be resolved in most ideal ways, and this approach well 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[1] acts as a supporting and organizing method for thinking and helps to define and choose the right solution strategy.

Numerous 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 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: TRIZ-educated people know that bi-systems (those systems which result from combination of two similar or different systems) have a higher degree of efficiency than mono-systems. But TRIZ never rejected "free will" creativity. The course of Creative Imagination Development is still regarded as a very important component of increasing inventive capabilities [Salamatov, 1999].

4. Role of Management

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

[1] It is important to note that TRIZ is only a part of what we call "Systematic Innovation" since Systematic Innovation includes a number of other tools and defines a process of creative innovation from information gathering to concept evaluation, while original TRIZ is a collection of specific problem solving techniques and underlying philosophy of inventive problem solving and technology evolution.

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 neglected 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.

5. 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 A, 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.

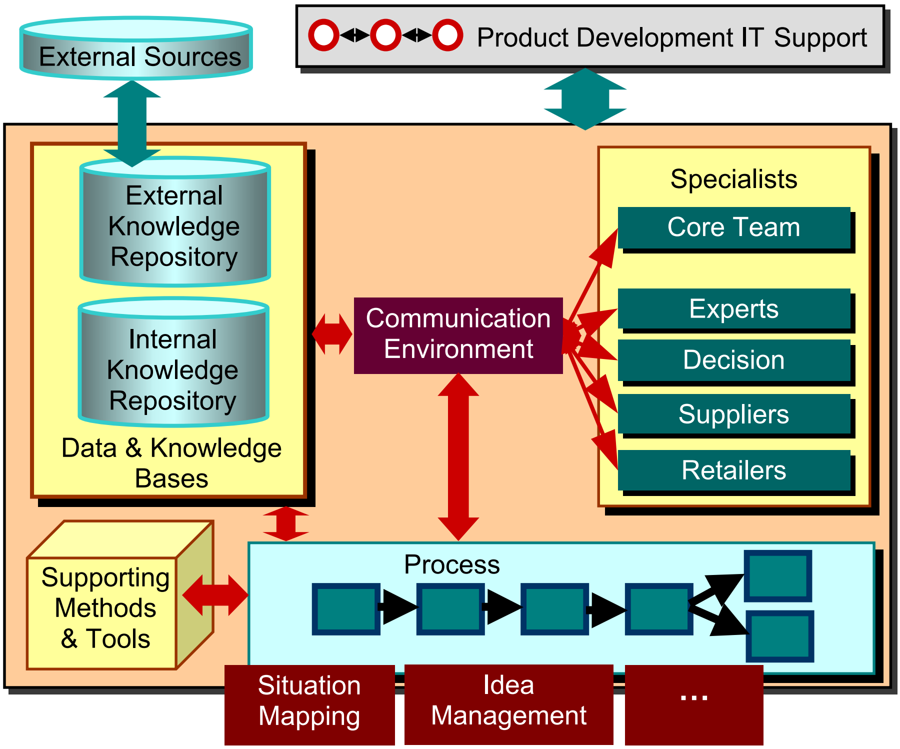

Figure 2. Architecture of IT System to support innovation processes

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.

6. Establishing Innovation Infrastructure

Summarizing, we can outline four major components of a modern innovation infrastructure (Fig. 3):

- *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 D, 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.

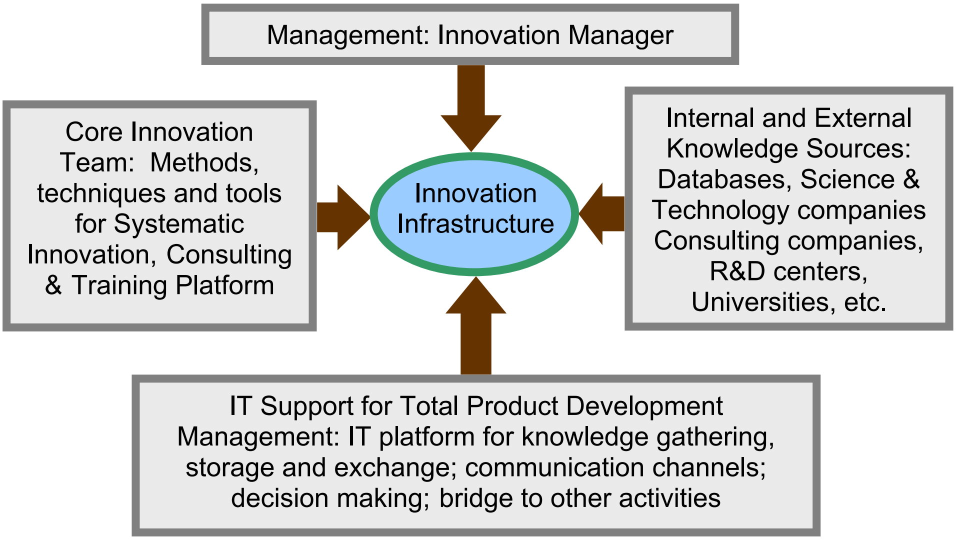

Figure 3. Necessary components of innovation infrastructure

7. 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 belongs to almost every department which is related to the product/technology lifecycle: 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 close to 2005 now and we see that this becomes a 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 knowledge economy.

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THE ROLE OF TRIZ CHAMPIONS: A REVIEW OF CURRENT PRACTICE

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Abstract
Despite the increasing availability of resources the take up of TRIZ in industry has been slower than expected. The research community is now addressing issues around the integration and dissemination of TRIZ. This paper looks specifically at the role that champions play in disseminating TRIZ in enterprises. Interviews with TRIZ champions from companies across different sectors of UK industry reveal the practical activities undertaken in their companies. This paper reports on both successful and unsuccessful initiatives and the organisational environment needed to support these activities.
*Keywords:*TRIZ champions, interviews, UK industry, dissemination, practical activities.

1. Introduction

Over the last decade the availability of books and training on TRIZ has grown. In the UK, there are now about eight organisations and consultants offering courses and the number of English language texts has steadily increased. The take up of TRIZ in industry has however been slower than expected and many authors have reflected on this phenomenon.

Some of the more commonly quoted reasons for the limited uptake of TRIZ in industry are (Campbell, 2002; Nakagawa, 2001; Domb & Kowalick, 1997; Mann, 2001; Hipple, 2000):

- People in industry are too busy to learn complex tools and have often had disappointing experiences with new tools.
- Companies with existing project management structures struggle to integrate TRIZ.
- Specialised technical people are often sceptical about the ability of a generic tool to deliver something of relevance to them.
- Much of the literature has failed to provide accessible introductions and new users often have difficulties using TRIZ on their own problems.
- The success of TRIZ is hard to prove because the origins of ideas may be hard to trace back to TRIZ.

The research community is now addressing issues around the integration and dissemination of TRIZ. Practitioners and trainers have begun to share their experiences of spreading TRIZ through enterprises. Some examples of current dissemination strategies are: running pilot projects to solve real problems (Domb & Kowalick, 1997); supporting new users (Campbell, 2002); and appointing TRIZ champions (Domb & Kowalick, 1997; TRIZ journal, 1997; Slocum, 1998).

This paper looks specifically at the role of TRIZ champions in companies. TRIZ champions naturally emerge when an individual discovers TRIZ for themselves and becomes an avid user (West, 2004). A TRIZ champion continues to teach himself or herself more TRIZ tools and applies them to the real problems that they encounter in their work. Mann (2002) describes these users as 'TRIZ pragmatists' or 'TRIZ infected'. In some cases TRIZ champions have been recognised by their organisations and officially appointed. Some TRIZ champions are even charged with improving the inventiveness of the company as a whole.

'Innovation champions' are used in companies more widely to foster specific projects, tools, methods or technologies. Chakrabarti (1974) for example, discusses the need for 'product champions' to nurture ideas through early development stages and organisational obstacles. De Bono (2004) suggests appointing a 'process champion' to be responsible for introducing creativity across an organization.

1.1 Methodology

For this paper, eleven TRIZ champions across different UK industries were identified and contacted. At the time of writing this paper, four of those were formally interviewed, whilst others exchanged emails on this topic. The interviews were conducted by telephone, recorded and transcribed. The industries represented by the interviewees ranged from: a global synthetic fibre producer; a high-tech network storage manufacturer; to an automotive component manufacturer. This review paper is based on the content from these interviews.

1.2 What are TRIZ champions?

The term TRIZ champion has been used indifferent ways, some examples of the meaning understood are:

- The person who spreads an approach throughout the organisation (TRIZ journal, 1997)
- The person who orchestrates the introduction and institutionalisation of TRIZ (Domb & Kowalick, 1997)
- A sort of volunteer who tries the new process and then shares and spreads the experience through the company (Hipple, 2000)
- A new user who demonstrates the value of TRIZ through a real case study in order to achieve corporate acceptance of the method (Slocum, 1998)

Within these four descriptions there are two quite different views of what a TRIZ champion is. A champion is either a self-appointed TRIZ enthusiast or someone formally charged with spreading TRIZ through the company. The TRIZ champions interviewed for this paper also fell within these two types. They were either disseminating TRIZ from the bottom-up or top-down. It is useful to distinguish between these two models. The rest of this paper refers to a bottom-up self-appointed TRIZ enthusiast as a type-1 champion and a top-down formally-appointed TRIZ person as a type-2 champion.

Words used to describe a: Type-1 TRIZ champion	Words used to describe a: Type-2 TRIZ champion
self-appointed volunteer demonstrates TRIZ through case studies	formally-charged orchestrates introduction and institutionalisation top-down

Table 1. Describing the distinction between two types of TRIZ champion

1.3 How do people become TRIZ champions?

TRIZ champions come from different disciplines and hold a variety of posts in companies. For example, people contacted for this paper included: a programme manager, a senior technologist, a training manager, a senior designer, and a chief engineer. Each has experienced a different pathway to becoming a TRIZ champion. One example of such a pathway is shown in figure 1 below.

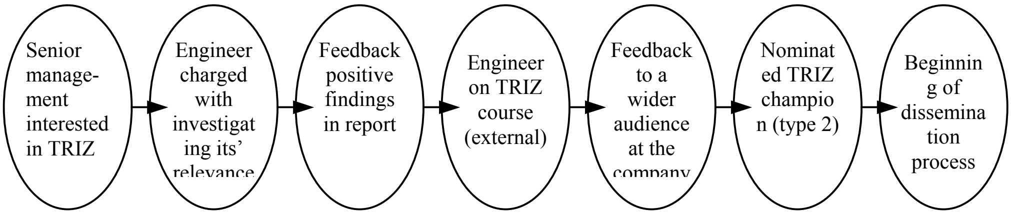

Figure 1. Example of a pathway to becoming a TRIZ champion

The TRIZ champion's position in the company, combined with the organisational environment, determines the influence they have. This aspect varied most between the TRIZ champions. Figure 2 below shows three schematic representations of the spheres of influence that the interviewees described.

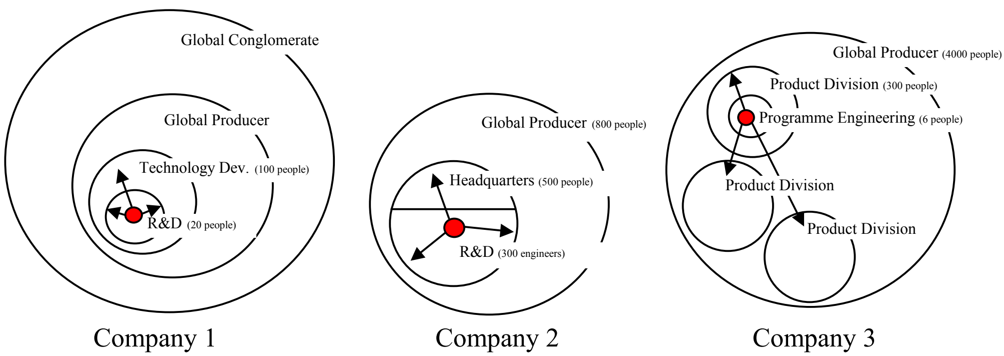

Figure 2. Examples of organisational environments and TRIZ champions' spheres of influence.

2. Descriptions of Current Use

2.1 Strategic approaches observed

Even from the limited number of interviews conducted, it was possible to see that the TRIZ champions had very different strategies for disseminating TRIZ in their companies. Some examples of those are: introducing classic TRIZ, personal piloting and customising TRIZ.

> *'We're just going to do classic TRIZ stuff to start off with, in Mechanical Engineering… Just on pure inventive problem solving in technical mechanical engineering areas and mechanical processes: traditional TRIZ.'*

> *'My approach is to continue piloting [TRIZ] through me as an individual, using it for local problem solving without heralding TRIZ as an initiative.'*

> *'I filter the fairly wide-ranging, amorphous world of TRIZ and make sense of it, for the company perspective. I then make it practical and worthwhile to our company…'*

Table 2 summarises the main strategies that emerged from the interviews. All four strategies are largely determined by the company's culture and previous experiences of introducing new tools, methods and personnel development.

	TRIZ champions type 1	TRIZ champions type 2
more pragmatic	Local personal use Develop body of case studies Collect financial evidence of benefits	Use in technical problem solving Integrate with existing management systems (e.g. Six Sigma) Classical TRIZ tools
more proactive	Develop collective use Internal support network Proactive external networking	Parallel dissemination in technical and non-technical areas Using new TRIZ ideas

Table 2. Four main dissemination strategies that emerged from the interviews

2.2 Current typical adoption rates

Despite the variations in strategic approaches, several of the interviewees had initially conducted similar activities. They were able to provide information on the practical adoption of TRIZ following those activities. The table 3 below summarises what the outcomes were in three different cases.

The third TRIZ champion referred to in table 3, is working in a fairly mature non-innovative company with a strong hierarchical structure. This makes the dissemination of any new technique more difficult as there is resistance to change. Strategy - including the selection of tools and methods - is done high up in the organisation. This means everyone else is mainly implementing those strategies and there is little scope for 'bottom-up' initiatives.

Initial exposure	Formal TRIZ training	Adopters
TRIZ champion provides introductory seminar 20-30 people	External week-long course 12 people interested and attend	Using it day-to-day approx. 3 people
TRIZ champion gives positive feedback to management about TRIZ	External week-long course 12 people selected and attend	Using it day-to-day approx. 4 people
TRIZ champion gives introductory seminar to management	No funds or time allocated for training	No new people using TRIZ

Table 3. Typical initial activities and adoption rates

If more results were available it would be possible to establish which dissemination strategies lead to the highest adoption rates and what the influential factors are. It would be possible to compare external vs. internal training, or to look at the effect of internal support networks and resources.

The main problems with TRIZ stated in the existing literature - such as 'complexity of the method' and 'time to learn' - were confirmed and reiterated by all the interviewees.

> *'It's not a quick fix… it's quite complicated… you need a few days to get your mind round it…'*

> *'Everyone who has come into contact with it [TRIZ] and taken the trouble, has got quite excited about it. It [the problem] is getting them to that point.'*

2.3 Support, Recognition and the Organisational environment

The fastest route to dissemination is if the TRIZ champion is directly charged with the task by senior management, the organisation has an openness to tools and methods, and there is a general willingness to learn. There needs to be an environment where managers view training as important and set aside time for staff to 'stop and reflect'.

> *'...the good news is that it [the request] came through the very senior management, and now it [TRIZ] is in the process of being reflected back in a form that people will want to use.'*

To get recognition most TRIZ champions describe the need for internal case-studies and evidence of success. Some champions focus on collecting solutions to real company problems, whilst others look more at the effects on personnel. One TRIZ champion argues that it is very hard to prove that the solutions would not have been found without TRIZ and states that evidence is needed to prove that a solution was found in a more time-efficient way.

> *'If we can make it [the use of TRIZ] efficient, so that they can see that the people who go on those [TRIZ] training courses, become more efficient at making good ideas work, then it will just be used.*

'If you can demonstrate good practice and it increasingly leads directly to a financial metric that is very positive, that wouldn't otherwise have been achieved, then people sit up and take notice.'

'[TRIZ] was very quickly looked at in terms of time, effort and money and the question came back: 'well, why?' You have to demonstrate the added value first, in order to get the investment to proceed.'

3. Practical activities described

Internal presentations

All TRIZ champions have delivered several TRIZ awareness presentations. Most with the objective of sparking direct interest with engineers or generating management support for a TRIZ initiative. In order to make the most of these opportunities, the content of the presentations needs to be tailored to the audience. One of the explanations for the difficulty of getting management support is a lack of such tailoring. Classical TRIZ examples of 'nesting', or 'expanding metal boxes' are not interesting or relevant to them.

In-house training

In situations where there are ambitious plans to disseminate TRIZ, the only sustainable way to do it, is to develop in-house training. One TRIZ champion is developing materials for short courses that 'concentrate on the basics'. He also points out that the training can be done quite quickly but it is the questions from new users that are time-consuming.

User groups

All interviewees said that the training courses they had sent people on, were successful. However, in order get people to adopt TRIZ, a lot of follow-up and support is needed. Two interviewees talked about the importance of getting a critical mass of users and about users needing: 'TRIZ mates', 'to talk the same language', and 'to work in TRIZ mode together'. In the long run, user groups become more independent and need less support. User groups will sometimes help disseminate TRIZ as they have many examples of successful outcomes and some enthusiastic users 'evangelise'.

External Support

One TRIZ Champion described a useful 'exchange of experiences' when he got in contact with a TRIZ champion from a different company. They compared their dissemination strategies and openly shared ideas on what the next steps might be.

Another champion is doing a part-time research degree, investigating the use of TRIZ to improve the innovation process in his company. Not only does this mean that this work is recognised by the managers - who have sanctioned the expenditure and time allocated - but the champion can also call on academic support for in-house training and analysis of the benefits to the company.

Intranet

Intranet sites have been developed by several TRIZ champions to support their activities. These sites provide a place for internal case-studies. They show how TRIZ is used and how solutions save - or make - money for the company. The intranet sites are also used to provide support materials such as:

- TRIZ tool descriptions, to remind people of the tools they have been taught on courses - instead of a course folder or book.
- Blank pro-forma's, sheets that help new users deploy the tools in a step-by-step way.
- Links to external public-access sources such as TRIZ journal and TRIZ discussion groups.

Use of software

None of the interviewees felt that the use of software tools was crucial to the adoption of TRIZ. One felt that database software had helped them come up with strong solutions. Another TRIZ champion discussed the integration of TRIZ software within their existing project management software. In general, books were quoted over software as the most useful resources.

Use of free resources

One of the key benefits of TRIZ over other tools is that, a lot of information is freely accessible and in the public domain. TRIZ does not have to be interpreted by external experts. It is possible to get a long way - in terms of learning TRIZ and even using the tools - without having to buy proprietary materials.

Undercover use

One of the interviewees uses techniques from TRIZ - especially the problem definition tools - in normal brainstorming sessions without explicitly promoting it as a TRIZ. This is one way to avoid resistance to 'new initiatives' and simply get on with using it. However, it does not actively promote or particularly help the dissemination of TRIZ.

4. Future Plans and Ideal Strategies

Most TRIZ champions are not solely charged with the dissemination of TRIZ, they normally have several other responsibilities. The proportion of time that they are able to allocate, and their other responsibilities, determine how fast progress can be made. One TRIZ champion gave an indication of how much time would be needed for the dissemination of TRIZ if he was able to work on it full-time. He quoted: two weeks of programme planning, followed by six months of activities, training and setting up the internal support needed.

One champion is working on the simultaneous integration of TRIZ in both technical and managerial departments. His plans for the future are to take a 'large problem' - a strategic business problem - and get a multidisciplinary team to use TRIZ. Team members from both managerial and technical departments will use both 'TRIZ for management' and 'classical TRIZ'. Examples of problems to be tackled are: 'How do we get into new markets?' or 'How do we reduce the cost of our products by 50%?'. The activity would convince senior management of TRIZ's relevance and get managers and technologists talking the same language. He plans to use an external TRIZ consultant to help ensure that the outcomes from this activity are considered successful by all parties.

> *'I would like to see every engineer be totally aware of it [TRIZ] and see it spread into the management hierarchy. I actually believe that the Management and Business application is even more powerful than the technical one. I think that technologists already do a lot of it anyway, without realising, and not calling it TRIZ. So that's what I would like to see, a meeting of minds, a common language between the two opposite camps.'*

Another TRIZ champion is looking closely at a way to disseminate TRIZ within the existing management system. The company has already successfully implemented Six Sigma to a high level. He sees an opportunity to integrate the problem definition tools from TRIZ into the Six Sigma processes. Ideally, he would like a TRIZ champion in every product division and a central 'black belt' TRIZ champion. However, he is careful about the way the initiative is presented. Calling it 'innovation management' and making sure it is seen as a tool to 'support' innovation, in the same way that Six Sigma is a tool to support business.

> *'What we would do is have a formalised method for creative problem-solving, it would be just like an 8-D version of the steps. The [solution] tools [from TRIZ] would be added on as people feel that they would want to use them. The problem definition part would be the 'key' to unlocking the need for [TRIZ] tools and training.'*

One of the interviewees still needs senior management to recognise the value of a TRIZ initiative. The current company climate means that it is not possible to pursue a proactive approach. He will continue to use TRIZ in his own work, document successful outcomes and develop access to free resources. However, in the future he hopes to take a proactive approach again. He believes that the easiest way to prove the value of TRIZ, would be to get a consultant to solve a problem that the incumbents have not been able to solve.

> *'If the consultant comes up with the basis for a development project or solves a problem that has been on a production plant for a year or two, and the existing incumbents haven't been able to solve that problem, you can say 'hey presto, in two hours consultancy this was the direct benefit'…'*

5. Discussion and Conclusions

From these interviews it became apparent that type-2 champions are a rather new phenomenon and we have no examples of the longer term effectiveness their activities - beyond 2 years. Type-1 champions, on the other hand, are often some of the earliest UK adopters of TRIZ. They may already have 6-8 years of experience using TRIZ. However, there are fewer examples, where a type-1 champion has been successful at disseminating TRIZ through their company.

It is interesting to note that several of the type-2 champions contacted, work in companies where Six Sigma has been implemented. Senior management have been introduced to TRIZ by Six Sigma consultants who include basic TRIZ in their portfolio of products. The relevance of TRIZ to a Six Sigma company is also reinforced by the large number of papers written on this topic. There is substantial TRIZ awareness within the ‘quality movement’. Some champions have been asked to review the TRIZ material provided by Six Sigma consultants.

In a recent article Hipple (2004) reported on a panel discussion on the implementation of TRIZ. The panel members were TRIZ users from industrial companies. One of the outcomes from the discussion was a list of ideas for improving the implementation and use of TRIZ. This discussion builds on those ideas.

TRIZ a little at a time (without making a big deal of it):
This describes a bottom-up approach that a typical type-1 champion might take. Examples from this research include: ‘undercover use’ and ‘local, personal use’.

Actually using the tool
This idea is about combating the tendency to ‘evangelise’ but instead, get on and use the tool. Most champions do not concentrate on selling TRIZ, but instead are focussing on implementing practical activities. Examples from this research include: delivering training and setting up networks to support new users.

Practise to excel (Creating a link between training and use)
This idea is about helping new users to deal with the complexity of TRIZ. All the interviewees stressed the importance of providing follow-up for new users attempting to apply TRIZ in their day-to-day work. Examples from this research include: creating a critical mass of new users, setting up user groups and intranet sites, and being prepared to deal with the questions that come after TRIZ training.

Integration into existing, mandated, accepted organizational process
This describes a typical top-down approach that a type-2 champion might take. It can also be a bottom-up strategy when a type-1 champion attaches TRIZ to an existing successful process. Most of the examples in this research describe the integration with Six Sigma processes.

Internalising skills (independence from consultants/trainers)
The role of a TRIZ champion is inherently about disseminating TRIZ from within the company. In the long-term, this is the only sustainable dissemination strategy. This paper describes the various practical activities that champions have undertaken to internalise skills.

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SELECTING OF KEY PROBLEMS AND SOLUTION SEARCH AREA IN FORECASTING

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Abstract
Serious TRIZ analysis of technical systems and their subsystems reveals hundreds of problems and contradictions. In forecasting, the problem is aggravated by that the number of generations of systems under consideration may reach ten. Correspondingly, the number of revealed problems also grows. Solving these problems singly is not a TRIZ way in forecasting. How not to sink in a sea of problems, how to select key problems, which, when solved, will make unnecessary solving tens and hundreds of problems?
At the analytical stage and in modeling, the structural and functional approaches allow revealing critical parameters that hamper further evolution of the system being forecasted. The analysis of casual chains in historical modeling exposes key changes of TS in time, reveals lost properties and functions. Presenting the accumulated information in the form of subsystem transformation trees visualizes and simplifies the process of elaborating forecasting solutions.
The principle questions to be answered in forecasting are which new subsystems will make a constituent part of the forecasted TS, what changes will happen to the existing subsystems of TS, which systems the TS subsystems will combine with during trimming.
"Strong" forecasting solutions arise not while trying to eliminate disadvantages of existing TS but during the search for solution ways in order to satisfy the growing needs of the subsystem. In this situation, it is also necessary to search for new solutions in the supersystem, where the needed knowledge, technologies, and technical solutions are already accumulated, and utilize them for solving the problems aggravated during the TS evolution.
One should, certainly, know what and where to search for. First is what. Here the previous modeling, analysis of the forecasted system resources and IFR will be helpful. They allow distinctly formulating which properties or technologies we need for solving a problem. Second is where. TRIZ has accumulated a vast knowledge base, methods of work with large volumes of information and search engines. Especially large possibilities in this respect are offered by IMCorp software, such as TechOptimizer and GoldFire.
Keywords: prediction, forecast, combine harvester, technical system, TRIZ, evolution, modelling.

1. Introduction

A serious TRIZ analysis of technical systems and subsystems reveals hundreds of problems and contradictions. In predicting, the situation is aggravated by that the number of generations of systems under consideration may reach ten. Accordingly, the number of revealed problems and contradictions is growing. Solving them singly is not a TRIZ way in predicting. The question is how not to sink in the sea of problems, how to select key problems which will make unnecessary solving tens and hundreds of problems. S.S. Litvin and V.M. Gerasimov have proved that solving the key problems during value-engineering analysis produces a super effect – reduces labor consumption for problem solving, simplifies TS and eliminates its disadvantages [1,2].

The ideas obtained while solving the key problems make unnecessary solving a great number of small and large subproblems, which just disappear. As a rule, this produces prerequisites for creating a new generation of TS, imparts a new quality to TS and transfers it to a next evolution stage. Thus, search for and solving the key problems is one of the prediction goals. But first, it is necessary to determine which of a set of problems is a key one. Our article is devoted to the selection of key problems and narrowing of the solution search area in prediction.

2. Modeling and selection of key problems

The principle questions to be answered while predicting are as follows:

- What new subsystems will be integrated with TS?
- What changes will take place in the existing subsystem of TS?
- what systems are TS subsystems going to combine with while trimming?

To answer these questions, it is necessary to study TS being predicted, reveal its key problems and subsystems, analyze the history and evolution trends as well as the evolution trends of its subsystems. The key problems are those creating the greatest number of negative functions; restrict the system development and productivity growth.

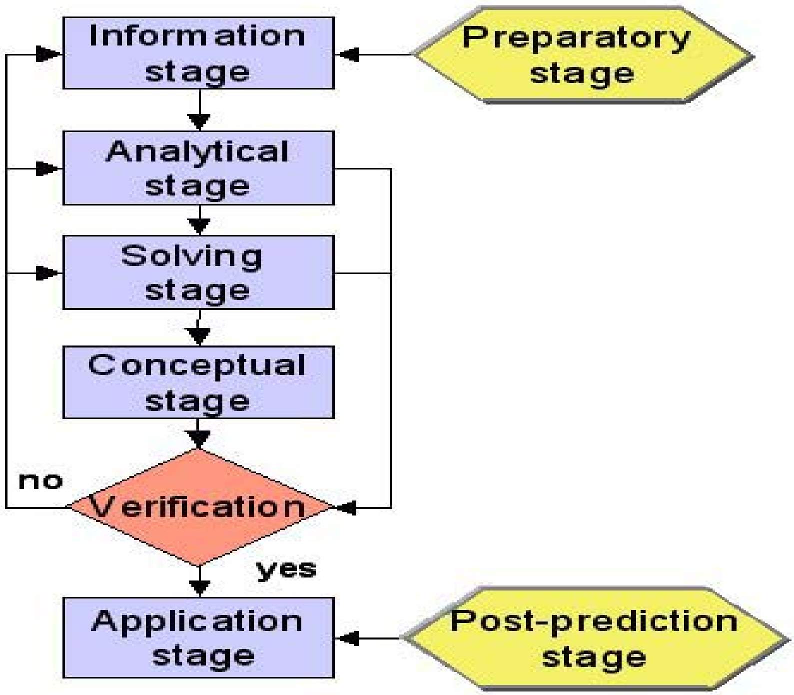

Fig. 1 TS prediction technology

When and in what manner should the key subsystem be integrated with the object being predicted? This usually occurs at the analytical stage of prediction during structural, functional, parametric and historical modeling and evolution trend construction, whereas the key problems are solved and the solution search area is narrowed at the solving stage (Fig. 1).

When modeling, structural and functional approaches allow revealing subsystems creating the greatest number of negative functions, which restrain and prevent further evolution of the system. This is the most important tool for revealing the key problems.

For example, while predicting a grain-harvesting combine of a new generation, it was revealed at the structural and functional modeling stage that the straw shaker is the subsystem, which generates key problems. It has a large size, which, properly speaking, determines the entire combine size, produces strong vibration and has no adjustment capabilities.

The parametric modeling is also helpful in search for critical parameters and, accordingly, for the key problems which restrain the evolution of subsystems.

Example. The parametric analysis has proved that the pressure of combine wheels on the soil exceeds the ecological requirements of the supersystem. The combine weight tends to grow and one of the principle factors is the increasing hopper size. The higher the combine productivity, the greater the hopper the combine should have to decrease intervals between stops for discharge. A large tank holds much grain, but its frame needs reinforcement and the combine needs to be equipped with a more powerful engine to move the load on the field. The key problem, the contradiction to be solved is evident.

Historical modeling and analysis of casual chains make it possible to identify trends, changes of the key problems of TS in time, as well as to reveal lost properties and functions. These properties are taken into account while creating a new generation of machines.

For example, the historical study of the combine revealed that in the pre-combine times full-value grains were separated from heads before thrashing. Those grains were used for sowing. That useful function was lost in the combine.

Analyzing the evolution trends of TS and its supersystem is the most important prediction tool, which determines the selection of a key problem and narrows the solution search area. Analyzing the subsystem evolution trends makes is possible to improve existing systems in accordance with the technology evolution laws. In constructing the evolution trends, data of patent and historical analysis are utilized. Fig. 2 shows a detail of the evolution tree for combine thrashing units. Visual presentation of information about the subsystem evolution trends in the form of a transformation tree simplifies the process of prognostic solution development. Transformation trees or maps indicate the solution search direction based on the technical systems evolution laws and narrows the solution search area [3,4].

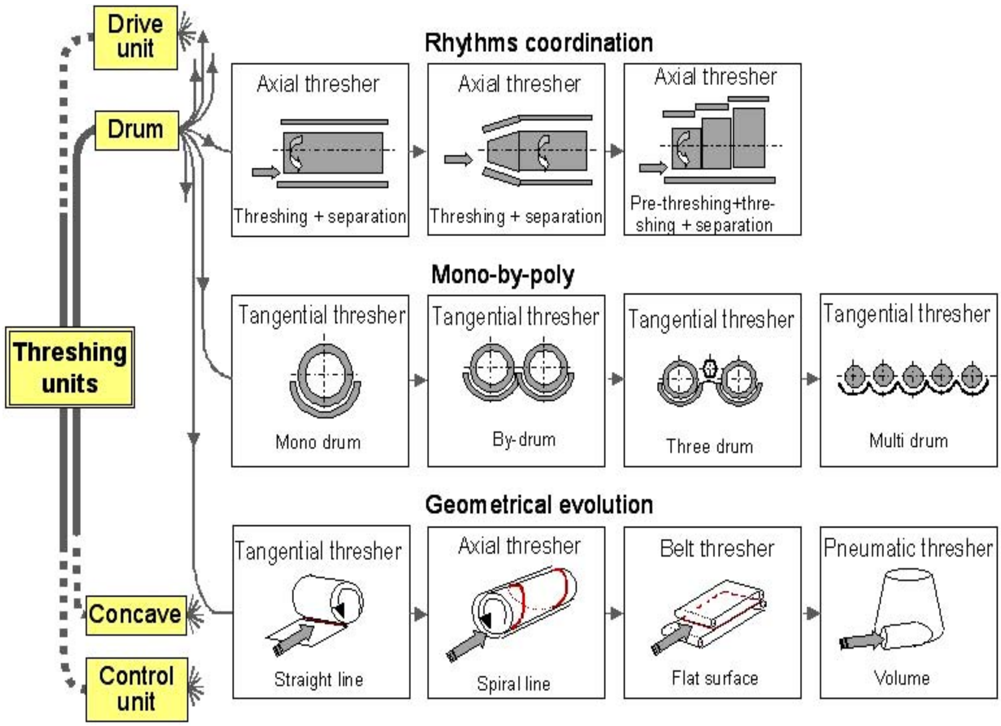

Fig. 2. Fragment of the evolution tree of combine thrashing units.

"Strong" prognostic solutions appear not at the attempt to eliminate disadvantages of the existing TS, but during the creation of a new TS, which better satisfies the growing demands of the supersystem. This is the growth of the supersystem's requirements for the performance quality of the main useful function that leads to a change in generations of technical objects.

Studying the changes in the supersystem's requirements for subsystems during historical modeling makes it possible to identify change trends in the supersystem's requirements. This promotes the understanding of the in-depth reasons for TS changes. Studying the changes allows predicting the appearance of new demands and methods for satisfying these demands. Demands change with the development of society, appearance of new or alteration of existing objective conditions, development of scientific knowledge and appearance of new technologies. Studying the supersystem change trends also promotes identification of key problems and, together with the functional analysis, offers an answer to the question what systems subsystems will combine with while trimming.

For example, the increasing requirements for ergonomics, comfort, and safety of combine drivers increase the cost of the combine cabin and control. This, in turn, has a negative effect on the combine cost and, in the final count, on the grain cost. At the same time, tractors and tool carriers are being developed in the supersystem. The cab comfort level of these machines satisfies the requirements and their load-carrying capacity and power-to-weight ratio are high enough. Prediction proved that removing (trimming) the straw shaker, thereby reducing the combine size, could turn the combine into a linkage-mounted or semi-linkage-mounted harvester aggregated with a tractor or tool carrier.

Thus, all the information obtained at the analytical stage of prediction reveals quite definitely one or several most vulnerable subsystems, which need changes. When selecting the key problems, it is necessary to take into account the results of several models at the same time. Information obtained during structural, functional, parametric, and historical analysis and development trend construction should be compared.

3. Narrowing of search area

As shown above, selection of key subsystems while creating a concept of a new TS reduces to a considerable extent the area of search for new solutions.

The second strong technique for narrowing the solution search area in prediction is trimming of subsystems, which is performed at a solving stage. Trimming leads to a radical change and simplification of the TS structure and transfers it to a new evolution level. In addition, trimming a subsystem reduces expenses on search for solutions and new information.

For example, while analyzing and solving problems, it was proposed to trim the straw shaker together with its disadvantages. However, to do without the straw shaker, it is necessary to reduce the amount of straw supplied into the combine. The analysis of the supersystem evolution trends proves, that stripping devices, which have been widely utilized recently, solves this problem.

We have already mentioned that the principle questions to be answered in forecasting and creating a technical system of a new generation are what new subsystems will be integrated with TS; what changes will take place in the existing subsystem of TS; what systems TS subsystems are going to combine with while trimming. The changing conditions of the product life and production are the main driving force of TS evolution. Changes occur because it is necessary to increase productivity and reduce cost, on the one hand, and, on the other hand, because science has already found and accumulated the necessary knowledge, technologies, and technical solutions, which can be utilized to solve problems aggravated during the TS evolution.

No doubt, it is necessary to know what knowledge and technologies exactly should be searched for. Here, pre-modeling and analysis of resources and trends of a predicted technical system and IFR may be helpful. At the solving stage, we obtain the problem solution in a general form. This solution determines quite clearly which properties of the TS subsystems or technologies we will need. The obtained information will help us formulate which property or technology is needed to solve the emerged problem. While making a search for new knowledge, solutions and technologies, it is necessary to take into account the evolution trends of subsystems in accordance with the evolution tree.

The second question is where new technologies and developments should be searched for. Search for new, ready-for-use technologies and technical solutions should be made in Internet, technical and abstract journals, publications of research centers and laboratories. TRIZ has accumulated vast knowledge bases, methods of work with large arrays of information and search engines. For example, GoldFire, the product of the IMCorp, provides excellent possibilities for information search through Internet.

4. Conclusion

The prediction purpose is the development of a concept of TS of a new generation. This may be achieved by performing analysis – constructing a structural, functional, parametric, and historical models of TS and evolution trends.

Selecting the key problems and subsystems from a multitude of problems at the analytical stage reduces the prediction cost.

Not only the system itself, but also changes in the supersystem's requirements for TS being predicted occurring during its evolution should be analyzed.

Trimming in solving key problems considerably narrows the new solution search area. The analysis of new knowledge, technologies, and requirements of the supersystem allows forming a new concept of a new generation of TS.

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APPLICATION OF THE TRIZ METHOD TO BUSINESS MANAGEMENT ACTIVITIES

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Abstract
This article presents the potential added value of the TRIZ principle for business management activities. An example of TRIZ concept application in this field is described. It has been used to define a first version of a new process for improving the innovation of products or services.
TRIZ is already used to raise the technical level of deliverables. Now, I would like to develop the application of TRIZ to Business Management; this could be a promising focus for a research project at Thales Research & Technology.
The method described here addresses not only New Product Development (NPD) but also the Product Re-Engineering Process (PREP) in order to improve the innovativeness of existing products or services. It could be applied to Fast Moving Consumer Goods (FMCG) as well as to industrial products and services.
Keywords: Business Management, Marketing, Monnier's Innovation Matrix© (MIM), Innovation Analysis Process© (IAP), Innovativeness, New Product Development (NPD), Product Re-Engineering Process.

1. Introduction

The aim of this article is to explain how the TRIZ principle could be useful for business management activities. Such a method is already used to define a process for improving the innovation level of industrial products or services; it also could be applied to FMCG.

Thales Research & Technology (TRT) is the Research Center of the Thales Group. The main objective of my research is to propose new concepts for new products or to integrate new concepts into existing products in order to give added value or to open new business opportunities. These new concepts could address Navigation, Communication, Displays, Sensors, Control, Surveillance Systems and Homeland & Civil Security.

Both New Product Development (NPD) and Re-Engineering could benefit from the application of TRIZ. This work is currently being proposed to the European Community for a potential research program.

2. Innovation Improvement

Innovation is a very special word; it could have many definitions depending on people and organizations. The generally accepted definition can be stated as:

*"**Innovation** is the **application** of new **ideas**"*

Therefore, it is not only an invention; a new idea needs to meet a market in order to be an innovation.

Engineers are able to provide very sophisticated concepts and complex systems where expertise is required. But we should ask ourselves if this level of complexity is really necessary. The natural tendency of a researcher is be to go further and to provide more sophisticated products than those required by the market.

Marketing plays a major role here. My work aims to add marketing tools for improving the financial return on a product or service, for optimizing R&D investment in order to enhance the innovativeness and the profitability of the company.

The 6 steps of the initial method I suggest are:

1. product / service selection,
2. evaluation in a specific matrix to assess the current situation,
3. analysis of the situation: where are we?, where would we like to be?
4. definition of a strategy for moving from one position to another,
5. implementation of the proposed way of moving,
6. re-evaluation of the modified product / service, snapshot of the new situation.

1.1 Product/service selection

The methodology is intended to be efficient for new products from the “start-up” phase of the product life cycle, as well as for existing products in all the subsequent phases. In the case of existing products, the aim is to maintain marketability and value in a mature or decline phase.

A product or service is selected at a very early stage, according to its current state of development, the cost involved, the potential market, the level of maturity of the concept, ….

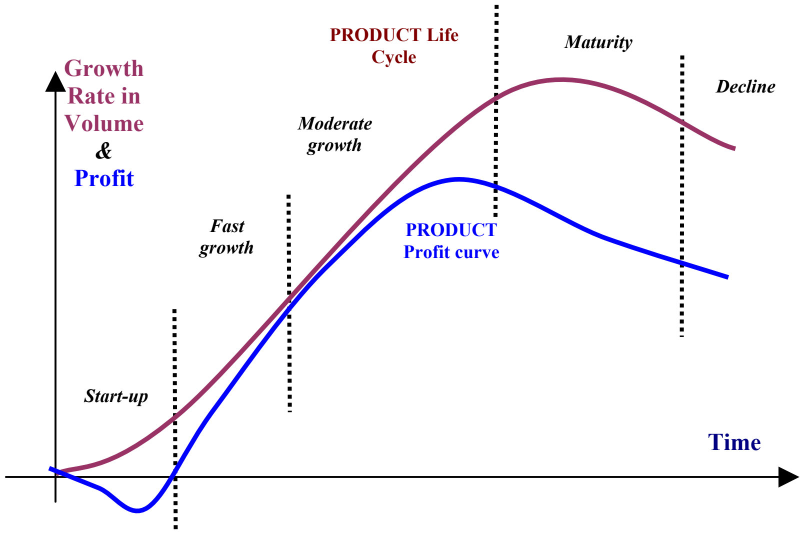

Figure 1. Product Life Cycle & profit curve

1.2 Evaluation in "my" innovation matrix

I propos a specific tool for evaluating the current position of the product versus its innovation level. It measures the *innovation performance* of the company, concerning the product or service chosen to be evaluated. This tool is mainly composed of:

1. a two dimensional matrix where the "X" axis represents the market level and the "Y" axis the technical level of the products or services to be evaluated: *Monnier's Innovation Matrix©*[2] (MIM). Many parameters are considered for assessing each axis; the inventiveness level is included in the technical axis.
2. methods for moving from one quadrant to another more favorable one.

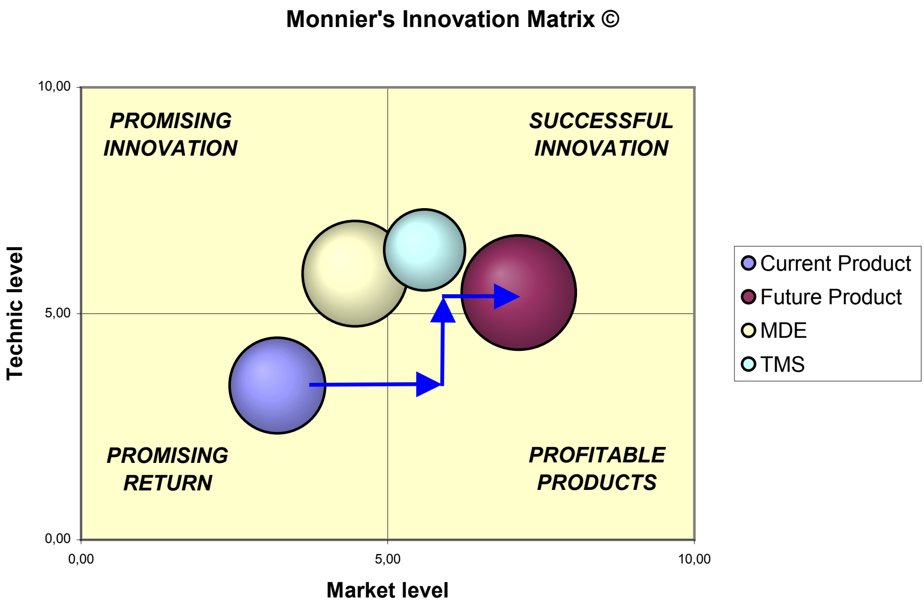

Figure 2. Evaluation of the current position in Monnier's Innovation Matrix©

This matrix could be considered as a standard measure for very different products or services. It is like a diagnostic framework to identify which parameters need to be focused on.

It appears that the best quadrants are those on the right, where the level of the market is highest; this means that a market has been found for this product/service. I provide a method with an associated tool to implement a move from one position to another more favorable one. This is the second focus of my future research.

1.3 Analysis of the situation

A meeting with senior management must be organized in order to assess the current position and to decide if we need to move from one quadrant to another.

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[2] Monnier's Innovation Matrix*: copyright© 2004 Bernard MONNIER. All rights reserved.*

1.4 Defining a strategy

A detailed analysis of each criterion on each axis could help to define a strategy for moving. Generally, the only movement we should want to make is to increase our market, so to move from the left to the right position. But sometimes, if we expect a high level of market share, we would also need to move up from a lower to a higher quadrant *(see example on the previous graph concerning current and future product positioning)*. For this reason, I propose methods for both movements in the matrix.

The Innovation Product Re-Engineering (IPRE) process is proposed for moving up. This is based on the TRIZ method applied for technical problems, which is the classical application of TRIZ methodology.

The Innovation Analysis Process[3] (IAP) has been defined to move from left to right, based on a new method partially applying TRIZ. It is a specific application for business management problems which has been a TRIZ research topic for a few years.

1.5 Implementation of methods

After defining the best strategy, it's time to manage the implementation of the method *(next chapter)*.

1.6 Re-Evaluation of the modified product/service

At the end of the process, the product or service should be quite different from the initial one. Modification should help it to move to a better quadrant. This phase is only to confirm that the expected position in the matrix has been reached. (Otherwise, the cycle needs to be executed one more time).

2. TRIZ for the Innovation Analysis Process©

2.1 TRIZ application for Business Management

A first version of the "Innovation Analysis Process"© (IAP) is proposed as a method for moving from left to right in Monnier's Innovation Matrix. This is a good example of how TRIZ could be efficient for business activities.

A first physical contradiction is to consider a simple and quick process *(time is always a killer)* which also needs to be complex and complete in order to be efficient and exhaustive.

TRIZ could be an appropriate tool for defining such a process. However, business laws and principles which have been proposed so far are not mature enough for this kind of application *(especially for my needs)*. The contradiction matrix for business management activities seems not to be robust enough to be used with the same efficiency as for classical technical problems.

If we come back to my case, the ideality should be a software system that allows us to enter the key words of the product or service for which we want to increase the market. This system should answer by defining what we have to do, how we should transform our deliverable, what should be the cost of actions, risks taken, ROI expected, … all major information needed to forecast the future with a high probability of success. All data need to be updated

[3] Innovation Analysis Process*: copyright©2004 Bernard MONNIER. All rights reserved.*

every day; they should contain political, economic, strategic information from around the world, which means that a huge, complex and various database system could be the "ideal" tool for marketing problems.

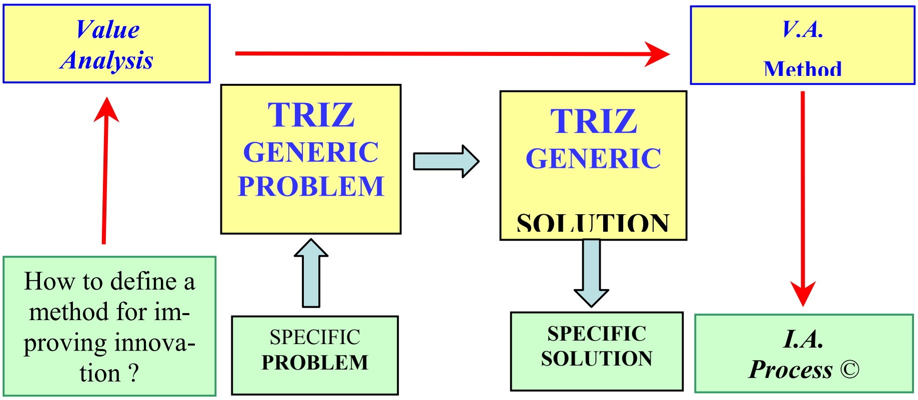

Figure 3. Application of the TRIZ method to management activity

Initially, the problem was to find a method to improve innovation for products or services sold. The solution was found after translating the problem into a generic one. The Value Analysis (VA) process was estimated as similar and the solution was derived from it, focusing more on innovation than on cost.

2.2 The Innovation Analysis Process©

I have defined a complete method associated with some useful templates in excel file format to report the results of each phase of the suggested process.

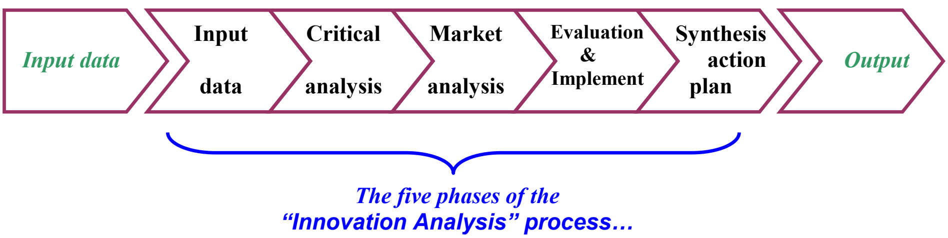

Figure 4. the IA Process ©

The IA Process is split into 5 distinct phases:

- *Phase 1* : input data; state of innovation level, FSS input, evaluation of market needs & innovation needed, …
- *Phase 2* : critical analysis; specification, process, customer satisfaction, …
- *Phase 3* : market analysis; SWOT analysis, five forces, …
- *Phase 4* : evaluation, innovation plan; proposal for implementation, …
- *Phase 5* : summary of the study, recommendation, proposal for a suitable innovation for the product, …

2.2.1 Phase 1

The first action consists in collecting all data about the product to be evaluated. The initial Functional Specification Statement (FSS) is needed.

Next, two templates are proposed for this first analysis of the situation. They present the product and its environment in a simple way:

- Problem worksheet N°1 : the first page collects general information about the product to be evaluated for its innovation capability. It must include a brief description of the product, its composition in terms of functional blocks, the service it provides and finally information about the development background.
- Problem worksheet N°2 : the page saves the objectives of this process and the potential ways to go. It must define the best direction we have to take to find a solution, to justify this choice and to estimate the existing constraints.

2.2.2 Phase 2

This phase provides a critical analysis regarding a potential failure of innovation. Even if the overall process is focused on market level growth, this phase inevitably involves technical issues.

A check-list has been drawn up based on "value analysis" studies but with an innovation driven focus rather than a cost focus.

Therefore, the 5 points could be:

1. *How is the functional block constructed?* Material, shape, tolerances,… for hardware products; specifications, language, validation process,… for software products.
2. *What are the innovation key items and why?* Where are they in the block or where are they expected to be?
3. *Alternative known solutions.* Ideas for potential solutions could be suggested by others (suppliers, competitors, …). Organize workshop with suppliers…
4. *Why is it done in this way?* What is the comparative added value of each part?
5. *Conclusion: what should be the innovation process strategy?*

An associated template has been provided:

- Critical Analysis worksheet : this table collects all information needed to understand the functional block, to split it into different items if necessary and to provide a support to save ideas and an innovation process strategy.

2.2.3 Phase 3

The major goal of the IAP is to help the company to move its product on the market axis; therefore, this phase is the main one of the whole process. This phase is dedicated to the market analysis, among other marketing tools.

Generally speaking, there are two types of project:

- "MARKET DRIVEN" :
  project idea coming from the observation of customers' needs *(commercial information, satisfaction studies, marketing surveys, etc…)*
- "TECHNOLOGY DRIVEN" :
  project idea coming from the technique *(R&D, Diversification).*

This phase 3 is useful for understanding the rationale behind the project.

Methods suggested for use in this phase are:

- Marketing mix (the 4P's)
- Key Success Factors (KSF)
- Strength and Weakness, Opportunities and Threats (SWOT) analysis
- 5 forces

Two different templates are dedicated to this phase of analysis. They present the product and the environment in a simple way:

- <u>Market worksheet N°1</u> : this template saves the evaluation of customer satisfaction.
- <u>Market worksheet N°2</u> : this paper is used to synthesize potential solutions.

2.2.4 Phase 4

This phase crystallizes the best ideas for designing *(re-designing)* the product or service with useful new techniques perceived as innovative, if innovation was considered to be necessary.

The template for this phase of analysis is:

- <u>Solutions worksheet</u> : this template presents a list of solutions and a manager of each action.

2.2.5 Phase 5

This phase is the last one. It is dedicated to finalise the study by a synthesis of all suggested actions.

Information about complexity, cost, lead time, commercial effort … must be provided by the person in charge (as decided in the previous phase). These data are essential for decision making.

A final template is dedicated to this final phase:

- <u>Final worksheet</u> : this template is to be used as a final paper for presentation to decision maker(s).

3. Conclusion

An innovation process is proposed which is both technology and market driven. This approach is currently being evaluated at THALES Research & Technology for a European Commission project in the Software Research Group. If successful, it could be implemented throughout the Thales Group. It is applicable not only to manufacturing industry but also for many other activities and services.

This research could benefit the IA process itself and also improve TRIZ methodology for further business applications, providing a basis for defining new principles and business laws. It will take several more months to achieve a complete re-design process. The main focus of my studies at Thales Research & Technology will now be to find a suitable contradiction matrix and to define major principles. An example of contradiction could come from R&D which drives high prices and risks whereas the market demands the lowest total cost and minimum risk.

This future work should be assisted by contributions from academic institutes for the theoretical part of the project and also for building an associated toolbox from existing TRIZ tools, encapsulating knowledge, strategies and best practices from the business domain. TRIZ has been approached from an engineer's point of view; many of the trends address engineering concerns directly. The goal is to match TRIZ theory to business management applications for a sustainable competitive advantage.

Glossary

4P's	:	Product, Price, Place, Promotion
EC	:	European Commission
FMCG	:	Fast Moving Consumer Goods
IA	:	Innovation Analysis
IAP	:	Innovation Analysis Process©
IM	:	Innovation Matrix
IPRE	:	Innovation Product Re-Engineering
KSF	:	Key Success Factor
MBA	:	Master in Business Administration
MIM	:	Monnier's Innovation Matrix©
NBD	:	New Business Development
NPD	:	New Product Development
PLC	:	Product Life Cycle
PREP	:	Product Re-Engineering Process
R&D	:	Research and Development
R&T	:	Research and Technology
REP	:	Re-Engineering Process
ROI	:	Return On Invest
SWOT	:	Strength & Weakness, Opportunities & Threats
TIPS	:	Theory of Inventive Problem Solving (≅TRIZ)
TRIZ	:	Teoria Reschenia Izobretateliskih Zadaci (≅TIPS in English)
TRT	:	THALES Research & Technology

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IMPROVING INNOVATION USING TRIZ

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Abstract
This paper describes the initial findings of an M.Phil research project between the University of Bath (UK), and Avon Vibration Management Systems (VMS). The objective of the research is to understand the impact of TRIZ implementation upon the effectiveness of innovation in an Engineering business setting.
The paper explains how the IDEF0 methodology was used as a process modelling tool. The technique is briefly explained, in the context of the project. The resulting model has aided in developing the Avon definition of Innovation as being 'the *process* of adding value by adapting and furthering available knowledge, to satisfy business and customer constraints at minimum cost.'
Also presented is the formulation of a metric, derived from the process definition. This is used to measure the historical innovation profile of Avon VMS and act as the benchmark for TRIZ inspired innovation as the method is rolled out across the company.
Keywords: Innovation, TRIZ, implementation, IDEF0, measurement, metric.

1. Introduction

Avon Rubber PLC is a multinational company (T.O. £250 million, Euro375 million), founded in 1885. It has developed on the basis of manufacturing and design skills in rubber, and has been involved in many and varied markets. Today, it has two divisions, Avon Automotive, and Avon Technical Products.

Avon Automotive is a major player in the European Automotive hose markets, but also operates in markets such as transmission and chassis mounting systems (VMS - Vibration Management Systems). Avon Technical Products operates in markets as varied as photocopier rollers, respirators, dairy and aerosol gaskets.

Six Sigma was adopted by Avon in 2001 as part of its continuing drive for Business Excellence. In 2003 a major project was initiated to develop innovative hose manufacturing techniques. The project team was drawn from several European plants. At the suggestion of the European Automotive director, the team received internal TRIZ awareness training, and attended an external two-day TRIZ workshop. The project has been successful in generating new intellectual property, and radical cost effective methods of manufacture.

Because the initial TRIZ implementation was project focused, the trained practitioners are spread thinly across several plants, and no resource or framework exists for their continued use of TRIZ. TRIZ can therefore only be considered to be in its infancy at Avon.

The role of TRIZ champion is to research the world of TRIZ, and disseminate elements most relevant to Avon. To aid this, it was decided to embark upon a research programme with University of Bath. The research team selected Avon VMS as the reference site. This was because of its proximity to Bath, and more importantly that it is a self-contained business unit, with product development and manufacturing occurring on one site.

The research team decided that the Action Research methodology would be used. This is an iterative 'plan, do, reflect' cycle, which enables rigorous academic learning by doing. This is similar to the Define, Measure, Analyse, Improve, Control, Transfer (DMAICT) improvement steps. It is planned that TRIZ will be implemented in several mini projects. Reflective learning will be conducted after each phase, and the lessons passed to the next stage. This paper concerns the first two phases in the project - Definition and Measurement.

2. Definition

In order to define innovation, the first step was to recognise innovation as an Avon business process. A literature survey revealed limited case study material that had modelled innovation in this way. Past experience suggested that the IDEF0 modelling tool could be considered. IDEF0 is a hierarchical method, which means that the depth of detail can be increased to whatever level becomes necessary.

There are two building blocks within IDEF0, boxes and arrows. See ref 1 www.IDEF0.com. A box represents an activity, and should contain a verb, such as 'process customer orders' or 'design tooling'. The word Innovate, is a verb, and therefore can have an IDEF0 box. Linking the boxes are arrows. These point into or away from boxes, and link them together similar to a basic flow diagram using a very defined nomenclature. (Fig 1.)

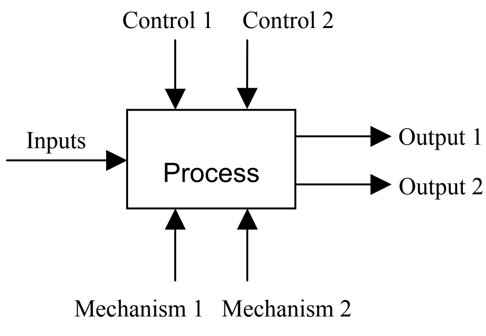


Fig 1. IDEF0 – top level example

Inputs are transformed or consumed by the process - (the raw material or ingredients)
Controls specify the conditions for the function to produce the correct output
Outputs are the data or objects resulting from the function.
Mechanisms are the means and resources which support the process.

The top level diagram sub divides into up to 6 boxes on the next level, which in turn sub divide into further sub levels and so on. The arrows also break down into more detail at the lower levels. This would be too much detail to present here. Fig 2 shows the model of innovation resulting from the definition phase.

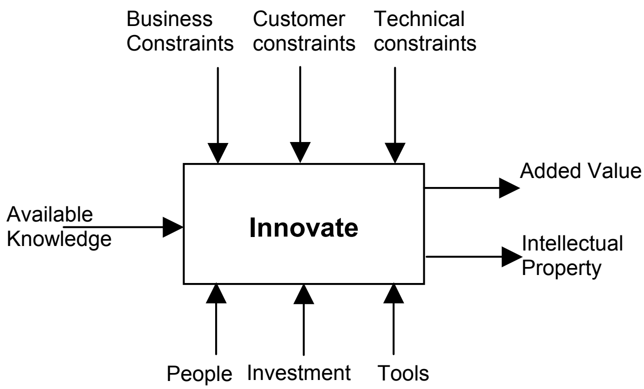


Fig 2 - IDEF0 top level model of Innovation

2.1 Inputs to Innovation

One of the difficulties in generating IDEF0 diagrams is to distinguish between inputs and controls. 'Customer requirements' for instance, were initially defined as an input. But customer requirements are not specifically *modified* by Innovation. They should be defined as a control.

When presented with a new design specification, the first thing a designer at Avon does is to search the existing product portfolio to find the closest match, which is then *modified* to achieve the new requirement. If a standard technology cannot achieve the specification, then a more creative solution is required - and a wider search is conducted for technology on which to base the design.

Many of the TRIZ solve tools invite the user to look for ways to take an existing technical system and *modify* it according to a trend, or principle. It is concluded therefore that 'existing technology' is modified by innovation. This clearly is categorised as an IDEF0 input.

Much consideration has been given as to how to more precisely define this. For instance, the term 'technology' implies only hardware. The term 'state of the art' was considered, but implies that only the latest developments are considered. It is therefore concluded that the input to Innovation is 'available knowledge'. The word 'available' is used because the innovator cannot work with all knowledge within a field. Some of the knowledge will always be hidden.

2.2 Controls

It was determined that there are three factors controlling innovation at Avon, and these can be termed constraints. These are the customer, the business itself and the constraints of technology. A designer is constrained by the need to achieve cost, design for manufacture and other Avon objectives, and simultaneously achieve detailed customer specifications. Often there are conflicts (or contradictions) between the customer and Avon requirements, caused by limits of technology.

2.3 Outputs

Economic theory credits innovation as being the underlying mechanism of macro economic growth, which can be measured in monetary terms (Sahal, 1981). Two outputs therefore result from Innovation. The first, and most important from a business perspective is added value, which can be measured in terms of profitability. The second is intellectual property, which adds to the global body of knowledge.

2.4 Mechanisms

The means by which innovation is delivered includes the people involved, the investment in hardware development and time, and the tools used - which includes software systems, engineering /mathematical tools and methodologies, such as TRIZ.

A conclusion from this research is that from Avon's standpoint, effective innovation is

'the *process* of adding value by adapting and furthering available knowledge, to satisfy business and customer constraints at minimum cost.'

Further levels of the hierarchy were created, but not presented here. The objective of defining the innovation process clearly and accurately has been achieved. If further definition is required later in the project, the model can be expanded in greater depth. But for now, the model is sufficient on which to base the next stage - of measurement.

3. Measurement Methodology

As with the innovation process definition, there was not found to be a readily available measurement system for innovation in the public domain. It was clear that a relevant metric needed to be derived, which would fulfil the following criteria :

- Simple to use and apply
- Able to be applied to all types of innovation relevant to Avon
- Able to be applied retrospectively
- Consistent and repeatable comparative over time

Using the IDEF0 model, five sub categories were identified that could be measured in the style similar to the World Class Benchmarking system (Avon Internal Benchmarking guidelines; EFQM). These are :

- Commercial Potential
- Inventiveness
- Value Added
- Implementation Cost
- Risk

Each of the scoring categories is now explained in detail. In keeping with Altshuller 5 levels of inventiveness, each category is given 5 levels - with a higher score always being better. See appendix 1 for the score sheet. It will help to read this in conjunction with the following section.

3.1 Commercial Potential

Two areas of the model are relevant here - Customer Constraints and Added Value. This is the view of the idea from the standpoint of the sales and marketing department. Where will this idea take the Sales figure of the business? Avon's primary marketing targets are large Automotive customers which have many departments often with conflicting requirements. Each of these requirements can become the highest priority, dependant upon characteristics of the vehicle development project.

There are two factors to consider - the breadth of the impact and the depth. A deep but narrow product offering would for example be a new technology that is very attractive to only one department within one customer and confined to one product. This is unlikely to result in a high increase in Sales. This is typical of a technology that is developed to address a specific technical problem, on a specific vehicle under specific conditions.

An example of the other extreme of a broad but shallow technology would be apply to all customers and products, but not be highly attractive to any. This is also unlikely to result in a large increase in sales. The highest scores should be given to ideas that are broad and deep – that is ideas that affect many products and are highly compelling to many customers.

Questions that help in this assessment are:

- How well does the idea match the needs of the customer?
- Does it help to resolve a difficult trade-off currently accepted?
- Does the idea differentiate Avon from competitors?
- Does it give benefit to the customer that cannot be obtained by other methods ?

Cost is a factor in assessing this question, because price is certainly a customer constraint and some ideas are very cost focused. However, cost is assessed later on, and should not be the primary concern here.

3.2 Inventiveness

This category is heavily based around Altshuller's levels of inventiveness (Altshuller, 2000). This factor is about how big a step forward is being made from existing technology. The patentability of the idea is a clear indicator of the inventiveness of an idea. If the proposal consists of a family of possible patents, the idea should probably be scored as highly inventive.

3.3 Value Added (Margin)

$$\text{Value added} = \text{Sales Volume} \times \text{Gross Margin}$$

Note : Gross margin can also be termed 'Contribution' or 'Direct profit'.

Gross margin is simply the difference between the unit sales price and the unit variable cost. The sales volume impact has already been taken into account of within the commercial potential category. The main factor evaluated here is the ability for Avon to increase its profitability - the difference between the cost, and the price.

Some ideas are highly inventive, and satisfy customer technical requirements, but are costly to produce. The customer may be willing to pay an increased price for the technology, but will almost always be reluctant to do so. Even with highly protected, patented technology, there will always be strong cost down pressure. The ideal is to achieve a win/win situation, where prices can be lowered whilst increasing margin. This is most likely to lead to increased sales volume, and therefore cash.

3.4 Cost (Development)

$$\text{Ideality} = \sum \text{benefits} \ / \ (\sum \text{Costs} + \sum \text{Harm})$$

To this point, all of the elements discussed have largely considered the benefits of the innovation - ie the top line of the ideality equation. The mechanisms and resources to deliver the technology to the marketplace are the cost to the business of developing the idea, and relates to the bottom line of the equation. Highly complex technology often requires long lead-times, and significant resource to develop. An important consideration is the ‘opportunity cost’ of the idea. The technology may use so much resource, that other developments cannot be undertaken.

Lead-time is a good indicator of development cost. If a technology is likely to take more than 3 years to develop, then it cannot be achieved within a single vehicle development programme. If a new idea is developed for a particular vehicle programme, it is usual for the customer to contribute to the development cost, especially prototyping costs. If this funding is not available, then the cost to Avon can be significant in the early stages.

Some ideas however address costly development issues with existing technology, making the resource level lower to implement than the existing technology. This is especially true if the idea reduces the parts count, or solves a durability issue.

3.5 Risk

This applies to all the sides of the IDEF0 box. Consideration is given to the risks that the benefits assumed do not occur, and if any harmful affects are generated. (Again referring to the bottom line of the Ideality equation).

Risk to the *input* - has the scope of development been wide enough ? If not, there could be other, superior technologies, unknown during the development that reduce the lifespan of the technology.

Risk with *Avon* internal *constraints*. Will the idea become outdated due to changing Avon requirements. Perhaps the idea relates to a product or process that is about to cease production, or maybe legal, environmental or strategic issues will affect it.

There is a risk that *customers* are not interested. Some ideas do not achieve their anticipated benefit because of changing *customer* perception over time. For instance, an idea that majors on vehicle refinement may be discarded because the customer puts more emphasis on sporty handling. There may be general market trends, or legislation that could work against the technology from the customer perspective.

Consider the *technical* risk to achievement of performance, or the risk of hidden costs. These are mostly likely to be hidden in technical constraints. Many ideas do not succeed because of unanticipated technical problems. On the other hand, some ideas are strong because they reduce the risk of using the existing technology, in which case they should score very highly here.

Finally, consider the risk of the development resources. Do the resources exist to support the development to production, and is there a risk that resources may be insufficient? Unless a very strong business case is made, additional resources are not easily obtained.

4. Assessment Approach

An objective of the research is to detect any change to the innovation process as a result of TRIZ implementation. Therefore, the measurement needs to be historical, and consistent when applied to future innovation. The use of sliding scales are not considered reliable in determining absolute values. However, by providing examples for each score, the scoring method becomes comparative, which is fundamentally more repeatable.

Ideally all past ideas, regardless of application should be assessed, within a constant environment with minimum external influence. However, there is no formal wide-ranging database of ideas on which to conduct the study, such as a suggestion scheme. Looking into the past to select ideas would be time consuming and subject to bias.

Avon VMS policy towards patent generation has remained largely consistent over the assessment period. The patent history is therefore the selected reference database. The initial assessment has been made by discussing each patent with individuals involved at the time. The scores are recorded as though the session was conducted at the time of filing the patent.

5. Results

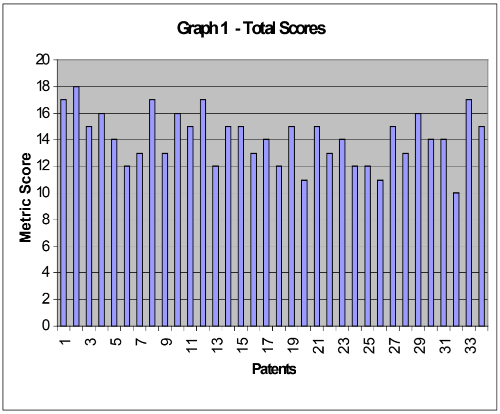
A total of 34 patents were analysed. These have been recorded in chronological order. Avon VMS has grown as a business due to the development of hydraulic engine mount technology. The majority of the patents relate to developments in this and closely related markets. The data can therefore be considered to belong to one generic product family.

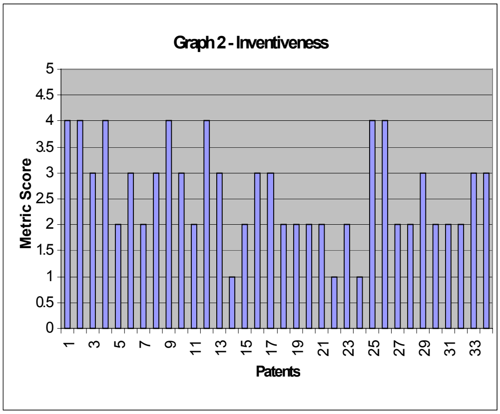
The purpose of this measurement is to set a standard, so that any changes to the nature of innovation at Avon can be detected when TRIZ is widely adopted. It is comparative, rather than quantitative. However the data reveals some interesting trends.

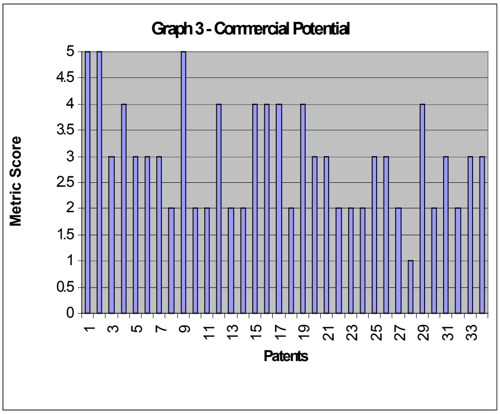
The results (see successive page), show that the overall score for innovation (Graph 1) has remained little changed over the period. There does appear to be a slight downwards trend.

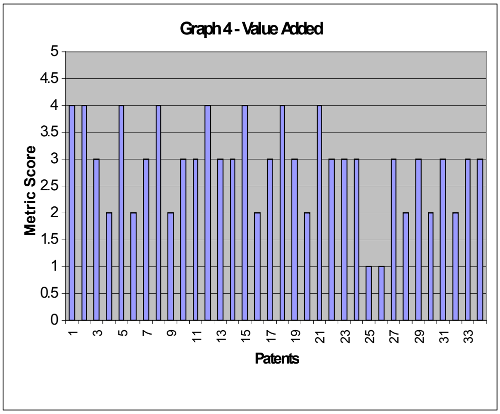
The inventiveness score (Graph 2) has reduced over the period. This is not surprising, as the first patents were based upon little available knowledge. Also, the more inventive patents take technology from outside of the industry. After the first use of this technology, this can no longer be claimed, and the score must therefore reduce.

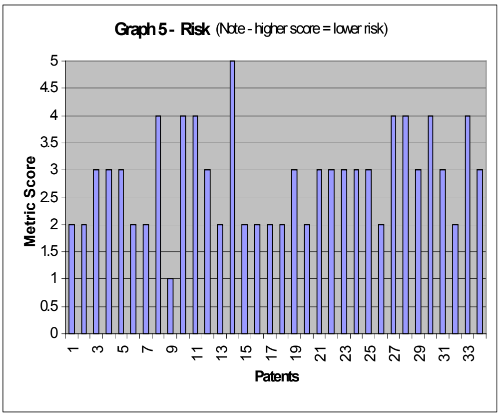
Both added value (Graph 4), and commercial potential (Graph 3) would also appear to have reduced. This is because the largest commercial gains are forecast when the company is entering new markets. At this stage, the generic technology has broad appeal, and the technology is most likely to be compelling to customers because the offering is more likely to be ahead of competitor technology. However, as the business has matured, further developments have more often been applied to niche segments, ie a narrow and deep appeal, with consequentially smaller sales effect.

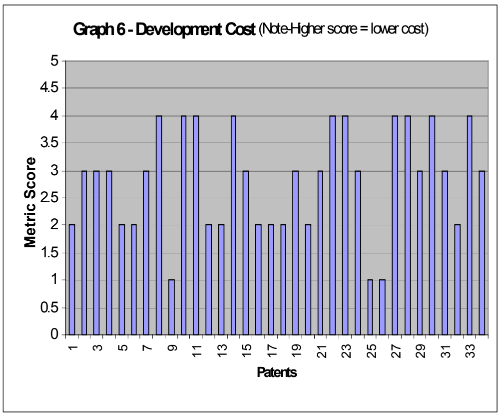












Over the period, the ideas would appear to have become less risky (graph 5).

There would also seem to have been an improvement in the development cost score (graph 6), although this is not such a clear tend. However, the two low scores at positions 25 and 26 probably mask the underlying trend. These two scores relate to the long-term development of a highly complex new fully active technology. This technology can be considered to be towards the end of the development S curve.

6. Discussion and Conclusions

Definition

The use of the IDEF0 method has been found to be very useful in the definition phase. When defining the arrows, the exact wording and terminology was very important. This created significant debate about what terms should be used and how they should be classified. However, the debate and initial uncertainty about the terms and categorisation was found to enable clear learning about the innovation process.

Further research will be done to look for ways in which the model could be used to improve innovation, not just necessarily the use of TRIZ. For instance, because the input to innovation is available knowledge, then making more knowledge available would seem to be a good idea. And there are many ways that this could be done. (i.e. using information technology, using consultants or recruiting from a wider skill base) However, this may well improve the inventiveness of the organisation, but may not improve innovation. Because the output of innovation is controlled by internal business and customer issues, these must be fully understood, and presented to the innovator.

One can speculate as to why TRIZ has the potential to improve innovation. It allows the user to use a huge database of knowledge, but without the cost of assembling it. The method also puts a high priority upon understanding contradictions within the technology that prevent improvements to customer or business requirements (constraints). Further work is being conducted to develop the lower levels of the innovation IDEF0 model. This will enable the research to understand the more detailed interactions between the sub functions, which in turn is expected to allow a more detailed understanding as to how to improve the system, and propose the best way to implement TRIZ.

Measurement

The derived measurement method has so far proved easy to use, by several individuals. However, there are some potential pitfalls. The overall score is clearly only part of the story, and a full understanding of the picture has to be gained by looking at the trends within each section.

The data so far has been scored as it would have been at the time. But there is no way of knowing this for sure. As such there is no reason why the metric could be further modified and re-scored if necessary. As long as the approach is consistent, then the tool will be useful for the purpose of measuring change.

The most significant limitation, is that the source data is missing the large body of ideas that have not been patented. The future comparison work therefore must maintain this rule. As the company develops, it is likely that a larger number of low inventive ideas will be generated, which will in fact by virtue of low risk and development costs, be highly innovative. But because these are not patentable, they cannot be included.

However, it should be anticipated that the use of TRIZ will generate new product sub groups with their own development S-curves. As such, the number of patent applications made by Avon VMS, could start to increase within the next two years. And this will provide comparative data with which to benchmark TRIZ and find out if does make a difference.

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APPENDIX 1

Innovation Metric

Idea title :

Write the title here

		Score	Example	Comment
Commercial Potential				
1	Supports continuation of existing business - maintaining market share. Keeping pace with competitors.	3	New and Improved material selection	
2	Some growth within a specific product group, or specific customer segment. Small increase in market share. Generates a USP of interest to some customers, or parts of the customer organisation.		Improved sub system	
3	Significant growth potenial across a product group. USP attractive to most customers, or parts of the customers organisation.		High tech solution to high end vehicle problem	
4	Major Growth within the Industry - widely addresses major customer needs. Significant competative advantage is achieved, this would seriously worry competitors.		New product, significantly better than competition	
5	Enables penetration into attractive new markets - a very significant growth opportunity. Avon is probably a new entrant.		First Hydraulic Engine Mount	
Inventiveness				
1	Non patentable low level improvement - limited technical benefit	3	New and Improved material selection	
2	Patentable or non patentable low level improvement - based upon small changes, probably to subsystem, but with limited improvement to system		Improved sub system	
3	Patentable improvement - novel implementation of knowledge within automotive VMS industry		New product, significantly better than competition	
4	Patentable improvement - multiple patent family, or novel implementation of knowledge outside of automotive VMS industry		High tech solution to high end vehicle problems	
5	Discovery of new technology / phenomenon that applies to many products / processes.		No Avon examples	
Cost / Added Value (Effect upon Contribution / Direct Profit)				
1	Benefits achieved with significant cost increase - customer reluctant to pay.	3	No Avon examples	
2	Benefits achieved with significant cost increase - customer accepts the need for higher price in return for benefit.		High tech solution to high end vehicle problems	
3	Cost and price neutral with respect to existing technology, allows continutation of business at current margins.		Improved sub system	
4	Improved margin, but price not substantively changed.		New product, significantly better than competition	
5	Benefits achieved with reduced price to customer, and increased margin.		Confidential !!	
Cost (Investment, Development Resource, Timing)				
1	High development costs - with high requirement for Avon funded hardware. Requires significant resource, very involved testing - likely to require greater than one vehicle programme cycle to develop. Significantly more complex than existing technology	3	High tech solution to high end vehicle problems	
2	High development costs with some requirement for Avon funded hardware, requires significantly more resource than existing technology. Needs full vehicle programme cycle for development.		High tech solution to high end vehicle problems	
3	Medium development costs - some Avon funding requried, slight increase in resource levels for implementation - when compared with existing technology. Developed within vehicle programme timing.		New product, significantly better than competition	
4	Low development costs - with limited Avon funding required for hardware. Can be achieved within resource levels used for standard technology. Easily developed within vehicle programme timing		Improved sub system	
5	Simpler process and tooling than existing technology, minimum validation and development.		New and Improved material selection	
Risk				
1	Significant uncertainty that the technology will work. Risk that technology is not of interest to customers.	3	No Avon example	
2	Significant uncertainty that the technology will work, but it will be of interest to customers.		High tech solution to high end vehicle problems	
3	Some uncertainty that the technology will work. Customers will certainly be interested		New product, significantly better than competition	
4	Risk is considered to be similar to existing technology, in both technology and customer perception		Improved sub system	
5	Risk lower than existing technology		New and Improved material selection	
	Note : For all questions - high scores are best	15	**Total Score**	

THE POSSIBILITY OF EFFECTIVE NEW PRODUCT PLANNING ACTIVITIES BY UTILIZING" THE PATTERNS OF TECHNOLOGICAL SYSTEM EVOLUTION"

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Abstract
The focus of Japanese manufacturers is shifting from the viewpoint of “enhancement of competitive edge based on capabilities of manufacturing technology (quality and costs)” to that of “enhancement and reinforcement of competitive advantage based on research and development capabilities (product and technological development)” using the new keywords of “creativity and uniqueness”.
Therefore, this paper refers to the effectiveness of introducing TRIZ (especially "The Patterns of Technological System Evolution), which has attracted attention recently, into new product planning activities, from the results of the survey for the actual situations of research and development activities conducted at Japanese manufacturers under the age of R& D capabilities. The latter half of this paper proposes introducing one of case studies about effective new product planning activities by utilizing "The Patterns of Technological System Evolution”, which are the TRIZ techniques for supporting the formation of development image (ideal posture in the future) of a product (technology), based on the examination outcome of the survey result.
Keywords: R & D capabilities, Patterns of Technological System Evolution, New product planning activities, Survey about R&D activities in Japanese manufacturers, Ideal posture in future

1. Introduction

The first half of this paper refers to the possibility of introducing TRIZ (especially the Patterns of Technological System Evolution), which has attracted recently, into new product planning activities from the results of the survey for the actual situations of research and development activities conducted at Japanese manufacturers under the coming of R&D capability’s age. Then, I propose introducing one of case studies about effective new product planning activities by utilizing "The Patterns of Technological System Evolution”, which are the TRIZ techniques for supporting the formation of development image (ideal posture in the future) of a product (technology), based on the examination of the survey result.

2. Purpose and Overview of the Survey

2.1 Purpose of the survey

This survey was conducted in September 2000 in order to investigate how engineers, the main force of the R&D and engineering divisions, recognized specific management and op-

erational challenges for "enhancement and reinforcement of competitive advantage based on research and development capabilities (product and technological development)" and what actions they were going to take to respond such challenges. In this survey, the below three viewpoints were taken into consideration.
1) Status of how the R&D and engineering divisions of Japanese manufacturers recognize management challenges.
2) Status of how the R&D and engineering divisions of Japanese manufacturers recognize operational challenges.
3) Current status of how technology management and creative techniques are utilized as a tool in the R&D and engineering divisions of Japanese manufacturers.

2.2 Survey method and number of respondents

A survey sheet was mailed to 2,492 general managers or executives in the higher positions in the R&D and engineering divisions of randomly selected firms in Japan (number of employees: 300 or more) and effective replies were 325.

3. Consideration of the Survey Result

3.1 Characteristics of recognition of their own businesses by Japanese manufacturers

The number of engineers at Japanese manufacturers who recognize the industrial life stage of their own company as on and after "Growth - end" is high, reaching 81.54%. Namely, the most engineers have a saturated feeling technically and a cooped up feeling toward the development direction of products and technologies (they don't know in which direction they should develop). Meanwhile, 15.08% of respondents recognize that their businesses are in the stages of "Startup" or "Growth - beginning" (Table 1), and these engineers belong to the currently emerging information technology related industries (electric appliances, precision, information and communication).

Replies	Respondents	Ratio	
1. Startup	4	1.23%	**15.08%**
2. Growth - beginning	45	13.85%	
3. Growth - end	52	16.00%	**81.54%**
4. Maturity	175	53.85%	
5. Decline	38	11.69%	
0. No answer	11	3.38%	
Total	325	100.00%	

Table 1. Recognition of the Life Stage of their Own Company (Industry)

3.2 Recognition of management challenges in the R&D and engineering divisions

The tendencies of recognition of their own business challenges are as shown in Table 2. The most highly evaluated item is "Technical capabilities in the aspect of quality," which is called one factor for Japanese manufacturers' success, and the lowest item is "Mechanism of product planning stage," which realizes creativity of product (technology). Weakness of the latter is also supported by the answers for the question asking the operational stage recognized as the most serious problem (Table 3), and the tendency of recognizing “Product planning stage” and “Development and design stage” as a problem is outstanding.

Highly evaluated		Not evaluated highly	
Technical capabilities in the aspect of quality	3.30	Mechanism of product planning stage	2.72
Mechanism of manufacturing stage	3.19	Utilization of information technology	2.80
Lead time (compared with competitors)	3.15	Design review function	2.84
Brand appeal and market image	3.11	Cost engineering capabilities	2.90
Product/Technology development capabilities	3.07	Mechanism of development & design stages	2.94
Average of all replies = 3.0012 points (unit: point)			

Table 2. Status of Recognition of Management Challenges

Replies	Respondents	Ratio
1. Product planning stage	124	**38.15%**
2. Development and design stage	109	**33.54%**
3. Manufacturing stage	28	8.62%
4. Sales promotion stage	34	10.46%
5. Sales stage	16	4.92%
0. No answer	14	4.31%
Total	325	100.00%

Table 3. Recognition of Management Challenges in Each Operational Stage

3.3 Recognition of operational challenges in the R&D and engineering divisions

I want to focus on “challenges in the product planning stage” as one of the most important operational challenges in the R&D and Engineering Divisions.

The current main challenge in the product planning stage is “How to grasp market needs.”

But for priority, “Creativity (ideas) at the product planning stage” is the highest. And when limiting the recognition by the product development staff specifically, the tendency of selecting “Creativity (ideas) at the product planning stage” as well as “Prediction of product/technology development direction” as a challenge is high. It can be judged that they feel the importance of predicting the direction of development as a person actually performing the product development (Table 4). Recognition of “Creativity (ideas) at the product planning stage” as a challenge tends to be stronger in accordance with reaching to the upper stream of the operational stage (Table 5).

94.15% of respondents admit the necessity of “Prediction of product/technology development direction” (Table 6), but 49.54% answered that they do not have that image in reality (Table 7). The cross-analysis of the recognition of current “Development image of major products” and “Mechanism of product planning stage” revealed that recognition of “Mechanism of product planning stage” is greatly different whether they have “Development image of major products” or not (Table 8). If they have “product image,” the tendency that the recognition of "Mechanism of product planning stage" is good is high (33.42%). On the other hand, if the respondents do not have "product image," this rate is low (9.44%), and furthermore, the tendency of recognition that "Mechanism of product planning stage" is bad is quite high (40.06%). This indicates whether they have "Development image of major products" at present or not has strong influence on the recognition of "Mechanism of product planning stage."

"Evaluation of product planning operations" and "Evaluation method of product planning proposals" are not highly respected. But when considering the weakness of "Design review function" (Table 2) and that of "Rational evaluation system of development/design proposals" (Table 10), it should be considered that there is no good evaluation method in reality and specific development is hard to make, rather than the evaluation method being established.

	All replies				Replies from product development engineers			
	Current challenge		Priority		Current challenge		Priority	
	Respondents	Ratio	Respondents	Ratio	Respondents	Ratio	Respondents	Ratio
1. Method of determining product to be developed	131	15.30 %	25	12.82 %	57	14.84 %	22	12.22 %
2. How to grasp market needs	229	26.75 %	49	25.13 %	103	26.82 %	44	24.44 %
3. Prediction of product/technology development direction	195	22.78 %	43	22.05 %	91	23.70 %	44	24.44 %
4. Creativity (ideas) at the product planning stage	213	24.88 %	60	30.77 %	100	26.04 %	56	31.11 %
5. Evaluation of product planning operations	18	2.10%	1	0.51%	9	2.34%	2	1.11%
6. Evaluation method of product planning proposals	69	8.06%	17	8.72%	24	6.25%	12	6.66%
7. Others (　　)	1	0.11%	0	0.00%	0	0.00%	0	0.00%
Total	856	100.00 %	195	100.00 %	384	100.00 %	180	100.00 %

Table 4. Recognition of Challenges in Product Planning (Development Preparation) Stage

Creativity (ideas) at the product planning stage	Operational stage			
	Product planning stage	Development and design stage	Manufacturing stage	Total
Recognized as a challenge	35.86%	50.51%	13.64%	100.00 %
Not recognized as a challenge	23.25%	51.75%	25.00%	100.00 %

Table 5. Recognition of "Creativity (ideas) at the product planning stage" at Each Operational Stage

Replies	Respondents	Ratio
0. No answer	14	4.31%
1. I feel so.	306	**94.15%**
2. I don't feel so.	5	1.54%
3. Others ( )	0	0.00%
Total	325	100.00%

Table 6. Necessity of Reviewing Development Direction of Product (Technology)

Replies	Respondents	Ratio
0. No answer	19	5.85%
1. I have it.	130	40.00%
2. I don't have it.	161	**49.54%**
3. Others ( )	15	4.62%
Total	325	100.00%

Table 7. Development Image of Current Major Products

Image	Recognition for "Mechanism of product planning stage"					
	Very bad	Bad	Moderate	Good	Very good	Total
Yes	0.26%	15.42%	50.90%	30.85%	2.57%	100.00%
	15.68%		50.90%	**33.42%**		
No	1.79%	38.27%	50.51%	8.16%	1.28%	100.00%
	40.06%		50.51%	**9.44%**		

Table 8. Image of Current Major Products and Recognition of "Mechanism of Product Planning Stage"

3.4 Status of utilizing technology management techniques

As technology management techniques utilized comparatively, there are "QC," "Development/Design VE," "FTA/FMEA" and "Taguchi Method." Among those, "QC," "Development/Design VE" and "FTA/FMEA" have been established as commonly-used technology management techniques. For standardization of development/design activities, it is effective to utilize technology management techniques as the means for implementation. But judging from the fact that the degree of establishment of technology management techniques is so low, it is assumed that this situation is one of the causes for delaying standardization of development/design activities (Table 9).

	Management technology utilized		Management technology established	
	Respondents (A)	Ratio	Respondents (B)	Ratio (B/A)
1. Development/Design VE	159	**20.73%**	35	**22.01%**
2. QFD (Quality Function Development)	64	8.34%	6	9.37%
3. DFMA	16	2.08%	1	6.25%
4. Taguchi Method	62	**8.08%**	2	3.22%
5. FTA/FMEA	129	**16.81%**	27	**20.93%**
6. QC	208	**27.11%**	59	**28.36%**
7. IE	57	7.43%	2	3.50%
8. OR	9	1.17%	0	0.00%
9. PM	37	4.82%	1	2.20%
10. TOC	16	2.08%	2	12.50%
11. Others ( )	10	1.30%	3	30.00%
Total	767	100.00%	138	17.99%

Table 9. Managerial techniques Utilized and Established

4. Possibility of Introducing Patterns of Technological System Evolution into Planning VE as one of effective new product development approaches

Fig. 1 is the summary of recognition status of challenges based on the life stage recognition from the survey results. Most of the life stage recognition concentrates on “Maturity.” And the relationship between progress of life stage and stages of product making corresponds to the cycle from basic research → manufacturing → development design → product planning (→ basic research). In other words, in accordance with the progress of the life cycle, factors for competitive edge of manufacturers vary and thereby their main challenges change.

In the current Japanese manufacturing industry, the recognition that they are in “Maturity” to “Decline” exceeds 81.5%, and it simultaneously tells that challenges on the “Product planning stage” are becoming serious issues.

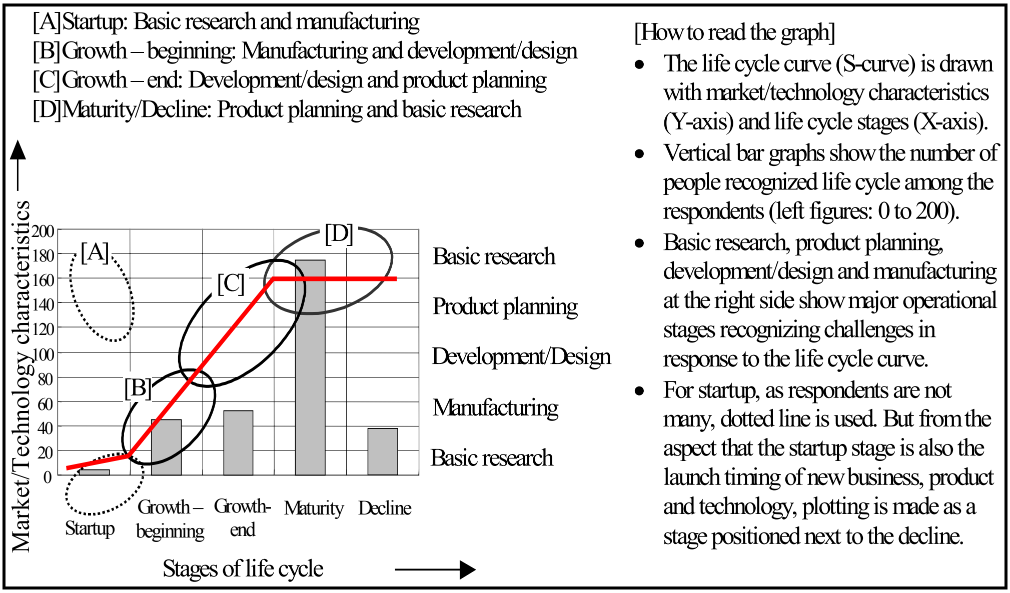

Fig.1. Challenges based on Life Stage Recognition

On the other hand, Table 9 shows that "Development/Design VE" have been recognized as commonly-used technology management techniques at product planning and development phase. Therefore, I want to consider the possibility of introducing Patterns of Technological System Evolution into Planning VE (including Development/Design VE) as one of effective new product development approaches.

To be concrete, I want to show you that the combination of "Planning VE" and "Patterns of Technological System Evolution" is one of best ways to predict (or create) next generation product through the case study at latter half.

5. Development of a Next Generation Product Scenario by Utilizing "Patterns of Technological System Evolution" in Planning VE Activities.

The relationships of the basic steps and work steps for developing a next generation product scenario can be summarized as Table10.

Development of a Next Generation Product Scenario: Basic Steps	Development of a Next Generation Product Scenario: Work Steps	
Step 1: Analysis and evolution of the system evolution to date	Step 1:	Collect information for the development theme.
	Step 2:	Sort out development history for the target system (past to present).

Step 2: Development potential scenarios of future evolution	Step 3:	Sort out development history for the target system (present to future).
	Step 4:	Map the Patterns of Evolution.
	Step 5:	Develop a concept for target system in the future – scenario writing.
Step 3: Decision-making	Step 6:	Evaluate each proposed concept (scenario) for the target system.

Table10: Steps for Development A Next Generation Product Scenario

The case study was conducted at Company X, a Japanese housing manufacturer, under the following theme:

Theme:
Panels, which are friendly to the environment and humans, are to be used in water usage areas

The work steps proposed in this paper (see Table 10) will be discussed individually while introducing some of the outputs from the case study.

5.1 Step 1: Collect information for the development theme

In this step collect information related to the development theme from every angle. This step corresponds to information collection of VE target, but is a Questionnaire for Collecting Information (see Table 11) combining the TRIZ perspective.

1. **Preconditions of the target system**

   Panels, which are interior materials, friendly to the environment and humans, to be used in water usage areas such as the bathroom and kitchen.

2. **Information of the target system to be evolved in accordance with the social change**

   1) Target system name: Environment friendly panel
   2) Main useful function: Not harmful to human beings
   3) Other useful functions of the system: Excel in waterproofing; clean appearance; soundproofing; prevention of hot and cold weather, etc.
   4) History of the system
      Sort out the changes of panels used in the houses from past to future over time.
      Material viewpoint:

Wood → Tile → Decorative laminated sheet (solvent paint)
(waterproof) (workability) ↘ Steel plates (design ability)
(durability) (dirtiness of joints)

3. Information on defects and risk elements of the technology/service related to the target system

1) Description of defect and risk element: The environment friendly type panel is weak in durability and heat resistance.

2) Reason why such defect and risk exist: The environment friendly type does not use solvent so it has permeability.

4. Previous attempts/ideas for the system improvement and development of new generation system

1) Attempts/ideas in the past to increase system's useful functions
Add the solvent to the degree not to influence human beings as a result.

2) Previous attempts/ideas related to the development of a new system

3) Previous attempts/ideas to eliminate/reduce system defects and harmful elements .Heat the product again at the plant before delivery to evaporate the solvent.

5. Information for the relevant systems

1) List of systems related to the target system including the environment of use
Kitchen, bath, toilet, and washroom system

2) List of other systems performing the same function of the target system, etc.

Table 11. List of Collected Information for the Target System (Partial)

This questionnaire always makes users think about the ideas of " Patterns of Technological System Evolution" so that history of technology evolution, which can be overlooked by the conventional market research type analysis, can be considered.

5.2 Step 2:Sort out development history for the target system (past to present)

Sort out the changes of the target system as well as its subsystem or supersystem (located at the higher position of the system) from past to present structurally. Sort out the history of technology evolution from the past to present utilizing Table12: Matrix for System Evolution of Panels. Specifically, a technological system, its subsystem and supersystem, which seem to be applicable to each cell of the matrix, should be stated. The contents described in the questionnaire of Step 1, which can be utilized (e.g., contents of the second item for this step), are copied. Of course the description in each cell is not limited to one, so if there are several items, all of them are stated.

5.3 Step 3:Sort out development history for the target system (present to future)

	Past	Present	Future
Supersystem	Kitchen: Kitchen consisting of independent elements →	System kitchen ↓ Open kitchen ↓ Kitchen with consideration for the aged	→ Automated kitchen
	Face washing: Washbowl →	Washstand with hair washing function ↓ Washstand with consideration for the aged	
	Bath: Japanese traditional style bath ↓ Tile bath →	Unit bath ↓ Unit with consideration for the aged ↓ Healthcare bath	→ Home sauna + Jacuzzi
System	Panel Wood → Tile → ↘ Steel plate ↑ Asbestos cement sheet	Decorative laminated sheet (with solvent paint) → Incombustible Hardness (H) → Noninflammable Hardness (2H) (Latter half of 90s)	Solventless panel • High reformability • Liquid crystal noninflammable panel • Ceramic board
Subsystem	Wood → Natural Plywood Steel plate → SUS Copper Iron	Polyester → Acrylic urethane Asbestos cement → Non-asbestos cement Pattern printed paper ↓ Pattern printed saturating paper	Inorganic material → Ceramic Fixing substance (adhesive) ↓ Velcro tape, magnet

Table12. Matrix for System Evolution of Panels (Partial)

With reference to the analysis result of the history from the past to present of the matrix prepared in Step 2, also structurally sort out the future. Specifically sort out the history of technology evolution from the present to the future utilizing Table12: Matrix for System Evolution of Panels, the same as Step 2.

5.4 Step 4:Map the patterns of technological system evolution

Map the Patterns of Evolution by applying the contents of the Matrix for System Evolution prepared in the previous step to each Pattern. In this case, without limiting to one Pattern, we tried to grasp any item, which fit into several Patterns.

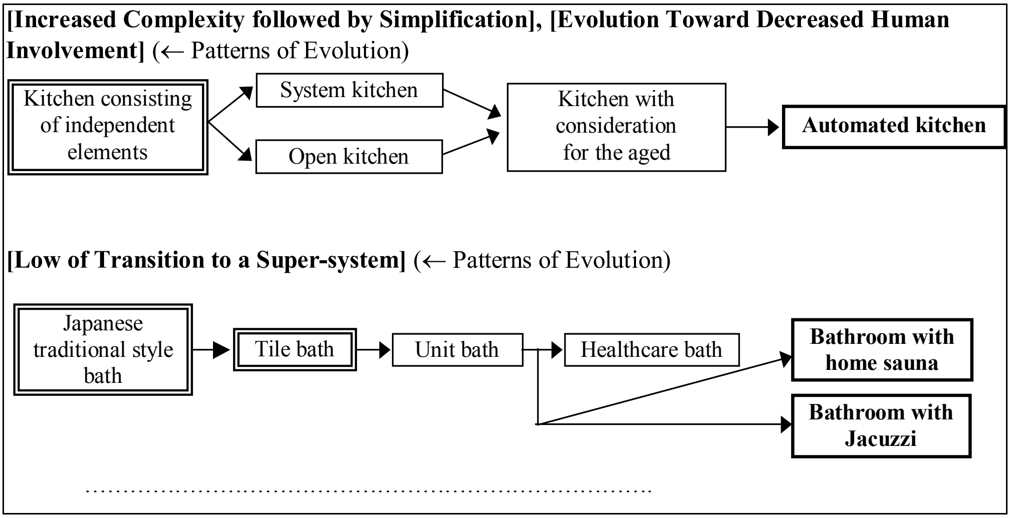

Fig .2: Mapping Chart of Patterns of Technological System Evolution (Partial)

Various Patterns of Evolutions are generally introduced in the TRIZ field and currently over 20 Patterns of Technological System Evolution are confirmed. (This paper excludes the explanation of each Pattern of Evolution.)

5.5 Step 5:Develop a concept for target system in the future-scenario writing

In this step, a possible scenario to be included in the product proposal will be prepared.

Develop several proposed scenarios related to the target system with reference to the Mapping Chart of Patterns of Technological System Evolution prepared in the previous step.

Specifically, review the method of combination between future events and develop scenario for each combination group while utilizing various Patterns of Technological System Evolution. In this case developed scenarios in combination with future events based on those clarified in the pattern-mapping chart while considering the relationships of independence and inconsistency.

The future events utilized in the combination scenarios can be categorized into three levels: subsystem, system and supersystem, and we tried to review the combination scenarios utilizing future events at all three levels. Fig. 3 shows some of these scenarios in this case.

	Concept A	Concept B	Concept C
	Automation arrives in kitchens and the concept of saving trouble in the housing will further be generalized. Therefore, development, which makes cleaning and maintenance enjoyable and easy, will be advanced. Under such trend, **maintenance-free board will appear as housing panel.** In terms of material, …	Automatic cleaning of lavatory will be enabled and cleaning of the healthcare toilet will be easier. This suggests that a flushing water type floor and wall will appear (dirt can be cleanly removed by water). Also under this kind of environmental change, a **maintenance-free board will appear.** This …	The demand for comfortable bathing is intensified. Under such circumstance, home sauna and Jacuzzi with compact size can be installed in a bathroom. It will also be possible to enjoy beautiful scenery using a large-screen TV (liquid crystal flat panel). This will be just like landscapes painted on the walls of the Japanese old time public baths but evolved to animated and clear image. Under this background, **the demand for liquid crystal (noninflammable) panel total coverage will increase.** Thus …
Technical limitation (Importance x 2)	4 x 2 = 8	3 x 2 = 6	4 x 2 = 8
Investment scale	3	3	2
Consideration to environment	5	5	2
Legal regulations	4	3	3
Marketability	4	3	2
Corporate profitability	4	3	5
Total point	28 points	23 points	22 points
Priority	No. 1	No. 2	No. 3

Fig.3: Scenario Generation and Evaluation

5.6 Step 6:Evaluate each proposed concept (Scenario) for the target system

Evaluate the feasibility of each concept (scenario) from the criteria including technical limitation, economical investment size, and legal regulations, and finally select the most valuable and promising scenario from them. At the time of evaluation, try to select the optimal scenario from among the several concepts of the team members. Especially it is recommended to establish criteria, which may exist in the future, and then evaluate in accordance with them. Although the author believes that normally the AHP technique known as rational decision-making technique is effective, this time, a simple five-point scoring model was used and finally the scenario was selected based on the consensus among the team members. Fig.3 summarizes the evaluation results of this case in relation to the previous steps.

After this step, the marketing approach is used to compile the product proposal.

6. Conclusion

In the first half, we understood that it is reasonable to suppose that Japanese manufacturers is shifting from the viewpoint of "enhancement of competitive edge based on capabilities of manufacturing technology" to that of "enhancement and reinforcement of competitive advantage based on research and development capabilities" through the result of survey.

Therefore, studying possibility of introducing Patterns of Technological System Evolution into Planning VE as one of effective new product development approaches is valuable thing. Because, survey's result shows that VE has been established as commonly-used technology management techniques at Product planning and developing phase .

In the latter half, the specific methodology of product scenario writing was systematized using the Patterns of Technological System Evolution. Application of this method can compensate the perspectives, which cannot be covered by the conventional marketing technique.

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DEVELOPMENT AND IMPLEMENTATIONS OF TRIZ THEORY

CONTRIBUTION TO EARLY STAGES ANALYSIS: A FRAMEWORK FOR CONTRADICTION'S COMPLEXITY REPRESENTATION

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Abstract
It is universally acknowledged that actual industrial situation regarding problem solving stages is of a critical matter for R&D robustness. A technical situation that causes inefficiency is stated as an "unsolvable problem" and treated as "best possible compromises". In fact they are the result of a complex situation where mental inertia leads the designer's attitude. Regarding the way TRIZ's theory addresses problem, it is also now worldwide recognized that a contradiction should be solved in a "non compromised way" in order to move toward inventiveness in accordance with laws of system evolution. Nevertheless, the stage of gathering data in such a shape that the initial fuzziness is reduced to an efficiently built physical contradiction remains unclear in the framework of classical TRIZ. Among others, this situation creates now an obvious obstacle to TRIZ's credibility in organizations. Our paper proposes a representation of a complex given industrial situation in a meta-net of contradiction in order to prepare any problem solving stage with the correct scientific models of physical contradictions and their inter-relations. An example of shaping the meta-net of contradiction in injection molding will be shown through a case example.
Keywords: Contradiction network, Injection molding, design, knowledge, OTSM-TRIZ

1. Stating the global problem and our proposed methodology

Technical artefacts are becoming increasingly sophisticated as technology evolves and competitive pressures pose new constraints on firms, especially concerning their ability to innovate (at the product or process level) at an ever increasing pace. The result is the need for firms to rebuild design potential, both in terms of human skills and methodological expertise.

A new situation is affecting the designers of these artefacts. It can be summed up as follows: are the tools and methods developed to aid the designer in his tasks still appropriate in the context briefly outlined above?

Two fundamental aspects make us think this is not the case:

- The gap between the rate of requests for human creativity and its actual capacity;
- The gap between the scopes of knowledge required in view of the level of complexity, and the inherent ability of a human group within a given organisation.

Contemporary designers are faced with a two-fold dilemma – that of having to ensure design tasks in a context where:

- The tools and methods available to assist them were developed within a context of optimising quality, as imposed in the 1960s-1990s. This means they are not always adapted to meet the requirements of current design tasks which are more focussed on optimising creative potential (Shaw, 1986) leading to higher efficiency in terms of inventiveness in the design act within the company (Holtj, 1992);
- The complexity of the artefact and the scope of knowledge required make their own creative capacity inadequate. This limitation is accentuated by the fact that a truly inventive act is often measured by the following yardstick: external knowledge (i.e. unknown at that time by the industrial sector in which the designer works) is technologically transferred to the designer's own field, thereby making the creative act inventive.

All design acts are carried out as cognitive acts encouraging the designer to solve a contradiction introduced by his act. This essential notion in TRIZ stipulates that the contradiction symbolises the obstacle which has to be understood and solved to enable the technical system to evolve in keeping with the laws. While cognitive reflexes often drive designers to a compromise solution, Altshuller purports that compromise does not arise from an inventive approach and that to move in the direction of inventiveness, the designer must refuse compromise despite his psychological inertia to solve the dilemma posed by the contradiction. After the work of Nikolaï Khomenko on OTSM-TRIZ (Khomenko, 2002) , it has been stated that the level of complexity involved in designing an artefact implies that a network of contradictions (also called problem flow technology) representing the corelation between problems and their subsequences should be built up in order to place the designer face to face with the challenges he has to raise.

The aims of this presented work is then to introduce from a theoretical and practical angle how we intend to represent a complex situation in a graphical form in order to efficiently manage problem solving process. The practical viewpoint will be given by an application in injection molding.

2. Complexity of design in injection molding

2.1 The particularities of injection molding technology

Injection molding design consists mainly of part design, material selection and mold design (Rosato, 1995). The machine used to process the plastic material is seldom designed for a specific project, but chosen out of the resources of the company. Part, material and mold are defined in order to reach some specific requirements: mechanical (stiffness, shock…) chemical (toxicity…) functional (easy to use, rigid…) processing (easy to manufacture, low tool wear…) cost (low prize of material, low mold cost…), see (Beiter et al, 1995). Requirements can be drawn out of the product life cycle (Chakravarty, 2001).

We can underline the following particularities:

- These three entities have to be designed one according to the other. For example: the mold has to be designed according to the part design; the part has to be designed according to the chosen material;
- Each can be adapted according to the requirements. For example: in order to eliminate sink marks or flashes, it is possible to change either the part design or the mold design; in order to reduce wear of feeding chanels, it is possible to change either the plastic material or the mold material;
- Requirements can be common or specific. For example: some processing defects, or processing time are relevant to both the material, the part and the mold whereas the amount of material is only relevant to the part design.

Therefore, the design task can get really complex: many technical contradictions can appear between requirements, and many physical contradictions can appear on parameters of the three designed objects. All those contradictions are linked, and generate a network that should be investigated in a smart way to converge rapidly to the definition of the key issue of a specific situation.

2.2 Design knowledge

Many scientific fields have to be considered within injection moulding design. The first and obvious is chemistry, which can explain the properties of molecules (interaction with environment, with mold, with user…). The second is rheology, and explains all the consequences of material flow within processing (molecules orientation, cristals creation, shear heat…). The third one is mechanics, used to preliminary and detailed design of parts (dimensions, frequency of use and force application…) or mold (thickness to reach a certain rigidity…). A fourth one can be named "technological knowledge" and is built on the experience of designers (capabilities of standard product configurations…). Furthermore, within each of these fields, many researches items are being conducted in order to facilitate, as a final objective, efficient design. Therefore, during problem solving, each field should be investigated and well understood in order to not miss the solution, but only the field of efficient solution needs to be known in order not to grow the complexity of the needed knowledge, and to reduce time of solving.

2.3 The methodology employed to represent this knowledge in a metamodel.

- *Creating an influence network*

In order to solve this contradiction we propose to structurise the required knowledge beforehand, in a way that can be usefull for TRIZ application (Altschuller, 1973). In order to harmonize design field and TRIZ paradigms, we propose to precise the contradiction pattern (see Figure 1) the following way (Eltzer, 2004):

- "Element" is whole or part of design objects (it can be obtained through analysis with first law of technical system evolution);
- "Parameter A" (which we will name "physical parameter" of the contradiction) is a parameter defining the designed object. It cannot be evaluation of the object. It represents what the designer can directly change. It can have different levels in design (conceptual, preliminary, detail (Pahl&Beitz, 1996)). It is the consquence of only the

designer choice. If the physical parameter fits those conditions, it is named "active parameter";
- "Value 1", "Value 2" are possible values of the physical parameter, each of them defining a specific system;
- "Parameter 1", "Parameter 2" (which we will name "technical parameters" of the contradiction) are criteria used to evaluate the design project. They can be relevant to design object (manufacturing precision for example) or to anything else (environment harms for example). They cannot be choices. They can represent constraint, functions, evaluation. If technical parameter fit those conditions, they will be named "evaluating parameter";
- "☺", "☹" are values of technical parameters as consequence of value of the physical parameter

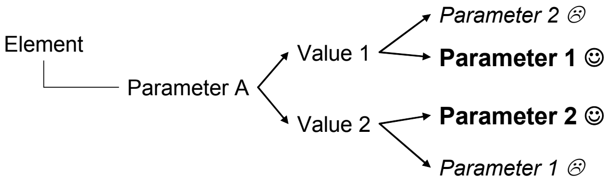


Figure 1. Contradiction pattern

The value of active parameter is the consequence of only the designer choice, and relations between designed objects have to be represented this way. In order to integrate precise knowledge and sharp explanation of conflicts, we propose to introduce "intermediary parameters" between physical parameter and technical parameters of any contradiction (Figure 2):

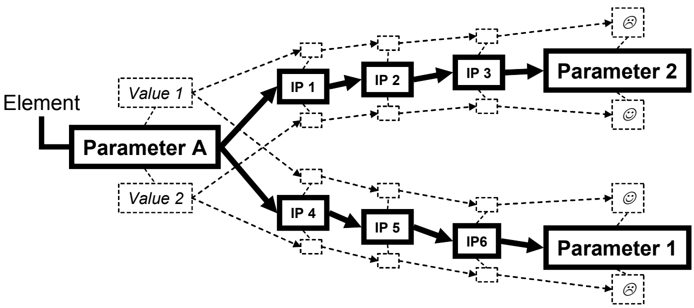


Figure 2. Intermediary parameters

These three families of parameters are linked with objective laws (presented as arrows on Figure 2). These objective laws are the bases of the knowledge required to design. Intermediary parameters can belong to more than one route from physical to technical parameters. As a consequence, a complete network of parameters is built on the bases of three families of parameters (see Figure 3), in order to represent problem solving in the frame of design activities:

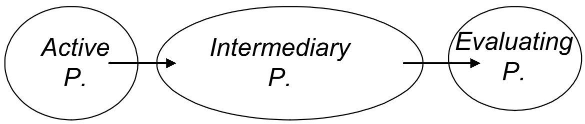


Figure 3. Families of network parameters

This network represents standard system design (as a set of generic active parameters, without their values), required knowledge (as the set and relations of objective laws) and classical criteria (as generic evaluating parameters). The generic nature of the network is brought by the set of generic parameters, and the specifity by their values.

- *Conclusion*

In order to help early stages of problem analysis, we propose to gather required design knowledge beforehand (all allong previous projects and research findings) and structure it through a network of influence based on three families of parameters (active, intermediary, evaluation) linked by objective laws.

This network is used to build the contradictions describing the specific initial situation. These contradiction can have different level of genericity, depending on the level of genericity of the parameters.

However, some generic contradictions appearing in this general network can be naturally solved according to specific situation, and other have to treated with TRIZ tools.

We will see in the coming sections that this representation can be used to treat contradiction networks.

3. Stating an initial situation: a case example

We present a specific industrial problem, taken from medical applications, to illustrate how to state the initial situation description and to treat the resulting contradiction net. We will choose the case of a very simple plastic part (Figure 4):

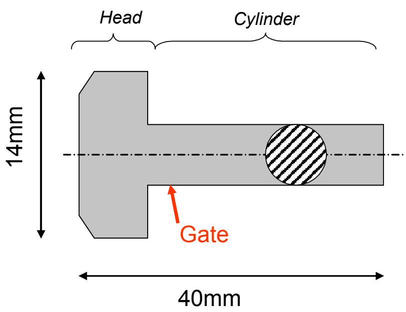


Figure 4. Plastic part

The project is at the design of the manufacturing mold, and mold designers forseen few manufacturing defects (warpage, voids, plastic deformation of degating (Malloy, 1994)). Part is parrallel to screw direction. The gate location is under the head of the part, and results in warpage. It is required to avoid flash allong the cylinder and the head.

3.1 Express the initial situation

The network representing any specific situation can be built with two different ways:

- Build the contradiction set from description of the situation (this depends on the ability of the designer to formulate contradictions);
- Build the contradictions based on the proposed knowledge structure (if it has been built beforehand).

- *From formulated contradiction*

The first way is to fomulate contradictions and to link them afterwards. After having gathered contradictions it is first necessary to put them in coherence with the proposed format (active, intermediary and evaluating parameters). Only six possibles types exist:

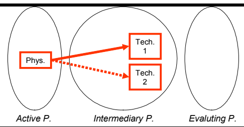
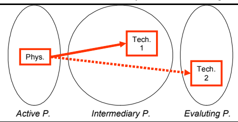
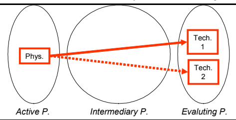
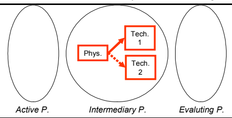
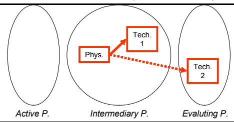
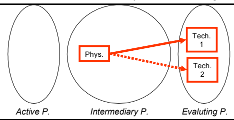
Type	Physical	Technical 1	Technical 2	Picture
1	Active	Intermediary	Intermediary	
2	Active	Intermediary	Evaluating	
3	Active	Evaluating	Evaluating	
4	Intermediary	Intermediary	Intermediary	
5	Intermediary	Intermediary	Evaluating	
6	Intermediary	Evaluating	Evaluating	

Table 1. Types of contradictions

We propose the following examples, taken from the specific case:

- Type 1: If gate diameter is high then degating constraint is high and shear heat is high, but if gate diameter is low then degating constraint is low and shear heat is low;
- Type 2: If gate diameter is high then constraint of degating is high and material burning is satisfying, but if gate diameter is low then constraint degating is low and material burning is unsatisfying;

- Type 3: If gate location is top of head then warpage deformation is satisfying and microstructure homogeneity is unsatisfying, but if gate location is top of cylinder then microstructure homogeneity is satisfying and warpage deformation is unsatisfying;
- Type 4: If cavity surface temperature is high then bulk melt viscosity is low and cavity thermal shock is low, but if cavity surface temperature is low then bulk melt viscosity is high but cavity thermal shock is high;
- Type 5: If gate diameter is high then degating constraint is high and lack of material in produced part is satisfying, but if gate diameter is low then degating constraint is low but lack of material in produced part is unsatisfying;
- Type 6: If shear heat is high then lack of material in produced part is satisfying but material burning is unsatisfying, but if shear heat is low then lack of material in produced partis unsatisfying but material burning is satisfying.

Second, it is important to complete the built network based on the generic one, to check the completeness:

- check if any evaluating parameter of the generic set should be added as a required property of the final concept;
- check if any active parameters of the generic set should be added as something that can be changed to reach the objective;
- check if any phenomenon, explained through intermediary parameters in the generic network should be added to clarify the conflict's reason;
- check if any generic conflict should be added to the specific network.

- *From the generic network*

The second way is to begin from the generic network and to select the portion representing the complexity of the specific situation (Figure 5):

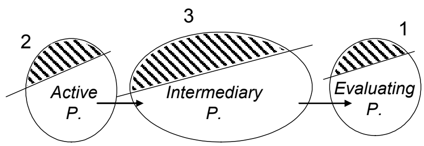


Figure 5. Three steps of extraction

- Extract the objectives (1): extract the evaluating parameters that are important as goals of the design, identify both their current and required value. In our case: cost (low => low), simplicity of mold (high => high), microholes (much => no), microstructure homogeneity (high => high), amount of material (low => low), molecules burning (low => low), degating deformation (low => low), warpage deformation (high => low), material burning (low => low), lack of material in produced part (high => high).
- Extract the frontiers of the existing system (2): extract the active parameters that can be changed, those which currently have a value, and those describing standard alternative configurations. In our case: gate diameter (0,5mm), diameter of cylinder (3mm), diameter of head (14mm), length of part (40mm), gate location (top side of cylinder), part position in mold (parrallel to screw), number of mold plates (2), feeding mecanism (cold), structure of mold (first category), number of cooling channels, gate location (top of cylinder)

- Extract the portion of intermediary parameters that link the selected active and selected evaluating parameters (3). In our case: Contraint of degating, Adhesion melt-mold, Molecules diffusion, Location of sections in cavity, Compensation of thermal contraction, Molecules orientation, Shear heat, Cavity surface temperature, Skin viscosity, Cavity thermal shock

As a result of these three steps, we obtain the portion of the meta model describing the specific situation. The next step is to draw out of it the network of contradictions:

- Starting from required changes of evaluating parameters values (warpage deformation, microholes), get back to required values of selected active parameters (gate location) to reach evaluating parameters values and go back to worsen evaluating parameters (microstructure cohesion, Runner ejectability).

Finally, it is necessary to check if any foreseen specific conflict and difficulty is well represented in the contradiction network, and if the advantages and disadvantages of the current system compared to other configurations are well represented.

3.2 Synthesis to a key issue

Three types of contradiction network can be built during analysis of initial situation. The first is based on contradictions as milestones of the problem solving (one is solved, another appears, which is solved again, a new one appear, and so on); the second on contradictions describing alternative system configurations, each of them tackling the same key issue; and the last one on contradictions describing many needs, generated by many resources in a single system configuration. We do not consider here redundant contradictions, which is a semantic issue.The problem of treating contradictions network in classical TRIZ can be summerised in the following conflict: we should apply classical TRIZ solving tool (Matrix, Physical principles, ARIZ, sufield (Altschuller, 1973)) in order to direct the solving and because they are the most efficient solving tools, but we should not use them because we have a network of contradictions which cannot be solved separately. In order to treat this problem, we propose to synthesize the network to allow application of classical TRIZ tools:

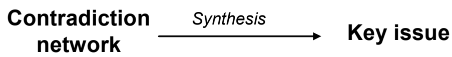


Figure 6. Synthesis of network

The «key issue» must have the following properties: its resolution leads to the greatest system improvement and it can be treated by classical TRIZ tools. We decided to use the pattern of contradiction for this key issue. This format is well suited for ARIZ, inventive principles of either technical or physical contradiction. The gap between the contradiction and sufield analysis will have to be filled by the solver. The synthesis we propose is based on two mecanisms, named selection (choose one contradiction out of a set) and convergence (merge many contradictions in a single one)

- *Selection*

The aim of this mecanism is to select, within a network of contradiction, the one that should be treated in priority. We propose a few selection criterias:

- Functional level of the elements described by the active parameters (Pahl&Beitz, 1996). In our case: if the part is changed, some contradictions related to the mold disappear, as the mold is developped according to the part;
- Priorities and weight of evaluating parameters (rigid constraint, flexible constraint, wishes, "bonus"…). In our case: warpage deformation is worse than flash; norms are firm; amount of material can be negotiated;
- Level of definition of active parameters (from conceptual to detailed level) (Pahl&Beitz, 1996). In our case: "mold structure has to be two plates to be simple but three plates to allow runner ejectability" compared to: "the gate diameter has to be large to allow good filling and small to avoid serious gate vestige";
- Weight of active parameter on evaluating one. In our case: tuning the process (speed, pressure temperature…) can reduce flashes, but it will never be as reliable as a good mold opening direction; cooling system design can influence warpage deformation but in a less reliable manner than gate location;
- Number of contradictions the active parameter is concerned with. In our case: gate location has consequences on runner ejectability, microstructure homogeneity, warpage deformation, gate vestige, degating deformation whereas number of sliding affects only mold simplicity and flashes.

- *Convergence*

The basic idea of this mecanism is to use one single contradiction to represent more than one contradictions. We will present this idea with a particular example of two type 3 contradictions, named contradiction A and contradiction B.

Contradiction A (Figure 7) is written with the classical format (Khomenko, 2002), and describes the influence of temperature of the melt at the entrance of the mold on both the cycle time and the good filling:

- If the parameter <entering temperature> is high, then the parameter <cycle time> will be unsatisfying and the parameter <lack of material in the produced part> will be satisfying;
- But if the parameter <entering temperature> is low, then the parameter <cycle time> will be satisfying and the parameter <lack of material in the produced part> will be unsatisfying.

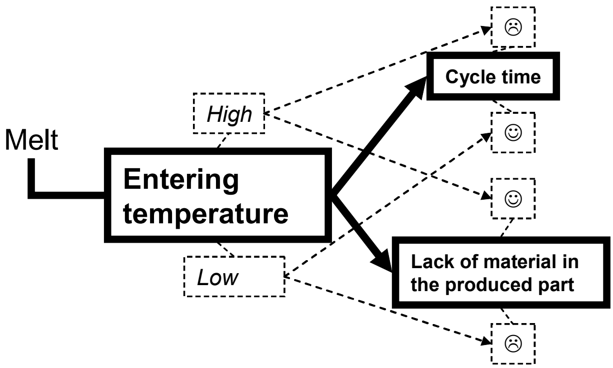


Figure 7. Contradiction A

Contradiction B (Figure 8) is written with classical format too, and describes the influence of the cooling design on both the cycle time and the filling:

- If the parameter <number of cooling channels> is low, then the parameter <lack of material in the produced part> will be satisfying and the parameter <cycle time> will be unsatisfying;
- But if the parameter <number of cooling channels> is high, then the parameter <cycle time> will be satisfying and the parameter <lack of material in the produced part> will be unsatisfying.

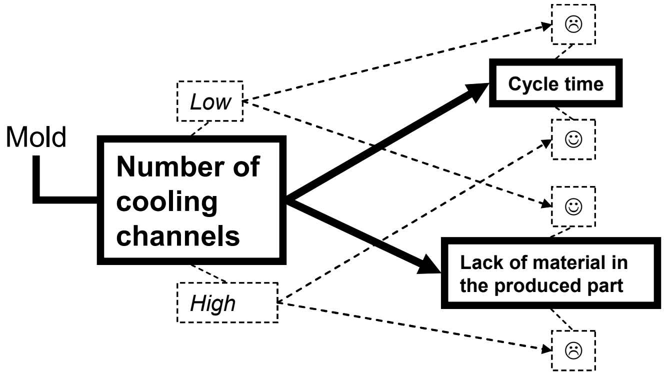


Figure 8. Contradiction B

As they have the same evaluating parameters, it is possible to join them (Figure 9):

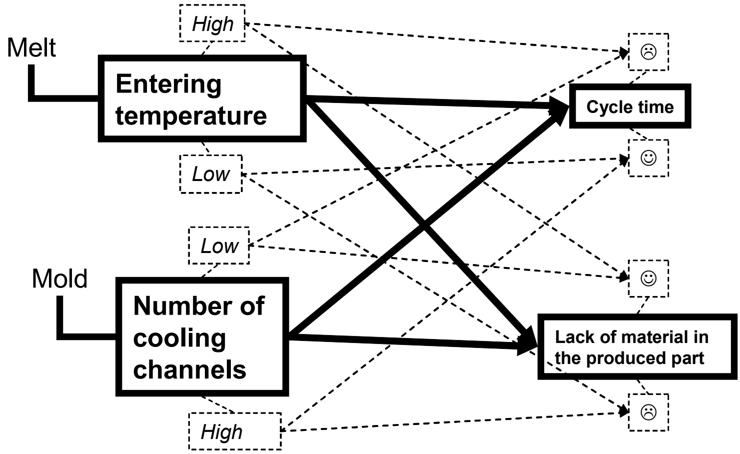


Figure 9. Joining

Second, we can identify the intermediary parameter (see (Malloy, 1994)) thanks to which we can converge these two contradictions (Figure 10). The more the viscosity of bulk melt is high during filling, the less time will be required to solidify the part, but the harder the material will flow:

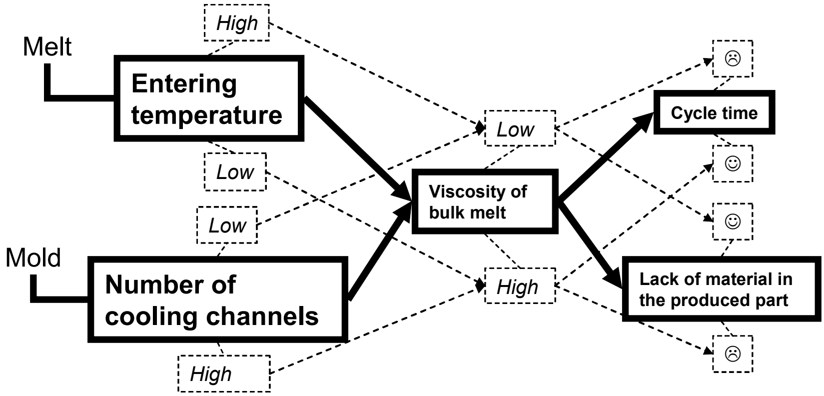


Figure 10. Intermediary contradiction

Contradiction A is adapted from Figure 7 to introduce the intermediary parameter:
- If the parameter <entering temperature> is high, then the parameter <viscosity of bulk melt during filling> is low, and then the parameter <cycle time> is unsatisfying and the parameter <lack of material in the produced part > is satisfying;
- But if the parameter <entering temperature> is low, then the parameter <viscosity of bulk melt during filling> is high and then the parameter <cycle time> is satisfying and the parameter <lack of material in the produced part> is unsatisfying.

Contradiction B is adapted from Figure 8 also:
- If the parameter <number of cooling channels> is low, then the parameter <viscosity of bulk melt during filling> is low, and then the parameter <cycle time> is unsatisfying and the parameter <lack of material in the produced part > will be satisfying;
- But if the parameter <number of cooling channels> is high, then the parameter <viscosity of bulk melt during filling> is high, and then the parameter <cycle time> is satisfying and the parameter <lack of material in the produced part> is unsatisfying

Hence, we can converge those contradictions in the following one (Figure 11):

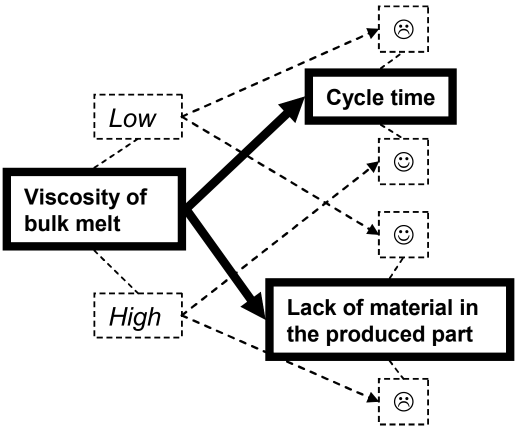


Figure 11. Converged conflict

The converged conflict of Figure 11 is expressed with the classic format:

- If the parameter <viscosity of bulk material during filling> is high, then the parameter <cycle time> will be satisfying and the parameter <lack of material in the produced part> will be unsatisfying;
- But if the parameter <viscosity of bulk material during filling> is low, then the parameter <lack of material in the produced part > will be satisfying and the parameter <cycle time> will be unsatisfying;

The same converging idea can be used for more than two contradiction, and for any type of contradictions listed above. The single condition is that contradictions have common portion of technical parameters (polycontradiction). This condition is not so restrictive because if contradictions are independent they do not need to be synthesised. The main advantage of this mecanism is that we do not discard any contradiction but on the other hand, the disadvantages are the followings:

- We do not take their relative weight into account;
- There can be more than two system configurations considered and more than two evaluating parameters to take into account into following ARIZ application;
- It is specific to a kind of contradiction links (they have common technical parameters).

- *Conclusions*

We presented two main mecanism to synthesize a contradiction network, the first is a selection and the second is a convergence. In real project those two mecanism have to be used simultaneously to reduce complexity of the situation representation without reducing the performance of the system improvement. However, our proposal does not eliminate human decisions: the two mecanisms might guide to more than one “key issue” and the solver will have to choose!

Two main issues remain:

- Mental inertia: designer will select the conflict that he feels more confident with, and can therefore miss powerful solution;
- Tests have to be done to find which criteria is the most reliable.

4. Conclusions

In this paper we presented a way to structure knowledge before tackling the problematic situation. It is based on three families of parameters, with which contradictions are formulated. We proposed two mechanisms to adapt the resulting contradiction net to typical TRIZ tools. One of the advantage if the possiblity to use a common “knowledge langage” for both problem free design projects and problem solving process. This will be very helpful to fully integrate TRIZ in any design process (from both industrial and academical point of view). However, the representation mode based on three families of parameters should be adopted during problem solving even if the knowledge stock is not present beforehand but gathered during problem solving.

Nevertheless, few points still need to be improved:

- the graphical representation of networks is not yet optimised;
- use of the proposed selection criterias has to be sharpen;
- semantics of generic parameters of any of the families might have to be adapted to the specific application: the distance from generic to specific is not only values of generic parameters.

Acknowledgement

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PATTERNS IN TRIZ CONTRADICTION MATRIX: INTEGRATED AND DISTRIBUTED SYSTEMS

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Abstract

TRIZ Matrix remains one of the most popular tools among the users, because it is simple and clear. It gives us usually not more than 4 different solutions. The question is: shall we use all of them, or just some of them? Obviously some recommended principles make sense for particular problem resolution, but some others – do not. Why? Trying to answer this question we found regularities in principles distribution in TRIZ Contradiction Matrix. We found that TRIZ Matrix contains 2 different rules for problem resolution and these rules depend on a degree of system integration. “Ant” rule is for distributed (loose) systems, and “Skin” rule is for highly integrated “solid” ones. This allowed us to simplify TRIZ Contradiction Matrix and make it more general and adaptable for new fields of engineering for problem (contradictions) definition and more precise in decision making according to the level of system integration.

Keywords: TRIZ, contradiction matrix, distributed systems, integrated systems, inventive principles.

1. Introduction

TRIZ Matrix remains the most popular tool to use because it is simple and clear. It gives us usually 4 different solutions. The question is – shall we use all of them, or just some of them? Obviously some recommended principles make sense for our problem resolution, but others – do not. Why? And what to do, if we cannot find variable we need to improve or causing a trouble variable in matrix list of 39 possible ones? G.S. Altshuller created the original contradiction matrix approximately 50 years ago and it was based on patents mostly in mechanical engineering. Table was purely empirical and its 39/39 size worked well. In our days many other different sciences came to engineering stage in their development (biology, biochemistry, physics of micro-world, etc.). Engineering made a greater progress in new technologies, materials; it operates in different scales from macro space technologies to nano-technologies. To find relevant position of a contradiction from a novel field of technology in the original ("old") matrix is more and more difficult. Does it mean that we need new matrices at least for each branch of new technology? Is it possible to extend or make this nice and useful tool extendible and how?

Trying to answer these questions we decided to find regularities in principles' distribution in TRIZ Contradiction matrix, because there is one possible way to enable matrix to be open for technology evolution – make it more general.

2. Methods

It was very tempting to find some regular pattern in TRIZ-Matrix (Seredinski, 2002). First we wondered, if there are some? To check this we tested the hypothesis that inventive principles are distributed in matrix randomly. Of course it does not mean that G. S. Altshuller put the principles into the matrix cell using a dice. It only means that probability to find some particular principle as a solution depends on how often this principle is used. So, our "0" hypothesis was, that there is no any pattern in contradiction matrix and it is pure empirical tool.

To enable us to compare very different variables we established 6 fields of operation in which all actions with any object can be done: "substance", "structure", "energy", "information", "space" and "time". The idea was that we always deal with construction, which behaves in some environment. The construction includes material structured in particular order and this order is hierarchically organised: sub-system – system – super-system. We call this pair "substance" and "structure". Behaviour or action requires some energy and needs to be regulated – these two features form two other fields of operation "energy" and "information". Environment can be described as some space for events that happen in some time scale. So, the last pair comes – "space" and "time". These 6 operational fields are suitable for describing the essence of both – problems (conflict) and resolutions (inventive principles) (table 1, table 2). The advantage of such classification is that it allows us to put problems and solutions into the same framework.

Field of operation	The essence of problem or solution	TRIZ Contradiction Matrix variables
Substance	Adding, removing or changing the properties of material	1,2 – weight of moving and stationary object; 23 – loss of substance, 26 - quantity of substance
Structure	Adding, removing or regrouping of structural parts	13 - Stability of the object's composition; 29 - manufacturing precision; 32 - ease of manufacture; 36 - device complexity
Space	Changing of special position or geometrical form of system or the shape its parts	3, 4– length of moving and stationary object; 5, 6 – area of moving and stationary object; 7– volume of moving object; 8 – volume of stationary object; 12 – shape.
Time	Retardation/ acceleration of the process, or changing an order of the actions.	9 – speed; 15, 16 – duration of action of moving and stationary object; 25 – loss of time; 39 – productivity.
Energy	Changing energy source or kind of acting field (magnetic, electric, acoustic, etc)	10 – force (Intensity); 11– stress or pressure; 14 – strength; 17 – temperature; 18– illumination intensity; 19, 20 – use of energy by moving and stationary object 21 – power; 22 – loss of energy
Information	Changing the interaction or its regulation (information exchange) of a system or system elements	24 – loss of information; 27 – reliability; 28 – measurement accuracy; 30, 31 – object-affected and object-generated harmful factors; 33, 34 – ease of operation and repair; 35 – adaptability or versatility; 37 – 38 – difficulty of detecting and measuring

Table 1. Classification of variables in Contradiction Matrix

Groups	Inventive principles	Prevalence	Number in matrix	Contradiction preference (χ^2>11,07)
Structure	Segmentation (1)	92	232	Str/I; I/Sp; Str/Sp
	Taking out (2)	94,4	221	E/I; I/E
	Local quality (3)	83	128	Sub/T; T/Sub
	Merging (5)	55	34	
	Universality (6)	78	84	Sp/E; E/T; Sub/Sub
	"Nested Doll" (7)	61	37	Sp/Sp
	Abundance (16)	80	99	
	Intermediary (24)	83	93	Str/I; T/Str
	Discarding and recovering (34)	89	105	T/Sp; Sp/T
	Composite materials (40)	89	96	Sub/Sub
Substance	Copying (26)	97	139	
	Colour change (32)	86	147	
	Homogeneity (33)	44	413	I / I
	Parameter change (35)	100	62	
	Phase transition (36)	53	31	T/E; E/E; Sub/E
Time	Preliminary Action 10	97	272	T/T
	Beforehand Cushioning 11	44	49	I/Str
	Dynamics 15	94	162	
	Periodic Action 19	89	158	T/E; E/E
	Continuity of useful action 20	28	19	T/T
	Rushing through 21	44	37	E/E
	Cheap short-living objects 27	75	122	Sub/Sub
Space	Asymmetry 4	72	75	Sp/Sp
	Spheroidality- Curvature 14	75	81	Sub/Sp; Sp/Sp
	Flexible shells and thin films 30	75	65	
	Porous Materials 31	55	48	Sub/Sub
	Another dimensions 17	89	85	Sp/Sp; T/Sp
Energy	Anti-Weight 8	64	45	
	Preliminary Anti-Action 9	39	25	E/Sub
	Equipotentiality 12	53	32	
	Mechanical Vibration 18	97	161	
	Mechanics substitution 28	92	232	Str/T; Sub/T; I/T
	Pneumatics and Hydraulics 29	86	115	Sub/Sp; Sp/Sub
	Thermal Expansion 37	67	59	
	Strong oxidants 38	53	47	T/T; Sub/T
	Inert Atmosphere 39	83	77	
Information	The other way round (13)	97	139	
	Blessing in Disguise (22)	61	84	I/I; E/I; Sub/I
	Feedback (23)	55	34	
	Self-service (25)	58	46	

Table 2. The inventive principles classification: universality and prevalence

Universal principles are in black cells, principles with contradiction preference are in other cells

For each principle we estimated its prevalence in the matrix and universality. Prevalence was calculated as percent of contradictions in matrix solved with the help of the given principal. Universality or principle preference for solving particular type of contradiction and was estimated by comparison of principle distribution within 36 types of contradictions with expected by "0" hypothesis principle distribution with the help of χ^2 test.

2. Pattern in TRIZ Contradiction Matrix

Testing the "0" hypothesis showed us that there is some regularity in inventive principles distribution (Fig.1). Distribution of frequency of inventive principles appearing in contradiction resolution is statistically proved to be different from normal distribution (t-test showed 1% probability difference - t=4,75; t(1%)=2,787). So, what are these regularities?

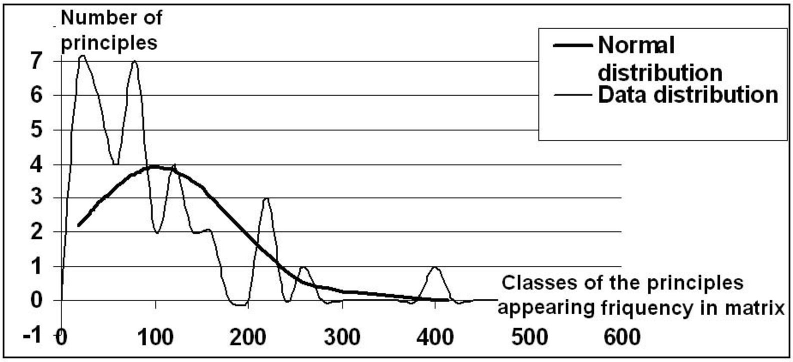


Fig. 1. Testing the "0" hypothesis: regularities of inventive principles distribution in TRIZ matrix.

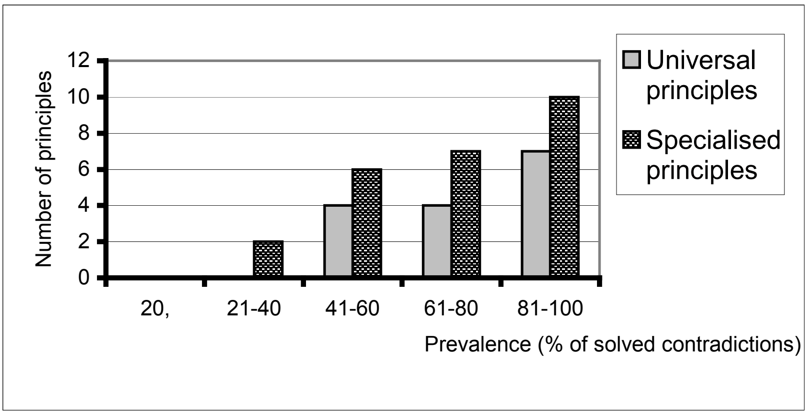


Fig.2. Principles universality and prevalence

We found universal principles that have not any preference to the type of contradiction that they solve (14 principles marked black in table 2) and 25 principles are statistically proved to have preference to be used in particular contradictions solving (table.2). We could expect that the most common and frequently employed principles will be the most universal ones. But surprisingly, principles, which do not express preference to contradiction type, are with different prevalence – often and not so often used ones (Fig.2). This allowed us to build general contradiction matrix (table. 3).

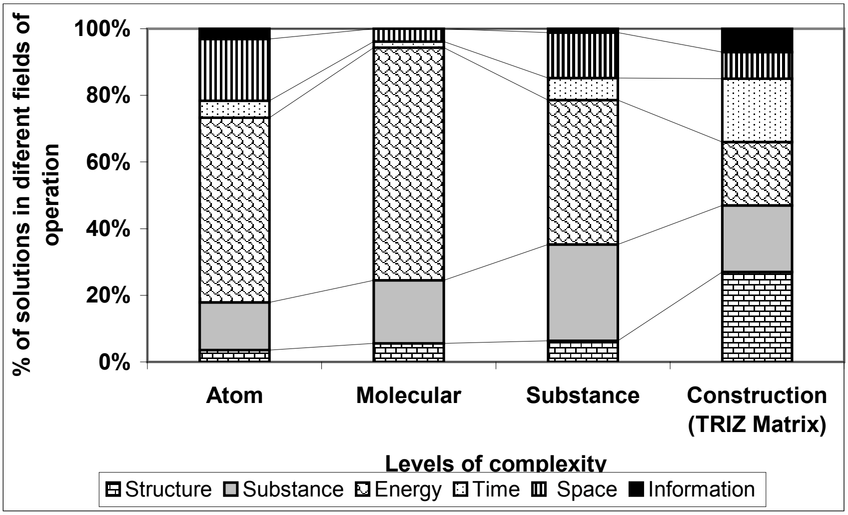
Operation fields that should be improved	Operation fields that cause problems					
	Structure	Substance	Time	Space	Energy/Field	Information/ Regulation
Structure		28	**1**			**1 24**
Substance		**6 40 27 31**	3 28 38	29 **14**	**36**	**22**
Time	**24**	3	38 **10 20**	34 **17**	**36 19**	
Space		29	34	7 **4 14 17**	6	
Energy/Field		**9**	6		21 **36 19**	2 **22**
Information/ Regulation	11		28	1	2	33 **22**

Table 3. General TRIZ Contradiction Matrix
Principles that solve problems using "skin" rule are in bold font, "ant" rule – regular font, empty cells contain only universal principle (5,8,12,13, 15,16,18,23,25,26, 30, 32,35, 37 39)

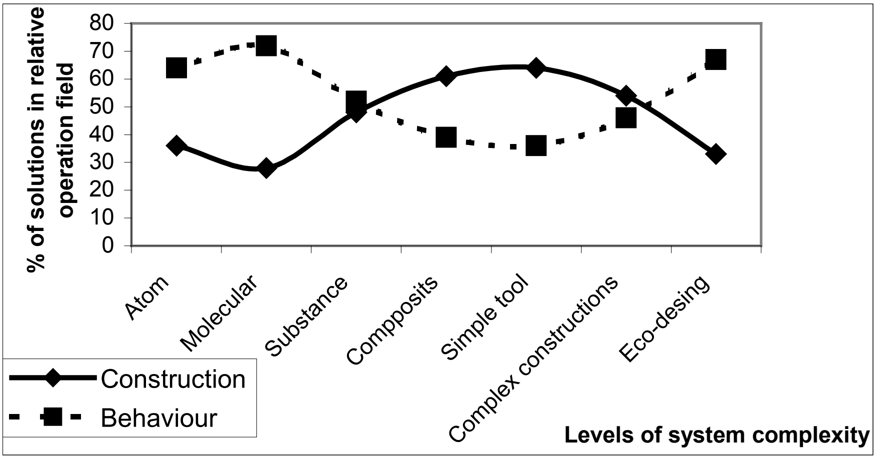
In problem resolution we found some regularities, which are hidden (incorporated) in contradiction matrix, but make difference in problem solving at the different levels of system structural complexity. Analysing physical and chemical effects we have found that at the different complexity levels solutions tend to use some fields of operation more often than others (Fig. 3). According to growing structural complexity from atom level to substance, solutions by changing construction (structure and substance) increase their percentage with system complexity; solutions in behaviour tend to decrease with complexity (in living nature situation is opposite), solutions in space and time do not depend on complexity at all. So, we found tendency in problem solving that depends on system complexity. TRIZ matrix assemble solutions on different complexity scales, so all fields of operation are represented more or less equally.

Another pattern that we can see from table 2 is connected with 2 rules for problem solving. According to contradiction type they solve, all specialized principles can be divided into 2 groups (table 2, 3): a group of principles that use for solutions other operation fields and a group of principles that solve contradiction mostly in the same operation field.

1. One pattern we have called "ant rule" (because we found it in our case-study on ant social behaviour, Bogatyreva, 2002) – never resolve contradiction in the operation field where the problem occurs, if you do not have specialized structure already existed for this purpose (table 2, principles marked grey).



A



B

Fig. 3 Solutions in non-living nature and system complexity
A – 6 operation fields classification, B – general trends of solutions in behaviour and construction

2. And another pattern – “skin rule” – delegate the solution down to all subsystems, which you have (we call it “skin rule”, because we found it in our case-study on cuticle, Vincent, 2004, in press). In other words, use the special structure to avoid and/or prevent the conflict. This rule allows solving a problem in the same operation field where it happens(table 2, principles marked white).

The question was: what provides the choice of rules, if this pattern also complexity dependent, or problem/contradiction dependent, or maybe there are some other factors that play role in this pattern performing. To answer this question can help following diagrams (table. 4 and fig. 4)

We can trace skin rule pattern in contradiction between structure and substance – on one hand and energy and time – on the other. Nearly half of all solutions – 52±2,6 % – for this type of contradiction are in the same field of operation – 2 from 36 possible, the other solutions are in the rest 34 fields and give different rule solutions approximately in 2% cases per each. Ant rule works for substance problems and mostly for improving information/regulation field: operation fields that cause problems are avoided while problem solving – only 20±2 % solutions occupy the same field of operation.

Operation fields that should be improved	Operation fields that cause problems					
	Structure	Substance	Space	Time	Energy	Information
Structure	24,1	48,6	34,4	39,4	41,9	40,6
Substance	52	18,3	30,4	41,5	43,8	24,4
Space	43,2	30,4	30,4	37,9	28,8	20,6
Time	40,9	38,8	36,4	3,85	54,6	29,3
Energy	42,9	46,2	33,1	49,4	12,3	17,5
Information	40,9	16,6	34,2	19,5	22	7,6

Table 4. Rules for problem solving and types of contradiction: percentage of all solutions for each type of contradiction that happens in the same field of operation.
"Ant rule" cells are gray; "skin rule" cells are black.

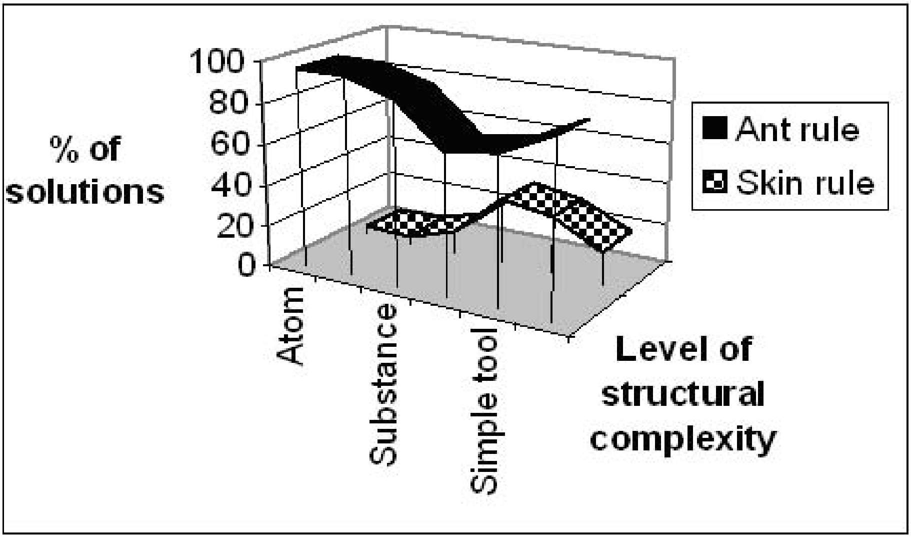


Fig. 4. Ant and skin rules are complexity dependent

We can say that, if ants rule work, it means that there is no special structure ready to solve the future conflicts, but if ants rule does not work, such structure already exists in construction. These patterns work in different scale of complexity, but still there are some cases that do not fit the found trend: on fig 4 we can see complexity dependence only till the substance level. It means that it should be something else except the complexity that drives a choice in problem solving.

4. Distributed and highly integrated systems

There is the other possible way to think: in terms of system integration: we found that “ant” rule is working in case of loose systems, where elements are low integrated, but skin rule works in very structured and integrated systems. The most obvious examples of integrated systems can be a car, an electric motor structurally complex ones and a pencil, a hammer structurally simple ones. Distributed system can be complex and simple as well, but complexity is mostly, connected with regulation of their behaviour: land mines, transport system (railways, network of logistics operating along roads), Internet, army, etc. So, the rule

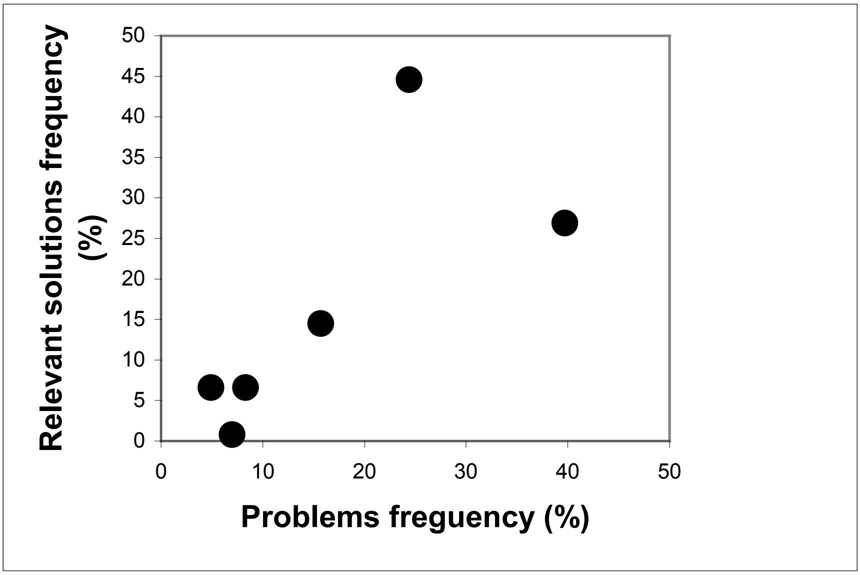


Fig.5. Integrated systems: rule for problem resolution

for loose distributed systems is “never look for a solution in the operational field of a problem” (Fig.5); and the rule for highly integrated systems is “delegate the solution down to subsystems and use any field of operation” (Fig.6). The idea is that if “ant” rule works, the number of problems and the number of resolutions in the same operation field will have negative correlation. If skin rule works – the correlation will be positive (fig. 5).

For example, technical problem of car engine can be described by integrated system behaviour, but technical problem of traffic control belongs to distributed systems. In these cases we need to use different principles for their resolution.

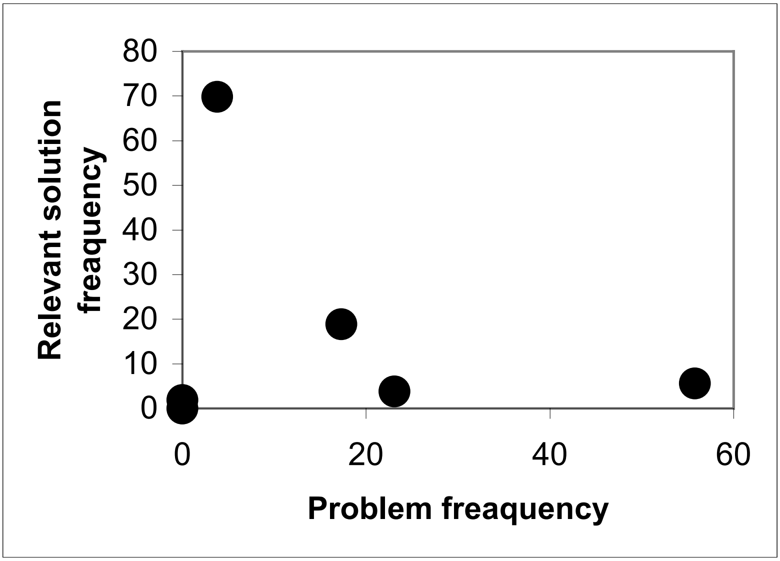


Fig.6. Distributed systems: rule for problem resolution

5. Conclusions

Generalising Altshuller matrix we have got its 6x6 version, which is able to comprise new entities. It means that we possess the tool capable for improvement and adaptation for new engineering realities, growth and evolution together with sciences.

We found that TRIZ Matrix contains 2 different rules for problem resolution and using these rules depends on system complexity and integration. The rule for complex loose distributed systems is “never look for a solution in the operational field of a problem”. And the rule for highly integrated complex systems is “delegate the solution down to subsystems and there you can use any field of operation”.

Acknowledgments

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LOGIC OF ARIZ

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Abstract
Algorithm of inventive problem solving (ARIZ) is a part of theory of inventive problem solving (TRIZ) developed by G.Altshuller. ARIZ consists of a program (sequence of actions) for the exposure and solution of contradictions, i.e. the solution of problems. ARIZ includes: the program itself, information support supplied by the knowledge base, and methods for the control of psychological factors, which are a component part of the methods for developing a creative imagination. Furthermore, sections of ARIZ are predetermined for the selection of problems and the evaluation of the received solution. Last modification of the algorithm developed by G.Altshuller is an algorithm of 1985 - ARIZ-85-C. ARIZ-85-C as a rule study step by step. Thus it is possible to solve problems, but it is impossible to understand all functions of ARIZ. ARIZ is intended not only for the solving difficult (not standard) problems, but also for development inventive (creative, system) thinking. The inventive thinking is thinking through contradictions. Thinking at which reveals an original causes (roots) of a problem. In my opinion, it is more important function. To carry out it is possible only having studied logic of ARIZ. The problem of given paper to consider logic of ARIZ.
Keywords: ARIZ, contradiction, logic, problem, solving, TRIZ.

1. Introduction

ARIZ is a step-by-step program for the analysis and solution of inventive problems. The first modification appeared in 1959 (ARIZ-59). Other modifications are ARIZ-61, ARIZ-71, ARIZ-77, ARIZ-82, and ARIZ-85-C. The basic sequence for the solution of problems with ARIZ has already been examined. The final modification of ARIZ included three basis components: *program, information support* and *methods for the control of psychological factors.*

1. The **ARIZ program** consists of a sequence of operations for the following operations: exposure and solution of contradictions (see the basic sequence of ARIZ); analysis of the initial situation and selection of the problem to be solved; synthesis of the solution; analysis of the received solutions and selection of the best variant; development of received solutions; collection of the best solutions and summarization of this material for the improvement of methods for solving other problems. The structure of the program and the laws for its implementation are based on the laws and regularities of technological development.

2. Information support are supplied from the 'knowledge base', which includes a system of '*standards' for the solution of inventive problems*; '*engineering effects'* (physical, chemical, biological, mathematical, and particularly geometric – the most developed effect at the present day); *techniques for the elimination of contradictions (inventive principles)*; *methods for the application of 'resources'* of nature and technology.

3. Methods for the control of psychological factors are necessary as a result of the fact that the program ARIZ is not intended for computers and that problems are not solved automatically, but with the help of a human being. Therefore, the problem solver often exhibits psychological inertia, and it is necessary to control this. Furthermore, these methods allow one to develop the creative imagination necessary for the solution of complicated inventive problems.

2. Concept about contradictions

Different technological means were and are developed to satisfy the needs of man.

But needs grow significantly faster than our ability to satisfy them, and this in its own way serves as a source of technological progress.

The development of a new entity more often than not entails the improvement of some set of technological parameters of a system.

Complicated inventive problems (of unknown type) require a nontrivial approach because the improvement of one system parameter leads to the inadmissible deterioration of another. ‘Contradictions’ arise.

The solution of problems with ARIZ constitutes a sequence for the exposure and solution of contradictions and the reasons that produce the given contradictions, as well as their elimination by use of the knowledge base. In this manner cause and effect relationships are determined – the essence of which is the intensification and aggravation of contradictions.

For this purpose, ARIZ considers three types of contradictions: *superficial, intensified* and *aggravated.* G.Altshuller named them respectively: *administrative, technical* and *physical*.

SUPERFICIAL CONTRADICTION (SC) – contradiction between the expressed need and ability to satisfy that need. This is sufficiently easy to determine. These contradictions are often produced by administrators or customers, and are expressed in the following manner: *"It must be completed immediately, but how is unknown", "Some kind of system parameter is faulty, so it must be fixed", "It is necessary to eliminate the shortcoming, but how we don’t know", "There is spoilage in the production of wares, but the reason is unknown".*

In this manner SC is expressed in the form of a ‘harmful effect’ (HE) - something negative, or the *necessity to create something new* by unknown means.

Example 1. In the late 50s the construction bureau of A.N.Tupolev was given the task of creating a new passenger aircraft with 170 seats and the capacity for prolonged flight. To achieve this, aircraft engines with a combined output of 50 ths. hsp. were necessary. The most powerful TV-2 engines in the USSR were only 6 ths. hsp. What can be done?

Example 2. It is necessary to increase the speed of a ship, but how is unknown.

INTENSIFIED CONTRADICTION (IC) – this is a contradiction between specific parts, qualities or parameters of a system. IC arises during the improvement of one part (quality or parameter) of a system at the expense of the inadmissible deterioration of another. It reveals the reason for the appearance of a superficial contradiction by intensifying it. More often than not, at the heart of superficial contradiction (SC) lies several intensified contradictions (IC).

As a rule, by improving certain characteristics of an entity, we dramatically worsen others. Usually it is necessary to search for a compromise, that is, to sacrifice something.

During the solution of technological problems, the technological characteristics of an entity are changed, therefore G.Altshuller named intensified contradictions *technical contradictions.*

A technical contradiction arises as a result of the disproportionate development of different system parts (parameters). When there are a significant number of changes to one of the system parts (parameters) and a sharp "lag" in development of another (other) of its parts, the situation arises in which quantitative changes from one side of the system acts in contradiction with others. Solution of this kind of contradiction often requires the qualitative change of the technological system. This is manifested in the law of transition from quantitative to qualitative changes.

Continuation of the above examples.

Example 1 (continuation). In order to achieve the required combined engine capacity it is necessary to use 8 engines. The farthest engines would have to be located at a distance of 25 m from the fuselage, but this would cause the wings to be lengthened to an unallowable degree. An intensified contradiction arises between the airplane's POWER and the inadmissible increase of the LENGTH of its wings.

We can formulate another intensified contradiction. If we turn to twin engines with a total output of 12,000 hsp., it is necessary to use a propeller with a diameter of 9 m. A diameter of 9 m. would necessitate lifting the airplane 5 m. above the ground. The intensified contradiction in this case is between the POWER of the engines and the great HEIGTH of the airplane.

These types of ICs in particular can be eliminated by the use of the technique "transition to another measurement."

A.N.Tupolev solved the described contradiction in the following manner. He suggested pairing engines in a single block and positioning two four-blade propellers that rotate in different directions directly on one shaft of the block. Only 4 blocks were needed (two per wing), and the diameter of the propeller consisted of 5.2 m. It was not necessary to greatly increase the height of the airplane. As a result, the TU-114 airplane was created with a rather high flight speed of 870 km/hr.

Example 2 (continuation). Increase of the weight-carrying capacity of a ship is connected with the reduction of its speed. In turn, increasing the speed of the ship leads to a growth in engine power and increased energy loss, which requires an increase in weight and the dimensions of the propulsion system and fuel stores. The excessive increase of these components may lead to a situation in which there is nowhere to place the payload. In the given example the following technical contradictions are exposed: WEIGHT-CARRYING CAPACITY – SPEED, SPEED – POWER, POWER – ENERGY LOSS, ENERGY LOSS – WEIGHT, etc.

Here are two more examples.

Example 3. Usually conductors in integral circuits are made of gold, which has the smallest resistivity to energy flow, but an inadmissibly poor adhesion with the backing material. What can be done?

An intensified contradiction between ELECTROCONDUCTIVITY and ADHEISION arises.

Example 4. "In the end constructors came to the conclusion that during the planing of a yacht's body it was necessary to attain a kind of optimal compromise in the observance of three basic pre-requisites:

1) minimal resistance of the body's form;
2) maximal stability;
3) minimal resistance from friction.

These requirements are contradictory. A long narrow yacht has little resistance of form, however, it is not very stable and can not carry a sufficiently large sail. An increase in stability by means of an increased ballast weight accompanies the simultaneous increase in draught and, as a result, increases the resistance caused by friction. Increasing the stability by means of increasing the width of the body results in increased resistance from the form of the body. The constructor's problem lies in the search for a 'golden median' in the application of three contradictory construction principles."

Before solving these problems, we will consider another type of contradiction incorporated in ARIZ.

AGGRAVATED CONTRADICTION (AC) – presentation of diametrically opposed qualities (for example, physical) in a certain part of a technological system. This is necessary to determine the reasons producing the intensified contradiction, i.e., aggravated contradictions constitute the further intensification of the contradiction. Amplification (intensification) of contradictions can be continued to an even greater degree for the exposure of the contradiction's initial cause. For someone unacquainted with ARIZ the formulation of AC sounds unaccustomed and even unorthodox – *some part of the TS should be located simultaneously in two mutually exclusive states*: to be *cold* and *hot*, *in motion* and *motionless*, *long* and *short*, *flexible* and *rigid*, *electrically conducive* and *non-conducive,* etc.

The study of reasons producing intensified (technical) contradictions in technological systems as a rule leads to the necessity of exposing contradictory *physical* qualities of a system. Therefore, G.Altshller gave them the name *physical contradictions*.

We continue the examination of example 4.3.

Example 3 (continuation). We will formulate the aggravated contradiction (AC). In order for the conductor in the IMS to have low resistivity, it should be made of gold, but in order for the conductor to have good adhesion with the backing material, it should be made out of another material. A more concise and more extreme AC can be formulated: the material of the conductor should be GOLD and NON-GOLD. A typical solution for this type of aggravated contradiction is the use of an INTERMEDIARY.

Remember this law. We will return to it again. It's clear you have already guessed the solution. First apply a *pre-coat* that has good adhension with both the backing material and with gold, and then spray gold on this base. As a pre-coat use nickel or titanium.

Example 5. For the power supply of most radio-technical equipment (RTE) a industrial network with an alternating current is used, although the majority of RTE blocks, for example, the amplifier, generator and others, need a constant power voltage. For this reason it is necessary to have an element on the outlet of the amplifier that has contradictory physical characteristics. It should be CONDUCIVE for the positive half wave of the sinasoid flow and NONCONDUCIVE for the negative one in order to supply the amplifier with a polarized supply voltage. The given aggravated contradiction (AC) is solved by means of a rectifier acting on the diodes that possesses the indicated physical qualities and transforms the alternating current into a constant one.

It is worth stressing again that contrary to intensified (technical) contradictions, which belong to the system as a whole, aggravated (physical) contradictions concern only a certain part of the system.

In this manner, the three types of contradictions we have examined form a chain: *superficial contradiction* (SC) – *intensified contradiction* (IC) – *aggravated contradiction* (AC), which determines the cause and effect relationships in the technological system under examination.

$$\textbf{SC} \longrightarrow \textbf{IC} \longrightarrow \textbf{AC}$$

We will illustrate this chain with examples.

Example 4.6. The non-ideal qualities of a switch for powerful transistors and diodes constitute the reason for loss of electrical energy. This energy heats the semiconductor and negatively effects its heating regime.

We will formulate the 'superficial contradiction' (SC): *"It is necessary to improve the heating regime of the transistor (diode) switch in the radio-electric apparatus in which it positioned."* Or: *"It is necessary to prevent the heating of the force transistor in the amplifier of the radio receiver."* In the first formula the PP indicates which quality must be improved, and in the second it shows the 'harmful effect' (HE) – *heating of the transistor*.

Elimination of the indicated superficial contradiction can be realized by creating a new transistor or by the application of a radiator, which improves the heating regime of the transistor. However, the addition of a radiator increases the dimensions of the radio apparatus.

The 'intensified contradiction' (IC) is between the *TEMPERATURE* and the *DIMENSIONS* or between the *LOSS OF ENERGY (POWER)* and the *DIMENSIONS.*

Improvement of heat abstraction necessitates the increase of the area of the radiator, but the decrease of the dimensions of the radio apparatus requires the decrease of the area of the radiator.

We will describe the 'aggravated contradiction' (AC): *area of the radiator should be LARGE to facilitate the removal of heat, and SMALL in order to preserve the small dimensions of the radio apparatus.*

It is possible to resolve this kind of contradiction by means of a change in structure. Ribs should be created in the radiator. The general area of the radiator remains the same as before, but the dimensions of the apparatus do not increase and can even be decreased.

Example 2 (continuation). We will examine the example in which the carrying capacity of a ship must be increased. It is possible to decrease energy loss by eliminating the underwater section of the ship's body. But this section is crucial for the boat's stability while afloat. And so the following aggravated contradiction arises: *the underwater section of the body should preserve buoyancy and should not cause a rise in energy loss during increased speed.*

Example 4 (continuation). The example about the body design of a yacht reveals several aggravated contradictions.

1. *In order for the yacht to travel with great speed (having little resistance in form), the body should be long and narrow, but in order to carry a large sail (to be stable), the body should be wide.*
2. The second aggravated contradiction is related to another part of the yacht – to the ballast (keel). *To increase the stability of the yacht, the ballast should be heavy, but in order for the boat to be more maneuverable, the ballast should be light.*

Example 6. The invention of the rifle was intended to improve the results of shooting. To this end threading was added to the smooth barrel of the musket, along which the bullet was firmly driven. As a consequence it took more time and became much more complicated to load the rifle. It became necessary to insert the bullet by means of a ramrod (before this the weapon was loaded from the muzzle).

An intensified (technical) contradiction arose between the accuracy of the shot (the advantage of the rifle's threading) and the velocity of the shot or the ease of loading (the advantage of a smooth-barreled weapon – the musket).

At the heart of this intensified contradiction lies several aggravated contradictions (physical). Here are a few of them:

1. *In order to increase the accuracy of firing, threading on the inner surface of the barrel is necessary, but in order to ensure the ease of loading (to increase the speed of firing), threading is unnecessary (the inner surface of the barrel should be smooth).*
2. *Or – in order to increase the speed of firing the bullet should not lie close to the inner surface of the barrel, but to increase the accuracy of firing, the bullet should lie close to the inner surface and even cut into the threading.*

Note that these aggravated contradictions are created for different parts of the system (rifle): 1 – for the barrel, 2 – for the bullet.

At that time the bullet turned by means of greased matter (plaster) and could be inserted into the barrel with a ramrod and without extra force.

It then became clear that to increase the accuracy and distance of the shot, the bullet must be given a rotating motion, which helps the bullet become steadier and maintain flight in the specified direction. Spiral threading began to be used on the inner surface of the barrel. The previous contradiction was aggravated to an even greater degree in connection with the fact that it became even more difficult to load the rifle.

The rifle to a significant degree surpassed the smooth-barreled musket in terms of accuracy. In addition, loading the rifle turned out to be sufficiently difficult. Ramming the bullet became an exhausting operation; powder and the bullet, wrapped in plaster, were placed in the barrel separately, and in the period of one minute it was possible to fire no more than one shot.

In this case an aggravated contradiction appears.

Threading should be spiral to increase the accuracy of firing and should not be spiral (should be straight) to increase the velocity of the shot.

Here is another situation characteristic for aggravated contradictions: An old-fashioned rifle needed to be short in order to ease the insertion of bullets – sufficiently short so that it could not be used as a shaft for a bayonet. *The barrel of the rifle should be short so it is easier to ram the bullets, but it should be long in order to serve as a shaft for a bayonet.*

Now, having examined different contradictions, it is pertinent to remark again that solving a complex technological system means improving the necessary indices of the system without sacrificing the effectiveness of others. This can be achieved by way of exposing intensified (technological) contradictions, determining the reasons that cause them, or even the primary reasons for these reasons (exposure of aggravated contradictions), and eliminating the reasons, i.e., the solution of aggravated (physical) contradictions.

The stage of exposing aggravated contradictions constitutes the exact formulation of the problem.

The exposure of an aggravated contradiction during the solution of technological problems requires a certain kind of directed search, which is possible only through knowledge of the answer. In an actual technological problem, the answer, of course, is unknown.

Finding the correct approach to the solution can be achieved by focusing on the laws of developing technological systems, and, above all, on the law of increasing the degree of “idealness” of technological systems.

3. The path to the ideal

The solution of mathematical problems and problems "by quick-wittedness" is often achieved by the method "reversing the process." The essence of this method lies in the fact that in order to solve a problem, you need to start with the end result. The answer is to determine the final result. Clarifying this, the road to the beginning, i.e., the solution of the problem, is "paved."

It would be misleading to undertake the solution of technological problems in the same way. But how can one find out the answer?

Truly, during the solution of technological problems, the end result is unknown, however, it is still possible to continue on ... It is possible to imagine the ideal of a developed construction – this ideal construction is the 'ideal final result' (IFR).

An *ideal technological system* is one that does not exist, although its function is fulfilled, i.e., the goal is achieved without the means. IFR is the beacon to which one should look during the solution of problems. The closeness of the received solution to the ideal determines the level and quality of the solution.

IKR is the solution we would like to see in our dreams, carried out by fantastic creatures or means (magic wand). For example, a road that exists only where it touches the wheels of transport vehicles.

Researchers of the ocean's depths also dream of ideal constructions: "of course, already for many years people have known that an *ideal* (author's stress) apparatus would be one that creates 'earth-like' conditions on the ocean floor."

Example 7. The ideal emergency device in water would be a boat that is unsinkable in any weather condition. "... ship building firms of a number of countries have developed an "unsinkable" emergency boat, fully hermetic and accommodating 35 people in the deck, who fasten themselves to the seats by means of emergency belts. The boast is constructed of durable light material and can catapult from a height of 25 m without any harm to its passengers. Even after submersion beneath water it returns to the surface, maintaining a normal position.

One of the basic traits of an "ideal construction" ("ideal machine") is that it should *appear only at the moment when it is necessary to complete the necessary action, and furthermore, at that time it should undertake 100% of the rated working load.* This trait has been long known to us in fairy tales - "Скатерть-самобранка," etc. Many examples can also be found in real life: retractable and folding objects. For example, folding and attachable furniture (tables, couches, beds, etc.), inflatable objects (boats, emergency vests, mattresses, pontoons, etc.)

Example 8. For the rescue of people during emergency aircraft landings in water, English engineers developed a safety device that constitutes pontoons which automatically inflate with compressed air.

The second trait of an "ideal machine" or an ideal construction is that it doesn't exist at all, but the task it should carry out takes place as if by itself (with the help of magic wand).

The ideal truck is a container transporting a load. All other parts of the truck are extraneous and are unecessary for the simple achievement of this goal.

IKR of a means of transport is when it does not exist, but nonetheless the load is transported (the load "itself" travels in the necessary direction with the necessary speed).

Here are examples of the quality of "idealness:"

Example 9. "Automobile seat belts must be changed periodically. The concern has been expressed that the material may weaken. Belts have been invented that show by their appearance when they need changing."

Example 10. "A layer of colored paint is applied to the tread of a protector and the number of kilometers traveled by the automobile before attrition of the applied layer is recorded. This method for evaluating the wearability of the tire is simple and useful during testing of the longevity of new types and constructions. This method can be used during the inspection of tires for their replacement.

Example 11. Window glass needs cleaning. To undertake this operation on high, large shop windows is somewhat labor-intensive. If the shops are "glazed" with lavsan film, then during a gust of light wind the film *itself* clears dust from the window. This film is transparent, light, and unharmed by hydroflouric acid fumes. For the "glazing" of windows with this type of film lightened frames can be used.

Example 12. The contact between трущихся surfaces made of steel leads to their wear, therefore points of contact are lubricated.

Polish specialists claim that any steel becomes *self-lubricating* (IKR), without loosing its best mechanical qualities when 0,3% lead is added to it. It is possible to increase cutting speed and extend the useful life of instruments.

Example 13. In order for the nut in bolt connections not to work itself free during use, a second (counter) nut should be screwed onto the bolt.

The ideal in the given situation would be a "nut that fastens (locks) itself." Now more than a few different varieties of self-locking nuts already exist. Here is one of them.

The nut is reliably held in place at the end of the prong by sharp edges, which are directed on a tangent to the threading hole and have an angle of 7-10°. This type of solution allows the self-locking nut to be used many times. Furthermore, the installation and de-installation time is reduced by 30%, the reliability of the connections is increased and the nomenclature range of the fasteners is reduced. This kind of nut is especially necessary for connections which experience different kinds of loads.

In bolt connections without nuts, the bolt ITSELF should lock "...on the face surface of the head (in this case, on the bolt, but it is also possible on the nut - authors), directed towards the connected part and carried out by concentric tapered ringed projections (with the filing] - authors) (see fig. 1).

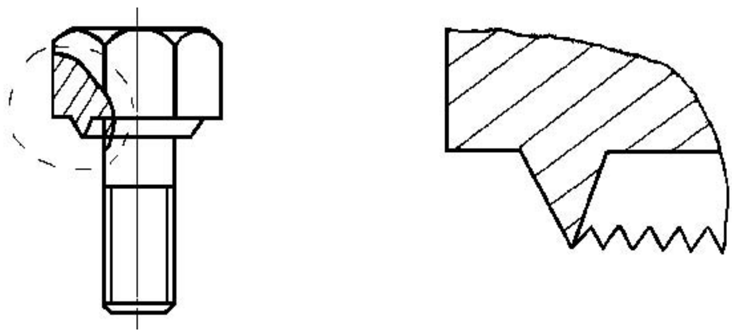


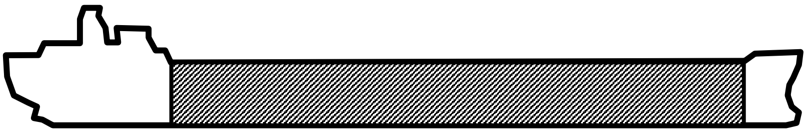
Fig. 1.

Striving for the ideal is the general tendency in the development of technological systems.

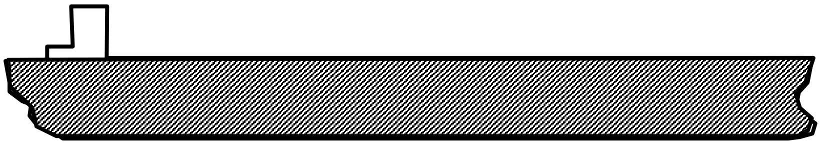
In means of transportation this tendency manifests itself particularly in the steady increase of the share of positive weight the transport vehicle uses. This explains the increase of displacement in ships, especially tankers.

A tanker that displaces 3000 tons uses 57% of its displacement beneficially, whereas a tanker displacing greater than 200,000 tons uses 86% - in this manner more closely nearing the ideal (fig. 2).

a) A tanker that displaces 4760 tons



b) A tanker that displaces 102000 tons



c) Ideal tanker

Fig. 2.

Example 14. The processing of parts with abrasive wheels is accompanied by an increase of temperature at the contact zone. The heat negatively acts upon the surface layer of the part and increases the wear on the wheel itself.

IFR in the given case is when the wheel itself protects the part and itself from overheating.

In the Machine-building Institute grinding wheels were developed that consist of traditional components, but contain endothermic additives in their composition. During the high temperatures that occur during grinding they disintegrate with the absorption of heat and remove it from the grinding area.

It is interesting to mention that striving for an ideal is inherent not only in technological systems as a whole, but also in their individual parts and in the processes that take place in them.

Therefore, in an *ideal substance* the substance does not exist, but its function (durability, impermeability, etc.) remains. For exactly this reason there is the tendency to use increasingly lighter and more durable materials in modern ships, i.e., material with an increasingly greater proportionate durability and strength.

Example 6 (continued). We will determine the ideal final result.

IFR of a radiator (heat abstraction) – the radiator does not exist, but the full removal of heat from the transistor is preserved.

The radiator should not exist, but the heat should be removed by means of the transistor itself. The radiator should appear only when the transistor begins to overheat. The radiator should be removed from the boundaries of the given radio electrical apparatus (REA) or the role of the radiator should be performed by some other element. In this manner directives for the solution are determined.

In the first directive, it follows to create a means of transport without the loss of energy, so that the problem of heat removal does not arise. This directive is the most difficult and, as a rule, is not useful for the development of the REA.

The second directive is fully acceptable because it is possible to create a heat conductor with tabs of Ni-Ti - Nickel-titanium alloys (nitinol) – material possessing the quality “shape memory”. During normal temperatures the tabs are pressed to the transistor, but when temperatures increase beyond acceptable levels, the tabs unfold, increasing the area of the conductor.

Removal of the conductor from the REA – the third directive – is sufficiently easy to accomplish by means of positioning the radiator and transistor on the exterior wall of the block, as it is done in measuring devices: digital voltmeters and frequency meters. Or it is possible to use a heating pipe, which allows locally produced heat to be removed a significant distance away from its source.

The solution of the fourth directive – use of the elements in the block for the removal of heat – is similar to that of the radio electronics model. In addition to heat-releasing semiconductor devices, the model contains elements with heat-conducting bodies that perform this function, for example, electromagnetic relay. In order to reduce the dimensions of the model, relays are positioned in two rows. Between the rows are fitted heat-releasing elements that allow contact with the heat-conducting bodies of the relay.

Example 15. The ideal body of an underwater apparatus should have a minimal relative mass and, above all, preserve the quality of the material: small density and great proportionate strength and rigidity, providing the corresponding relationship between the limits of yield and model of elasticity to the density of the material.

Therefore the body of modern underwater apparatuses are created from titanium. This metal possesses high mechanical qualities, resists corrosion in sea water, and is not magnetic.

In some cases it is also possible to speak of the *ideal form*. The ideal form ensures the maximum positive effect, for example, durability with the minimum usage of material.

Example 16. In an underwater device the ideal form for a durable body is a sphere. It possesses high stability and not a great density. Spherical forms have a minimum relationship of surface area to volume.

The *ideal process* is the achievement of results without a process, that is, instantaneously. Shortening the process of preparing a product is the goal of any progressive technology.

Thus, the sectional method of assembling vessels was replaced by a more progressive one – the block method. In the sectional method, the body of the ship was first gathered on the building berth from separate sections (deck, sideboards, ship bottom, etc.), and then the equipment was installed. The block method of assembly brings entire blocks to the building berth, which consist of large voluminous parts of the ship with previously installed equipment. Blocks are created in the assembly shop from separate sections. It is here that the necessary equipment is installed. In this manner, all that remains is to join together the separate blocks on the building berth.

The constant battle to increase the transport speed of loads also characterizes the tendency to strive for an ideal process. Increase of the transport speed is achieved by steady growth of the speed of transport means and by shortening the time required for loading and unloading operations.

Example 17. The median speed of container ships from 1960 – 1975 grew from 15 to 25 knots. Reduction of the time needed for loading and unloading operations is enabled by means that are nearly ideal. This is a ship with a horizontal method of unloading of the type "ro-ro" (trailer), on which the weight "itself" drives onto the ship and off of it onto wheels;

on lighters (barges) the weight "itself" swims to the ship and from the ship to the determined site (a kind of “wagon”).

The ideal solution, of course, is almost impossible to achieve. IFR is the standard for which we should strive. It is the closeness of the received solution to the IFR that determines the quality of the solution.

By comparing the real solution with the IFR, we determine contradictions. In this manner the IFR is an instrument, necessary for the exposure of contradictions and for the evaluation of the quality of the solution. Consequently, IFR serves as a kind of "guiding star" for the solution of technological systems.

4. The path to the idea of solution

Having examined the basic concepts of ARIZ – IFR, intensified and aggravated contradictions, – we can easily imagine the stages in the exact formula of a technical problem.

The definitive basic procedure for the solution of problems with ARIZ can be represented in the following manner:

$$\textbf{SC} \longrightarrow \textbf{IC} \longrightarrow \textbf{IFR} \longrightarrow \textbf{AC} \longrightarrow \textbf{SOLUTION} \quad \textbf{(1)}$$

From the point of view of ARIZ, the problem is formulated exactly when SC, IC, IFR, and AC are revealed in accordance with the chain represented above (1). To formulate of all its links, first of all reveal that which does not suit the "poser" of the problem in the given situation (superficial contradiction - SC) and what is faulty in the system (undesirable effect). What kind of requirements are necessary to expect from the system?

Thus the intensified contradiction (IC) is determined. Then the system is expressed in such a way so that the undesired effect is absent from it, yet the positive qualities are preserved. The result of expressing the system in this manner constitutes the formulation of the ideal final result - IFR. After comparison of the actual situation and the IFR, obstacles to the achievement of the ideal result are revealed, reasons for the appearance of the obstacles are sought, and the contradictory qualities that appear in certain parts of the system (operative zones) and do not satisfy the requirements of the IFR are determined. In this manner the aggravated contradiction (AC) is formulated, which constitutes the exact formulation of the problem.

The sequence (1) is characteristic of the basic modification of ARIZ. The development of ARIZ aspires to formalize and detail the described sequence and to more fully use the laws of developing technological systems and the knowledge base. A modification of the algorithm for the solution of inventive problems, ARIZ-85-C.

Example 18. A powerful radar station (PRS) has a rather massive antenna with a large area. The antenna is fastened to a shaft, but turns on it very rarely, and therefore does not have a mechanism, but rotates manually. After rotating, the antenna is supported on the shaft with a fixative device and a bolt connection. The effort needed to support the massive antenna on the shaft is significant, and therefore it is necessary to tighten the bolts rather strongly. However, the shaft deforms under the pressure of the strong tie-beams and it becomes practically impossible to turn it the next time. What can be done?

The ‘superficial contradiction’ (SC) is practically formulated already in the described initial situation: a fixative element is needed that does not cause deformation of the antenna shaft. ‘Harmful effect’ (HE) – *deformation* of the shaft.

‘Intensified contradiction’ (IC) - *fixation* of the shaft leads to its *deformation*.

'Ideal final result' (IFR) – the shaft should be *fixed*, but *without deformation*.

'Aggravated contradiction' (AC) – the fixative element should be *hard*, in order to support the shaft, and *soft* in order not to deform it.

Solution – the shaft is supported by a substance that melts during rotation. In the process of invention, it was finally determined that the shaft should float. In a melted state, liquid will support the antenna and more easily position it in a new direction.

Example 19. Finding a person buried beneath an avalanche in the mountains is very difficult. Many activation devices have been created for this purpose, like a transmitter that emits a signal in the area where the buried person lies. But all of these devices are not capable of working in the actual conditions of an avalanche. First of all, few tourists will agree to carry a transmitter "just in case." Secondly, the batteries that power the transmitter quickly lose their charge, and even if the emergency signaling device can be turned on only at the necessary moment, this is usually impossible when buried in snow. What can be done?

SC – it is necessary to minimize the mass of the device for detecting snow-covered victims and to make it capable of operating for a long period of time. But reduction of the dimensions of the transmitter is accompanied by the reduction of its energy capacity and operating period – this is the undesired effect.

IC – reduction of the mass and dimensions of the transmitter is achieved at the expense of decreasing the mass of the energy source, i.e., at the expense of shortening the time of uninterrupted work.

IFR – the transmitter works without an energy source for any length of time.

AC – the energy source should be large in order to preserve a long operating period for the transmitter, and small (zero), in order not to increase the dimensions and mass of the transmitter. Or – the energy source should exist and not exist.

Solution – The Swiss firm "Sulab" created a device that consists of a metal bracelet, which is given to everyone who goes into the mountains. The bracelet consists of a passive receiver device with an antenna of metallic foil, but no energy source or transmitter. The foil antenna receives the signal of the rescuers, which has a powerful transmitter. Its power is sufficient to excite a current in the bracelet, as it is done in crystal detector receivers. The current is fed by a nonlinear circuit, which doubles or halves the frequency of the signal and transmits it by means of the very same foil antenna. The rescuers listen to the reflected signal on a doubled or halved frequency and, using a directional antenna, can determine from where the signal is being emitted. The system works constantly, even if the person buried in an avalanche is unconcious, and the period of time the system can work is unlimited by a battery that could fail, because it doesn't exist.

5. Logic of ARIZ

The logic of solving problems with ARIZ shows the interconnections between elements in the basic sequence (1):

$$\mathbf{SC} \longrightarrow \mathbf{IC} \longrightarrow \mathbf{IFR} \longrightarrow \mathbf{AC} \longrightarrow \mathbf{SOLUTION} \qquad \mathbf{(1)}$$

The 'superficial contradiction' (SC) is described either as a need for the appearance of a *new quality* or *action* "A" (positive effect), or in the form of a 'harmful effect' (anti-B), which it is necessary to eliminate.

A 'superficial contradiction' (SC) more often than not is expressed in the form of a 'harmful effect' (HE), i.e. a parameter or requirement "B" in an undesirable, harmful or insufficient condition that we label "anti B." It is represented in a diagram like this:

$$\textbf{SC (HE): anti-B.}$$

For the determination of 'intensified contradictions' (IC), we expose two contradictory requirements of the system. We represent these requirements with the letters "A" and "B." The intensified contradiction can be presented as a need for the improvement of characteristics satisfying requirement "A," which leads to the unacceptable deterioration of characteristics satisfying requirement "B" (expressed as requirement anti-B). The undesired effect consists of requirement "B." Or the contradiction can be formulated in reverse – the improvement of "B" at the cost of the deterioration of A (expressed as "anti-A").

$$\textbf{IC: A – anti-B} \text{ or } \textbf{anti-A – B}$$

The formula of the 'ideal final result' (IFR) should aim to eliminate the harmful effect (anti-B), while preserving the positive requirement "A," that is:

$$\textbf{IFR: A, B.}$$

The 'aggravated contradiction' (AC) is determined by exposing contradictory properties "P" and "anti-P" (for example, physical), which should be possessed by the element of the system that does not correspond with the requirements of IFR. For this it is necessary to determine what property "P" the element should possess in order to preserve requirement B, i.e., in order to eliminate the undesired effect. Simultaneously, the same element should possess the contradictory property (anti-P) in order to preserve the positive effect A. In this manner, the element should possess the property "P" in order to satisfy the requirement B (expressed as $P \rightarrow B$), and quality "anti-P," in order to preserve the requirement A (expressed as anti-$P \rightarrow A$).

$$\textbf{AC:} \quad P \longrightarrow B, \quad \text{anti-}P \longrightarrow A$$

Further intensification of the contradiction takes place by means of exposing more deep (latent) properties "P_1," which are necessary for the creation (preservation) of the earlier exposed property "P."

$$P_1 \longrightarrow P$$

In some cases during the solution of complicated inventive problems, it is necessary to expose even deeper cause and effect relationships in the system. For this it is necessary to expose even more latent properties P_2, P_2, … P_n. The next quality in the progression determines the reason for the emergence of the previous quality, i.e., that which is necessary for the fulfillment of the quality.

$$\begin{array}{l} P_2 \longrightarrow P_1 \\ P_3 \longrightarrow P_2 \\ \dots\dots\dots\dots\dots\dots \\ P_n \longrightarrow P_{n-1} \end{array}$$

In these cases several aggravated contradictions are exposed (AC_1, AC_2, AC_3 … AC_n). This can be represented in a diagram:

$$\begin{array}{lll} AC_1: & P_1 \longrightarrow P; & \text{anti-}P_1 \longrightarrow \text{anti-}P. \\ AC_2: & P_2 \longrightarrow P_1; & \text{anti-}P_2 \longrightarrow \text{anti-}P_1. \\ AC_3: & P_3 \longrightarrow P_2; & \text{anti-}P_3 \longrightarrow \text{anti-}P_2. \\ \dots & \dots\dots\dots & \dots\dots\dots\dots \\ AC_n: & P_n \longrightarrow P_{n-1}; & \text{anti-}P_n \longrightarrow \text{anti-}P_{n-1}. \end{array}$$

‘Solution of the problem’ (SP) consists of the solution of the aggravated contradiction, for example, by means of separation of the contradictory properties P …P_n.

$$\begin{array}{rr|l} \textbf{SP:} & \textbf{P} & \textbf{anti P} \\ & \textbf{P}_1 & \textbf{anti P}_1 \\ & & \ldots\ldots \\ & \textbf{P}_n & \textbf{anti P}_n \end{array}$$

Typical methods of separating contradictory qualities are indicated in the textbook on ARIZ.

The logical diagram for the solution of problems with ARIZ is shown fully in fig. 3.

LOGICAL DIAGRAM OF ARIZ

$$\begin{array}{ll} \textbf{SC (HE):} & \textbf{anti-B} \\ \downarrow & \\ \textbf{IC:} & \textbf{A – anti-B} \\ \downarrow & \\ \textbf{IFR:} & \textbf{A, B} \\ \downarrow & \\ \textbf{AC:} & \textbf{P} \longrightarrow \textbf{B,} \quad \textbf{anti-P} \longrightarrow \textbf{A,} \\ \downarrow & \\ \textbf{SP:} & \textbf{P} \mid \textbf{anti-P} \end{array}$$

Fig. 3.

Problem 1

It is necessary to transfer all of the gas from a transport cylinder to two empty (working) cylinders. The capacity of each of the working cylinders is equal to one half of the capacity of the transport cylinder.

Two methods for transferring gas are known (fig. 4).

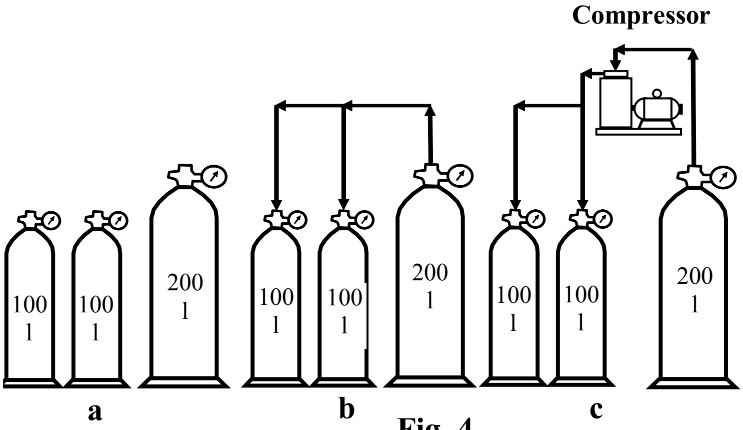


Fig. 4.

a) initial situation; b) direct connection of the transport cylinder with the working cylinder; c) connection by means of a compressor.

In the first method (fig. 4 b) the transport cylinder connects directly with the working cylinder. In this case, an equal pressure is fixed in all the cylinders, and one half of the gas will remain in the transport cylinder. The second method (fig. 4 c) is much more complicated: gas is pumped from the large cylinder into two others by means of a compressor. In this manner it is possible to transfer all of the gas, but it is necessary to use special equipment – a high-pressure compressor.

The problem consists of finding a method to fully transfer the gas from the transport cylinder to the working cylinder without the use of additional equipment (compressor).

This kind of problem is encountered during the "loading" of cylinders in deep-diving apparatuses at seaports. Compressed air is used for purging the cistern during surfacing of the apparatus.

SOLUTION OF THE PROBLEM

1. *Short formulation of the problem*

Find a simple method of transferring all of the gas from one cylinder to two others.

2. *Formulation of the superficial contradiction* (SC)

SC: anti-B

Part of the gas remains in the cylinder.
(Harmful Effect): INCOMPLETE (anti-B) transfer of gas.

3. *Determination of the aggravated contradiction* (AC)

In the given example, the transfer of gas is possible with and without the use of a compressor:

- with compressor

AC_1: B – anti-A

The gas transfers *completely* (B), but as a result the system is *complicated* (anti-A).
AC_1: Complete transfer of gas - *Complication.*
All of the gas can be transferred from the transport cylinder to the working cylinder using a compressor, which *complicates* the system.

- without compressor

AC_2: A – anti-B

The system is *not complicated* (A), but the gas transfers *incompletely* (anti-B).

AC_2: Simplicity - Loss of gas.

The *simple* method (direct connection) is used, but as a result one half of the gas is *lost*.

4. *Selection of AC***.** We select AC_2, because this formula is based on the use of a *simple method.*

Note: Within this step we selected a method of transferring gas only through the direct connection of one cylinder with another.

5. *Formulation of IFR*

IFR: A, B

The gas "itself" *fully* - (B) (with the same pressure and in the same quantity) transfers from one cylinder into two others, *without the use* (A) of additional equipment (compressor).

IFR: Simplicity – Loss of gas.

6. *Formulation of the aggravated contradiction* (AC).

AC: $P \rightarrow A$, anti-$P \rightarrow B$

In order not to complicate the system, it is necessary to directly connect the cylinder with gas to an empty (working) cylinder, but this increases the general capacity in which the gas is located (decreasing its pressure), therefore not allowing the gas to be fully transferred. In this manner the "extra" *capacity* (quality "C") should exist, so that the system remains *simple* "**A**," and should not exist (quality anti-C), so that the gas transfers *completely* "B."

Note: Remember that the basic characteristic of gas is to *occupy the entire available volume*. Therefore, during connection of the working cylinders, gas expands and occupies the entire capacity of the cylinders, while the pressure decreases.

7. *Formulation of aggravated contradiction 1* (AC_1).

AC_1: $P \rightarrow P_1$, anti-$P \rightarrow$ anti-P_1

So that there is not an *excess capacity* "P," the working cylinder should not be empty (it should be *filled*) "C_1," but to provide space for the *transfer of gas*, "anti-P," the capacity of the working cylinder should be *empty* "anti-P_1."

The connected *cylinders should be filled* to prevent the gas from expanding, but *should not be filled* (should be empty) so that they can be filled with the required gas.

Note: In this step we determined the exact formulation of the problem.

8. *Solution of the problem* (solution of the AC)**.**

The separation of contradictory qualities can take place:

- *in space,*
- *in time,*
- by changing the *system's structure,* specifically, changing the *aggregate condition.*

Therefore, the contradictory qualities are: the working cylinder should be FULL and EMPTY (filled and unfilled).

In space this contradiction *is unsolvable*.

Separation of the indicated contradictory qualities *in time* requires that the *substance* filling the working cylinder *gradually free space for the gas* entering from the transport cylinder and fill the freed space in the transport cylinder.

It only remains to explain what kind of substance should fill the working cylinder. For this**,** *structural changes of the substance* are used, changing the *aggregate condition* of the gas.

The substance inside the working cylinder is located in a gaseous state, which does not satisfy our conditions. That means it should be made *solid* or *liquid*.

Should the cylinder be filled with a solid substance? A solid monolithic substance does not possess the necessary qualities. In this manner we could ruin the cylinders. Of course it is possible to fill the cylinders with sand or ice. That condition might solve the problem in principle, but it is not sufficiently effective. It remains to use liquid.

If the working cylinders are filled with a liquid excluding gas, placed above the transport cylinder, and connected by means of pipes, than the gas (fully and without a compressor) will transfer from the transport cylinder to the working one (fig. 5).

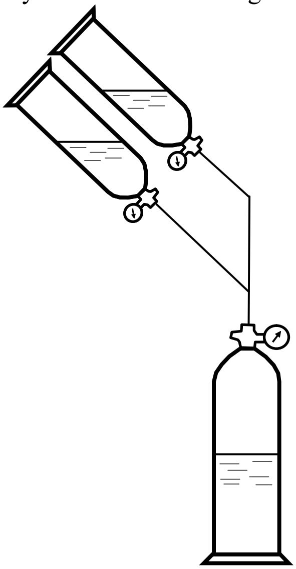


Fig. 5.

The idea of invention has been found.

6. Conclusion

The solution of problems with ARIZ constitutes a sequence for the exposure and solution of contradictions and the reasons that produce the given contradictions, as well as their elimination by use of the knowledge base. In this manner cause and effect relationships are determined – the essence of which is the intensification and aggravation of contradictions.

Use of the basic line of ARIZ and logic of ARIZ allows revealing original causes of a problem and relationships of cause and effect. Regular use of logic ARIZ allows developing the inventive thinking revealing and resolving the contradictions.

EMS MODELS: ADAPTATION OF ENGINEERING DESIGN BLACK-BOX MODELS FOR USE IN TRIZ

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Abstract

The Theory of Inventive Problem Solving (TRIZ) has been widely recognized as a powerful systematic innovation technique that can be applied to a wide arrange of disciplines. This paper focuses on engineering design and illustrates how modeling methods already familiar to engineering designers can be adapted for use in TRIZ. Specifically, the 'black-box' modeling technique, common in problem formulation and clarification in engineering design, is modified for use in TRIZ. The new technique, referred to as Energy, Material, System modeling, can not only serve as a substitute for substance-field modeling, but as it builds on existing knowledge in the engineering design community, removes one of the barriers to wider TRIZ adoption by not requiring designers to learn new and radically different modeling techniques. The efficacy of the technique is illustrated via several examples.

Keywords: Problem formulation, problem clarification, TRIZ standard solutions.

1. Introduction

TRIZ has been touted as a method that can be applied across numerous disciplines due to the generality of its collection of principles and tools. In trying generate a wider audience, most TRIZ texts use the general modeling methods and terminology developed over the years by the TRIZ community. The presentations, however, may also present a barrier to wider implementation due to the difficulty in relating TRIZ concepts typically discussed in the context of TRIZ modeling techniques to one's specific discipline.

Despite the power of TRIZ, it has not seen wide usage in the engineering design community, both in industry and in academe. This article explores ways to increase the implementation of TRIZ in the engineering design community by adapting and incorporating modeling techniques already familiar to engineering designers into TRIZ. This is achieved by adapting the black-box modeling technique, widely used in engineering design for problem clarification and decomposition, for use in TRIZ. The new technique, referred to as Energy-Material-Signal (EMS) modeling, can not only serve as a substitute for substance-field analysis, but also provide the following desirable features.

1. Builds on existing knowledge within the engineering design community, thereby removing one of the barriers to widespread TRIZ adoption.
2. Applicable to both physical and technical contradiction systems.
3. Inherently provides sequence of events within the modeled system.
4. Includes multiple scenarios in the same model.
5. Identifies the true problem to be solved, within the context of the overall system.

6. Includes all the resources available in the system that can be used to furnish a final solution. A separate resource list is therefore not required.

The development and use of the EMS model in the context of two examples follows in the rest of the paper. In addition, the standard solutions, most based on substance-field modeling, are modified to incorporate the new modeling method.

2. TRIZ

TRIZ, the Russian acronym for Theory of Inventive Problem Solving, was first developed in Russia by Genrich Altshuller and is now used across the world. It was originally based on analyses in the early sixties and seventies of thousands of Russian patents[1]. These original analyses articulated numerous solution patterns found across patents that can be successfully applied to solve new problems. These patterns have since been synthesized into numerous tools including (1) physical effects, (2) laws of evolution, (3) standard solutions, (4) technical contradictions and the contradiction matrix, and (5) physical contradictions and the separation principles.

TRIZ has been recognized as a concept generation process that can develop clever solutions to problems by using the condensed knowledge of thousands of past inventors. It provides steps that allow design teams to avoid the ``psychological inertia" that tends to draw them to common, comfortable solutions when better, non-traditional ones may exist. With reference to Figure 1, a design team using TRIZ converts their specific design problem to a general TRIZ design problem. The latter is based on the analysis and classification of a very large number of problems in diverse engineering fields. The general TRIZ design problem points to corresponding general TRIZ design solutions from which the design team can derive solutions for their specific design problem. The power of TRIZ, therefore, is its inherent ability to bring solutions from diverse and seemingly unrelated fields to bear on a particular design problem, yielding breakthrough solutions.

[1] Altshuller's work focused primarily on mechanically oriented patents. In recent years numerous researchers have begun to analyze worldwide patents in all fields and to update the TRIZ tools.

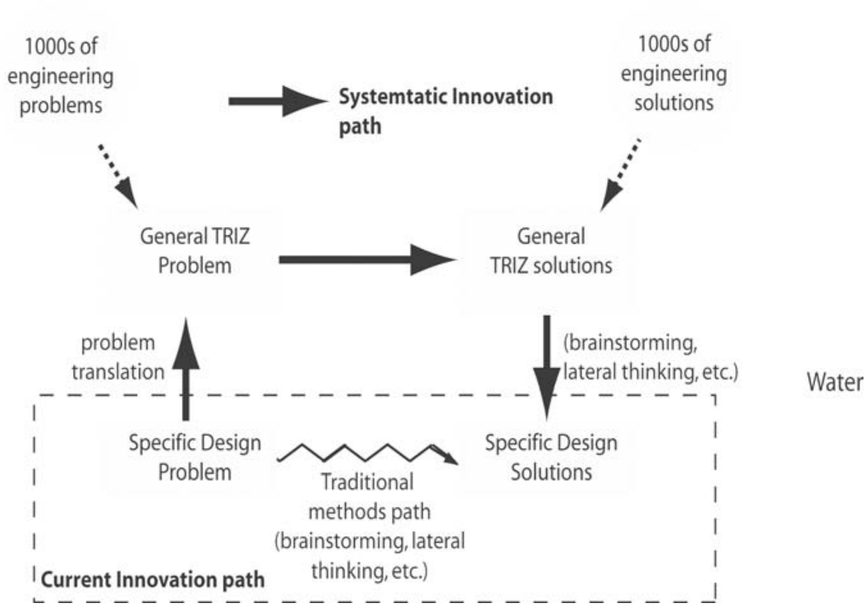

Figure 1. Generation of design solutions using TRIZ

3. Substance-Field Analysis and Variants

A key concept in TRIZ is the modeling of all material objects (visible or invisible) as *substances*, and sources of energy (mechanical, chemical, nuclear, thermal, acoustic, etc.) as *fields*. A *function* (also known as substance-field) can therefore be defined as a substance, S_1, acted upon by a field, F_1, created by a second substance, S_2. The substance-field for a complete system can be represented with the notation,

$$S_2 \xrightarrow{F_1} S_1 \tag{1}$$

where the arrow shows S_2 having a positive or desired effect on S_1 through the field F_1. Note that in the TRIZ literature the graphical representation for the substance-fields varies greatly. Equation 1 merely presents a possible representation.

The parameters S_1 and S_2 are often referred to as *object* and *tool*, respectively, where the tool is acting on the object to create the desired effect. Models that do not have all three components (tool, object and field) are referred to as incomplete. By adding the missing element, a problem that may have been present in the system can be solved. Alternatively, if the tool has a harmful effect on the object, the straight field line would be wavy to indicate that harm is being done.

Royzen(1999) proposed the use of the Tool-Object-Product (TOP) analysis, a variant of SFA, as the next generation modeling approach. In TOP analysis a complete system has four elements: tool, object, field and product. The latter is defined either as a useful product (UP) or a harmful product (HP). The TOP analysis for a complete system can be represented with the notation

$$T \xrightarrow{F_1} O \Rightarrow UP \qquad (2)$$

Equation 2 states that the tool creates the desired effect on the object via a field to produce a useful product.

Despite the appeal of both the SFA and the TOP models, they both require engineering designers to learn new modeling techniques, conventions and nomenclature and may therefore present a barrier to adoption. The following section will introduce black-box modeling upon which the presented energy-material-signals (EMS) models are based.

4. Problem Clarification with Black-Box Modeling

The following discussion of Black-box modeling is based upon the work by Pahl and Beitz (1996). An analysis of engineering systems reveals that they essentially channel or convert energy, material or signals to achieve a desired outcome. *Energy* is manifested in various forms including, optical, nuclear, mechanical, electrical, etc. *Materials* represent matter. Signals represent the physical form in which information is channeled. For example data stored on a hard drive (information) would be conveyed to the computer's processor via an electrical signal.

An engineering system can therefore be initially modeled as a black-box (Figure 2) with energy, material and signal inputs and outputs from the system. In black box modeling, energy is represented by a thin line, material flows by a thick line, and signals by dotted lines as shown. The engineering system therefore provides the functional relationship between the inputs and the outputs.

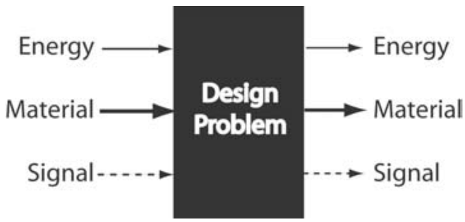

Figure 2. Energy, material and signal flows through a generic `black box' design

Problem clarification involves forming a clear understanding of the problem. The *overall problem* represented by the black-box can be decomposed into smaller *sub-problems*. Problem decomposition allows solutions to complex engineering design problems to be found by considering simpler sub-problems. Design teams can then focus on the sub-problems critical to the success of the project first, deferring others. Sub-problems are then mapped to sub-functions for which a design is created. Combination of all the designs that achieve each of the sub-functions results in the desired system solution that achieves the overall desired function. Note that the functional decompositions and the resulting black-box diagrams are generic and do not commit the design team to any particular technological working principle.

Black-box modeling of existing systems that are to be redesigned, on the other hand, decomposes the existing system into sub-systems as opposed to sub-functions. The subsystems would then be translated to sub-functions from where the redesign proceeds.

4.1 Black-Box Modeling Examples

Throughout the paper two examples found in the TRIZ literature will be used. They are presented here to illustrate the use of black-box models.

4.1.1 Automobile Airbag

The automobile airbag, when used in conjunction with a seat belt, provides protection to occupants during front end collisions. Airbag systems deploy when crash sensors located on the front of the vehicle detect high-rate deceleration. The sensors trigger the inflator module that through a rapid chemical reaction (a mini-explosion) rapidly releases nitrigen gas that fills the airbag. Typically the air-bag will be fully deployed within 1/20 th of a second after impact detection (Kowalick, 1997). An initial black-box model of the airbag system is presented in Figure 3(a). The entire airbag system is represented as a black-box with a single input, the mechanical energy from the automobile impact. Figure 3(b) illustrates the decomposition of the black-box into sub-systems, with the corresponding the energy, material and signal flows.

The sequence of events, indicated by the arrows, starts with the detection of an impact, that signals the chemical reaction, rapidly releasing gas and mechanical energy into the airbag. The occupant then slams into the airbag, that in turn collides with the car interior. Note that the double arrows between the occupant and the airbag, and the airbag and the car interior are used to indicate that the mechanical forces are bi-directional.

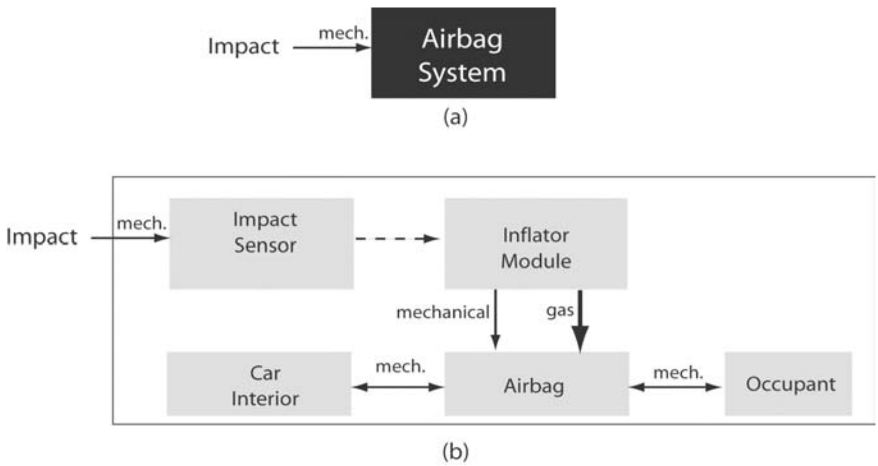

Figure 3. Black-box model of an airbag system

4.1.2 Computer Hard Drive

A computer hard drive is used to store and retrieve data (Figure 4). Within the hard drive, data is stored on a rotating magnetic disk, from which data is read using a read/write head. The head, situated at the end of a moveable actuator arm, can magnetize (write) or sense the magnetic field (read) on the disk. The head floats on the airflow generated by the disk rotation that maintains a very small gap between the two, preventing contact that may result in data loss. A black-box model of the hard drive in operation is shown in Figure 5.

Figure 4. Image of hard drive with cover removed to reveal magnetic disk, actuator arm and read/write head

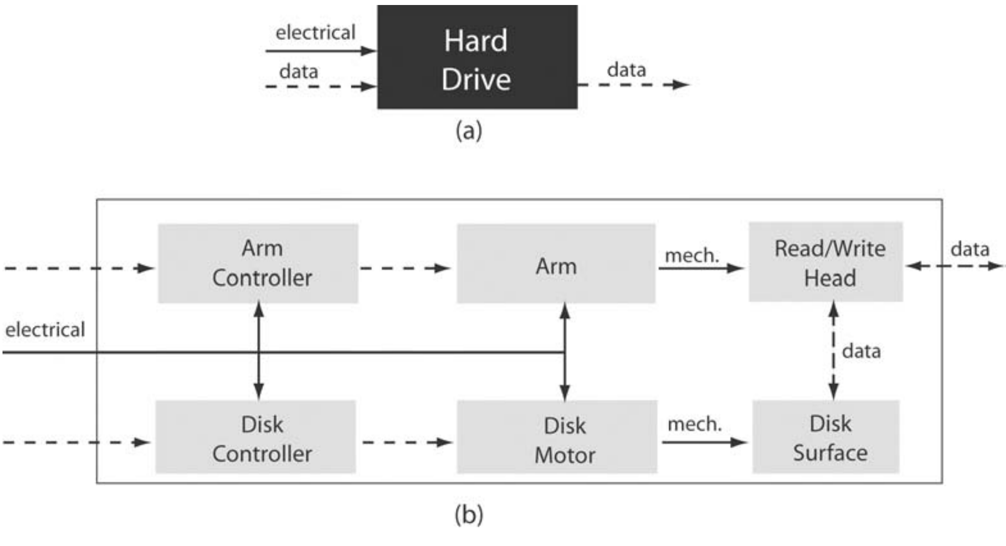

Figure 5. Black-box model of a computer hard drive

5. Energy-Material-Signal (EMS) Models in TRIZ

The EMS model extends the black-box model by incorporating symbols that indicate harmful and insufficient energy, material and signal flows with in the system. In addition, symbols are also included to allow the modeling of multiple scenarios and discrete time-separated events. Table 1 lists the new symbols with their corresponding description. The EMS model will be explained in the context of the previous two examples.

Despite the success of airbags at saving lives, they have also resulted in numerous deaths to smaller occupants due to their deployment force. An EMS model of the airbag system during a frontal impact is illustrated in Figure 6. A comparison of the black-box model and the EMS model shows that the main difference between the two is that in the EMS model, the generic occupant is now separated into a large and a small occupant, with the harmful effect of the mechanical energy on the small occupant shown. Within the context of the airbag system, one can clearly identify where the problem is that requires further attention. In addition, available system resources that could be used as part of the design solution are integrated into the problem clarification model. As such a separate list of resources is not required, as is traditionally the case if SFA or TOP analysis methods are used.

S	The original system
S^c	A copy of the original system
S'	A modification of the original system
A	An additive can be material, energy, voids, systems, sub-systems or super-systems
E	The immediate system environment
$\dashrightarrow$	Signal flow
$\boldsymbol{\longrightarrow}$	Material flow
$\longrightarrow$	Energy flow
$\boxed{I}$	When placed next to an energy, material or signal flow signifies that flow as being *Insufficient* to perform its desired task adequately.
	A wavy line representing any of the three flows (energy, material, signal) indicates that flow to be harmful to the system receiving it
$\downarrow$	Placed above a flow indicates a decrease in the flow level from the original problem
$\uparrow$	Placed above a flow indicates an increase the flow level from the original problem
	Discrete sequential events
	Each slot represents a different scenario and its effects on the EMS model

Table 1. EMS model symbols and description. System could mean an assembly, sub-assembly, function, user, and so on

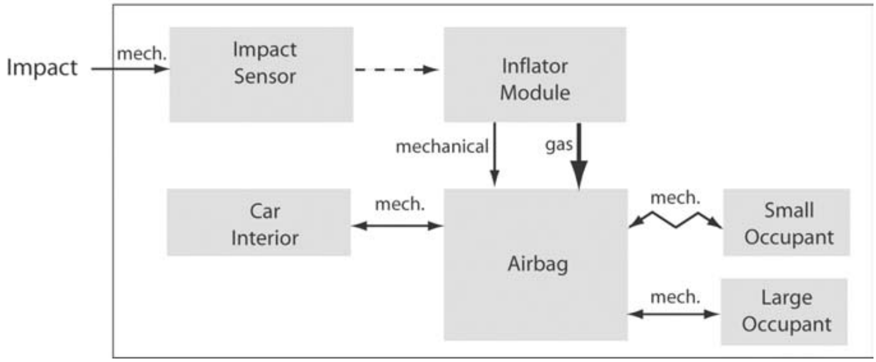

Figure 6. EMS model of an airbag system

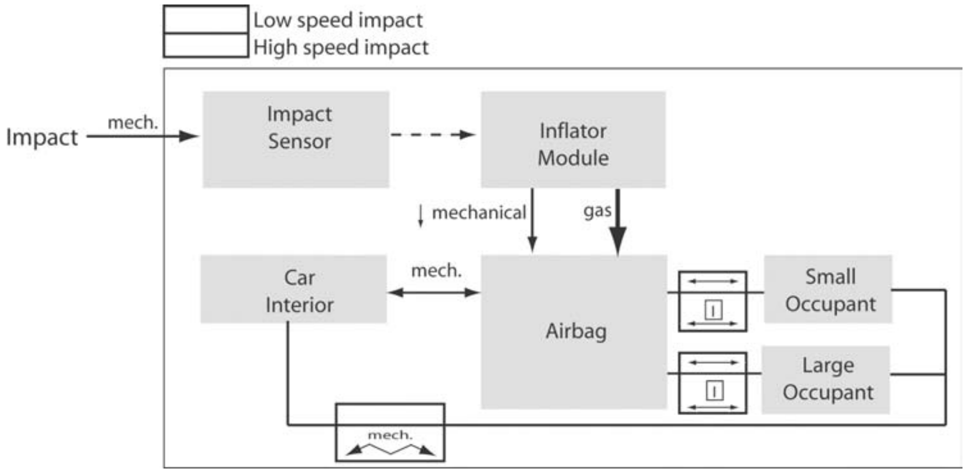

Figure 7. EMS model of proposed solution: De-powering of the airbag. This example illustrates the ability to model multiple scenarios in the same model

To reduce airbag caused fatalities, numerous automakers have installed de-powered airbags. The bags do not deploy as fast as the original ones and therefore do not cause harm to small occupants. The problem with de-powered air bags, however, is that they are less effective during high-speed crashes. This is because the time it takes to achieve full deployment for the de-powered airbag is not fast enough to prevent the occupants (both large and small) from hitting the interior of the vehicle. The two scenarios, low-speed and high-speed collisions, are illustrated in the EMS model in Figure 7. Using the multiple scenario symbol, the low speed impact scenario is represented by the top slots. In this scenario, the mechanical force from the airbag is sufficient to shield both types of occupants from colliding with the vehicle interior. In the second scenario, high-speed impact represented by the lower slots of the multiple scenario symbols, also results in airbag deployment. However, the mechanical force from the airbag is insufficient to prevent either occupant from colliding with the vehicle interior (harmful effect).

Turning to the hard drive example, an area of concern arises when the computer is off and receives a hard external knock. Without the hard drive disk spinning, the head can be knocked off its rest position and data on the disk destroyed. In the rest position, the head is typically held in place by a magnetic latch. When the computer is powered on again, the airflow from the disk motion raises the head, and a permanent magnet/electro-magnet system situated at the arm axes of rotation (the pin) generates enough force to release the arm from the magnetic latch and move the head to wherever data needs to be written or read (Royzen, 1999). An EMS model of this scenario is illustrated in Figure 8. In the model, one can track the sequence of events (the flow) from when the computer chassis receives a hard knock to the point where there is damage (harmful effect) to the disk surface by the read/write head. In the figure, the magnetic field is shown to be insufficient, and therefore an area that would be addressed.

A possible solution may be to use a stronger magnetic latch. This, however, may present its own problem by making it difficult for the arm to be released during start-up. The two scenarios are modeled in Figure 9, where the top slot in the multiple scenario symbols represents the hard knock scenario, and the lower slot the computer start-up. Note that by increasing the magnetic strength of the latch, a desirable effect is achieved in response to reduction of damage from external knocks, but it also produces an undesirable effect during system start up.

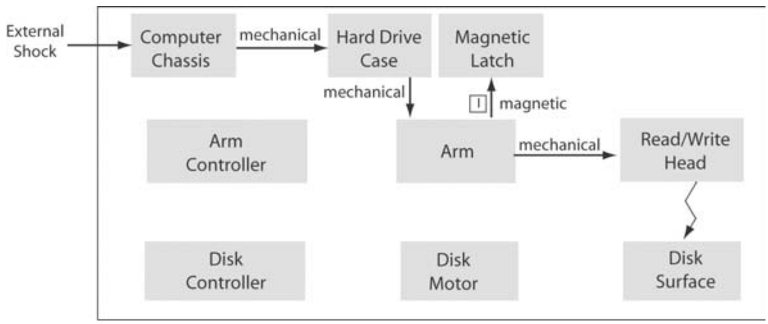

Figure 8. EMS model of hard drive when the computer is turned off. A hard knock on the computer dislodges the arm resulting in the head damaging the disk magnetic surface

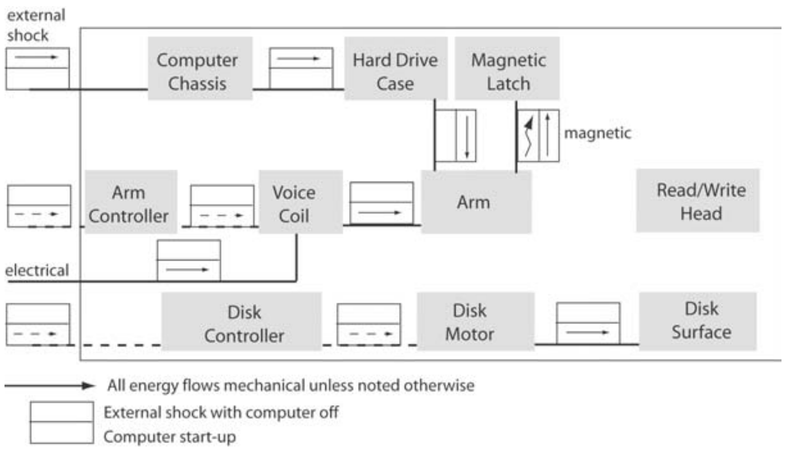

Figure 9. EMS model of hard drive with a stronger magnetic latch

The two examples presented have served to illustrate how EMS models can be developed to identify where harmful or insufficient effects occur in a system, focusing engineering designer's attention to those areas. In addition, the models present the problem area in the context of the overall system allowing engineers to see what resources are available that may be used as part of a solution. Further, unlike traditional black-box modeling, the EMS models allow the inclusion of multiple scenarios within the same model.

6. EMS Models and the 76 Standard Solutions

The 76 standard solutions are to a large extent, based on the substance-field modeling method. To effectively use the EMS models, therefore the solutions were modified and articulated in terms of EMS models. In addition, several authors have noted the significant degree of repetition amongst the standard solutions, developing their own reduced versions. Soderlin (2002) preferring to use `rules' as opposed to 'standards', reduced the number of solutions from 76 to 16 rules. Orloff (2003) renames the standard solutions as 'compact standards', and reduces the number to 35.

In this work, suggestions put forth by Soderlin (2002) and Orloff (2003) have been taken into account while generating a set of *Condensed Standards* composed of 27 solutions. In addition to reducing the number of solutions from 76, the Condensed Standards, (a) use the language and jargon typical in engineering design, and (b) replace the substance-field models found in the original 76 solutions with the EMS models. The classical 76 standard solutions fall into five classes:

1. Class I: Improving the system with little or no change
2. Class II: Improving the system by changing the solution
3. Class III: System transitions
4. Class IV: Detection and measurement
5. Class V: Strategies for simplification.

The Condensed Standards have reduced these five classes to three sets of standards:

1. Condensed Standards I: Improving the system with little or no change
2. Condensed Standards II: Improving the system by changing the solution
3. Condensed Standards III: Detection and measurement

The Condensed Standards incorporating the EMS models are presented in Tables 2 - 4 in the Appendix. Within the tables, the numbers in italics refer to the classic TRIZ standard solutions on which the condensed set are based. Where applicable, solution fragments based on the EMS model are included.

7. Concluding Remarks

TRIZ has been widely recognized as a powerful systematic concept generation technique that is applicable to a wide array of disciplines. This paper has described the development of a new modeling method, energy-material-signals (EMS) models based on the black-box models found in engineering design. By adapting a method already familiar to engineering designers it is hoped that one of the barriers to wider TRIZ implementation within the engineering design community will be removed.

References

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Appendix: Condensed Standards

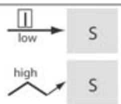
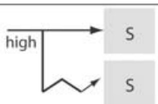
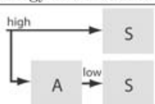
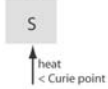
	Problem	Solution
1.1		Without changing the system, add a temporary or permanent, internal or external additive. The additive may or may not be present in the environment *(1.1.2-1.1.4, 1.2.1-1.2.2, 1.2.4, 5.1.1.1-5.1.1.3, 5.1.1.6, 5.1.4, 5.2.2,5.2.3)*
1.2		 Change the environment. *(1.1.5)*
1.3		 If a moderate energy is insufficient, but higher energy is damaging, apply higher energy to an additive that acts on the original system. *(1.1.7)*
1.4		 Both low and high energy levels are required. Use an additive to protect those sub-systems that require low energy. *(1.1.8, 1.2.3)*
1.5		 Heat a material above its Curie point to neutralize harmful magnetic effects. The Curie point is the temperature above which a ferromagnetic material loses its ferromagnetism. *(1.2.5)*
1.6		Use a small amount of a very active additive *(5.1.1.4)*.
1.7		Add additives to a copy or model of the object if it is not possible to add to the original *(5.1.1.7)*.
1.8		Desired additives can be obtained by decomposition of other materials *(5.5.1)*, such as hydrogen from water decomposition.
1.9		Desired additives can be obtained by combining other materials *(5.5.2)*.

Table 2. Condensed Standards I (9 solutions): Improving the System with Little or no Change. This class looks at ways to modify a system in order to produce a desired outcome or eliminate an undesired one. An *additive* can be material, energy, voids, systems, sub-systems or super-systems.

	Solutions
2.1	Apply an additional energy source to the system *(2.1.1, 2.1.2)*. Example: Use of water and detergent (chemical energy) is not very effective for washing clothes. Agitating the system (mechanical energy) improves the cleaning.
2.2	Replace or add to energy existing in the system that is difficult to control with energy that is easier to control *(2.2.1)*. From the Laws of Evolution, in order of improved controllability: mechanical to thermal to chemical to electric to magnetic to electromagnetic energy.
2.3	Replace uncontrolled energy with energy that has predetermined patterns *(2.2.5)*.
2.4	Replace a uniform or uncontrolled system with a non-uniform system having a predetermined structure *(2.2.6)*.
2.5	If it is difficult to accurately control small quantities, use large quantities and remove the extra *(1.1.6)*.
2.6	Match or mismatch frequencies of elements within the system *(2.3.1,2.3.2)*. Example: *Noise canceling headphones* introduce a second signal with the same frequency but 180^o out of phase.
2.7	A pair of incompatible or independent actions can be accomplished by running one during the down time of the other *(2.3.3)*.
2.8	Add ferromagnetic materials (objects or liquids) and/or electric generated magnetic fields (dynamic, variable or self-adjusting) *(2.4.1-2.4.11)*. For example: *Maglev trains* use dynamic magnetic fields to levitate and propel trains at high speeds.
2.9	Transition to the super-system. Simplify, improve the links between or create bi- and poly-systems *(3.1.1-3.1.4)*. Example: *Modern traffic lights* have replaced the use of a single light bulb with a large array of light emitting diodes (LEDs). LEDs have a longer life and use significantly less energy than regular bulbs.
2.10	Transition to the micro-level by dividing the system into smaller and smaller units *(3.2,5.1.2)*.
2.11	Make use of a material's phase transitions *(5.3.1-5.3.5)*.

Table 3. Condensed Standards II (11 solutions): Ways to improve the system by changing it. An additive can be material, energy, voids, systems, sub-systems or super-systems

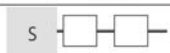
	EMS Model	Class III Problem
		Current measurements in the system are insufficient
	EMS Model	**Solutions**
3.1		Modify the system to make detection and measurement unnecessary *(4.1.1)*
3.2		Measure a copy or image of the system. *(4.1.2)*.
3.3		Make two detections instead of continuous measurement *(4.1.3)*.
3.4		Introduce an additive (into the system or its environment) that reacts to changes in the system. Measure changes in the additive or changes in the energy from the additive. *(4.2.2-4.2.4)*. Example: *Wind tunnels:* Adding smoke particles (additive) into the air flow in wind tunnels (original system) makes it easy to observe (measurement) the flow of air around objects.
3.5		Determine the state of a system by measuring the changes in scientific effects known to occur in the system. This could include the system's natural frequency *(4.3.1-4.3.3)*.
3.6		Add ferromagnetic materials (objects, particles, liquids) to the system or its environment and measure changes to the magnetic field *(4.4.1-4.4.5)*.
3.7		Measure the first or second derivatives in time or space *(4.5.2)*. For example: *Ground-based radar systems* measure *changes in the frequency* (second derivative of displacement) to accurately determine position, velocity and acceleration of an aircraft.

Table 4. Condensed Standards III (7 solutions): Detection and measurement. Mainly used for control. Often the best designs are those with automatic control that do not require detection or measurement, but utilize physical, chemical or geometrical effects within the system. An additive can be material, energy, voids, systems, sub-systems or super-systems.

USIT OPERATORS
FOR SOLUTION GENERATION IN TRIZ: CLEARER GUIDE TO SOLUTION PATHS

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Abstract
The biggest reason for slow penetration of TRIZ into industries in Western countries is that very rich contents of TRIZ knowledge bases and individual methods of problem solving have been tried to teach without clear overall procedure/structure for problem solving. It has been traditional that principal solution generation methods in TRIZ, including Inventive Principles, Inventive Standards, and Trends of Evolution, are applied separately on the basis of their own problem analysis methods. Present paper demonstrates, on the other hand, that Unified Structured Inventive Thinking (USIT) is a simplified and unified version of TRIZ which has overcome the above-mentioned weak-point. All the solution generation methods in TRIZ have been reorganized into a unified hierarchical system of USIT Solution Generation Operators. On this basis, USIT has a clear procedure for creative problem solving process as shown in a flowchart and also has a clear structure, as shown in a dataflow diagram, of transforming problem information stepwise into solution information. User's specific but vague problem is (1) first converted into a 'well defined problem' at the problem definition phase, then (2) further converted into the understanding of the problem system in terms of objects, attributes, functions, space, time, ideal actions, and ideal properties at the problem analysis phase, (3) modified by applying the USIT Operators into pieces of ideas of a new system in the solution generation phase, (4) constructed into conceptual solutions on the basis of user's technological background capabilities, and (5) finally implemented into user's specific solution(s) in the implementation phase. USIT guides at the steps (1) through (4). USIT has been taught fully in 2-day training seminars at the level of solving real industrial problems by the participants themselves.
Keywords: Solution generation, models, USIT, analogy, problem solving, TRIZ.

1. Introduction

Theory of Inventive Problem Solving (TRIZ) [1, 7, 9, 2] is a powerful methodology for creatively solving problems in a wide range of technological (and many other non-technological) fields. It has established knowledge bases (KBs) of technological facts with various useful indexing systems and of principles for inventive thinking and has also developed a large number of methods for problem definition, problem analysis, and solution generation. These KBs have been constructed by extracting world best solutions in science and technology, and the problem solving principles in TRIZ are at a high level of abstraction so as to be applicable to a wide range of problems.

In spite of expectations by TRIZ experts, however, TRIZ has not been spreading so widely and rapidly in the Western countries since its exposure in early 1990s. The present author [3] observes, as many would agree, that the penetration of TRIZ has been slow not because it is poor but because it is so rich in contents. 'How to choose an effective principle' and 'how to apply a principle properly to the user's specific problem' have been the issues for TRIZ users. Most TRIZ specialists have tried to teach the rich contents of TRIZ KBs and thinking methods in more or less orthodox forms, but most engineers in industries and engineering students cannot understand them up to the level being able to apply them to their real problems. Some specialists may say 'It is a problem of the students and the training period', but the position of the present author in this paper is 'It is a problem of the teachers and the system of TRIZ itself.'

Basic model and overall structure of TRIZ should be reviewed and discussed in this context. It is generally understood that TRIZ is based on the four-box scheme of problem solving [2] shown in Fig. 1. Instead of trying to solve user's specific problem directly to specific solutions staying at the concrete level, TRIZ advises to go around at a higher abstraction level using standard models which show generalized problems and their generalized solutions. TRIZ has adopted this scheme from the sound basis of science and technology.

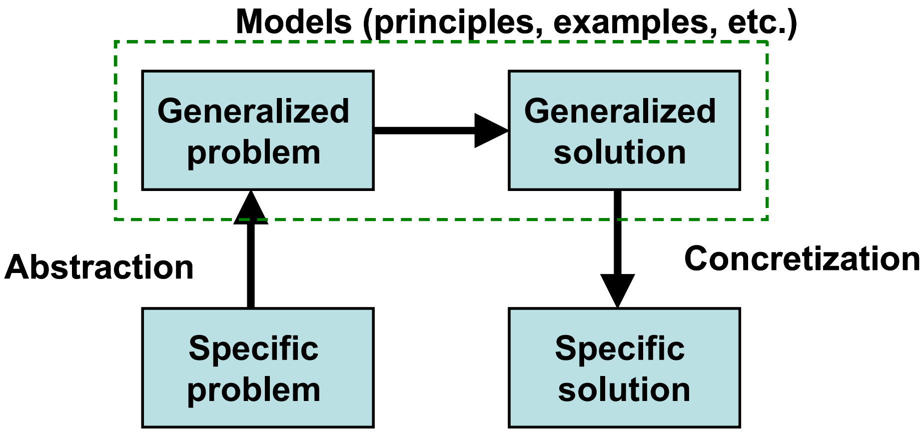

Fig. 1 Four-box scheme of problem solving

All the TRIZ KBs (such as Effect database, Inventive Principles, Inventive Standards, Trends of Evolution, etc.) have been built with the intention to let them serve as different models at the abstract level in this scheme.

Once models are established, the process of problem solving may be reduced to the following issues:

- Abstraction: How can we transfer the specific problem to the generalized problem in some known model? Do we need different abstraction methods for different models?
- Selection: Which model should we use among a number of models?
- Concretization: How can we transfer the generalized solution suggested by the model to a specific solution to our problem?

Generally speaking, these issues are not well understood unfortunately in many fields of science and technology. In each topic of a specialty field, one model is chosen and taught with a few examples. Then the students have to learn, study, drill and practice many times to understand by themselves that the model is useful for some kind of problems after some kind of abstraction.

TRIZ has developed a number of procedural methods of problem solving in technology, for the purpose of guiding us in the abstraction and selection (and little in the concretization) processes. These methods in TRIZ (such as 9-Window Method, Substance-Field Analysis, Technical and Physical Contradictions, etc.) are often very unique and powerful in the areas where no other effective methods and ways of thinking exist. Nevertheless, the overall procedure of problem solving in TRIZ has not been well established yet and is in a confusing situation for users.

In the present paper, the current situation of the TRIZ methodology is summarized briefly in this four-box scheme. Then I will demonstrate that Unified Structured Inventive Thinking (USIT) [8], i.e. a simplified and unified version of TRIZ, has established a clear structure of problem solving procedure by extending the four-box scheme into more meaningful six-box scheme. The key to this structure is the USIT Solution Generation Operators, which have been obtained earlier by reorganizing all the TRIZ principles and methods for solution generation [4, 5].

2. Current Scheme of Problem Solving in TRIZ

The current situation of the overall scheme of problem solving in TRIZ may be roughly summarized as shown in Figure 2 in the framework of Figure1. TRIZ KBs are shown in a box at the top and various TRIZ methods are shown in ovals according to the phases in problem solving. These components are established well [1, 7, 9, 2] and are summarized in the following subsections first and the overall structure will be discussed next.

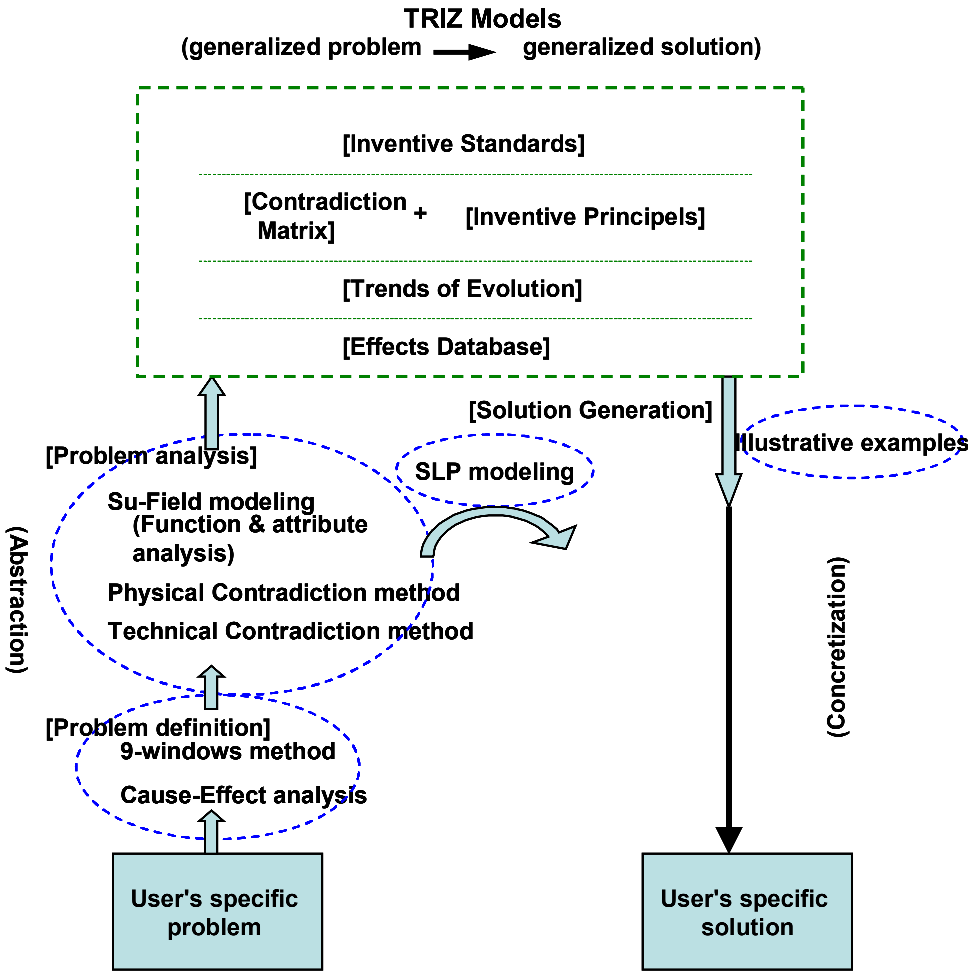

Figure 2. Overall Structure of Problem Solving in Traditional TRIZ

2.1 TRIZ Knowledge Bases of Principles and Facts

First type of KBs in TRIZ is the accumulation of facts and technical means, especially:

- Effects Database: facts database of physical, chemical, and mathematical effects and technical means.

This type of KB is useful to learn various facts and means known in different fields of science and technology and to apply them to our own fields in novel ways. Reorganizing the KB in the explicit hierarchical system of functions has been a major contribution of TRIZ.

Second type of KBs in TRIZ is at a higher level of abstraction of the principles for inventive thinking and has been the most important contribution of TRIZ. They include:

- 40 Inventive Principles: essence of ideas in inventions.
- Contradiction Matrix: information of which Inventive Principles have been most frequently used in which type of problem expressed in the Technical Contradictions

- 76 Inventive Standards: standard solutions corresponding to the situations expressed by the Substance-Field model
- Trends of Evolution of Technical Systems: patterns of evolution

These are the major models in TRIZ in the four-box scheme and provide problem solvers with generalized solutions for generalized problems. For each item in these KBs, examples of typical cases of application are accumulated and linked (e.g., to the Effects Database and to patent databases) and used for illustrating and stimulating users' analogical thinking. It should be noted that these KBs are presented to users as parallel alternatives, separated (and more or less overlapped) with one another, as shown with the separating broken lines in Figure 2.

2.2 Individual Methods and Techniques for Problem Solving in TRIZ

In the area of methods and techniques for problem solving in technology, Classical TRIZ has developed a number of unique and effective methods. Major ones are summarized below briefly with particular comments on their relationships to the TRIZ KBs:

- 9-windows method: to think over the problem in the 3 x 3 framework of system hierarchy (i.e., super-system, system, and subsystem) and time (i.e., past, present, and future). This is a general method to be used in the early stages of problem definition and problem analysis. It is loosely related to the usage of the KB of Trends of Evolution.
- Substance-Field modeling: to model the problem system with two substances (i.e., product and tool) and its functional relationship. This serves as the problem analysis procedure (i.e. an abstraction process) for using the KB of Inventive Standards.
- Technical Contradiction method: to model the problem in the scheme of a Technical Contradiction where the problem solver wants to improve one aspect (or parameter) of the system but another aspect of the system gets worth and preventing the improvement. This is a special method in the abstraction process for using the Contradiction Matrix (in the selection process) and then a few selected Inventive Principles.
- Physical Contradiction method: to model the problem in the scheme of a Physical Contradiction where two opposite requests exist simultaneously on one aspect of the system, and then to use the Strategy of Separation of the opposite requests. This strategy guides the solver to several selected Inventive Principles.
- Smart Little People's modeling: to imagine that a part of the system is composed of a crowd of smart little people who can and do perform any desirable action. This method stimulates to think of ideal solutions first and then to figure out solutions in feasible, technical terms. It does not utilize any KBs.

Recent works in TRIZ have added some more methods, including:

- Cause-Effect analysis: to model a network of cause-and-effect relationships in the problem, and to suggest a large number of smaller and more specific problems of preventing some harm or enhancing some good in the original problem. This serves in the problem definition process.
- Function and Attribute analysis: to model the functional relationships in the system (releasing the 'two-substance restriction' in the Substance-Field modeling) with some inclusion of attributes of objects.

2.3 Overall Procedure of Problem Solving in TRIZ

The above description of the components of TRIZ KBs and TRIZ methods and their positions shown in Figure 2 are basically agreed in the community of TRIZ specialists [1, 7, 9, 2]. The overall procedure of problem solving in TRIZ must further specify the recommendation of 'which methods and which KBs should be used in which order in which situation of problem.' This is the issue on which many TRIZ leaders have proposed and applied in many different ways, and is still under a confusing situation as follows:

Altshuller [1] who developed all the individual methods and KBs in Classical TRIZ also developed the overall procedure in the name of ARIZ (Algorithm of Inventive Problem Solving). Intending to make ARIZ more and more powerful for solving ever harder problems, he constructed various versions of ARIZ having complicated procedure of using various individual methods and their corresponding KBs. He recommended to use ARIZ after at least 80 hours of training, and for solving simpler problems he advised to use more standard methods (i.e., some appropriate individual methods).

Yuri Salamatov, in his orthodox TRIZ textbook [7], recommends to try several inddividual methods listed above and use ARIZ later only when no satisfactory solutions are obtained. Boris Zlotin and Alla Zusman [9] have proposed TRIZ Tool Map and recommended to use different individual tools depending on the type of sub-problems which are suggested by the cause-effect analysis.

Darrell Mann in his recent textbook [2] proposes a four-stage process composed of 'define the problem', 'select the solution tool', 'solve the problem', and 'evaluate the solution' stages. Though his explanation of individual methods is excellent and insightful, his overall process seems to contain two problems: Methods for problem analysis, i.e. the main part of the abstraction process in the four-box scheme, are described separately in the 'problem definition' and the 'problem solving' stages. In the 'tool selection' stage, he shows 19 situations of judging the results of the 'problem definition' stage and recommends for each situation up to four tools to select in the 'problem solution' stage. The selection table is too large and complicated to summarize here.

Thus these overall procedures of problem solving in the traditional TRIZ have in common the following weak points:

- The models of solution generation in TRIZ, especially the three principal models consisted of Inventive Standards, Inventive Principles, and Trends of Evolution, are placed separately and in parallel.
- Corresponding to the separated models for solution generation, the problem analysis phase provides separate methods of analysis, and usually carries out only one for each.
- Because of separated pairs of analysis and solution generation methods, the problem is analyzed only partially for each TRIZ model. This partialness is the origin of insufficiency in the power of the TRIZ procedure, and requires a complicated sequencing of selected methods.

3. Unified Structured Inventive Thinking (USIT) as a Simple and Unified TRIZ

USIT is a simplified and unified version of TRIZ, having reorganized all the TRIZ methods for problem analysis and solution generation, having constructed a clear full procedure for problem solving, and having a clear scheme of problem solving.

3.1 Main features of USIT

USIT was developed by Ed Sickafus [8] at Ford Motor Co. in 1995 by adopting and enhancing Israeli Systematic Inventive Thinking (SIT), which was a much simplified method of TRIZ developed in early 1980s. USIT has the following features:

- USIT provides a unified and simple procedure for the whole process of problem solving in technology. The process is characterized with three phases, i.e., problem definition, problem analysis, and solution generation phases.
- In the problem definition phase, users are requested to well define a problem with statements of an unwanted effect, the target and task stated in one or two lines, a simple sketch of the problem, plausible root causes, and minimal set of relevant objects.
- The system in problem is analyzed with the basic concepts of objects, attributes, and functions. The current system is analyzed in the functional analysis for clarifying the original intention of the system design and also in the attribute analysis for revealing as much factors relevant to the unwanted effect.
- With the Particles method, i.e., a refined version of Altshuller's SLP modeling, ideal solution is imagined first and is broken down to feasible technical solution concepts.
- Time and space characteristics of the problem are examined.
- Only five solution generation methods are used; they are Pluralization of objects, Dimensional change in attributes, Distribution of functions, Transduction, and Generalization of solution concepts.
- USIT procedure guides the group work of problem solving by stimulating people in unconventional views of the problem, for obtaining multiple conceptual solutions to real industrial problems. USIT does not depend on any handbook, knowledgebase, or software tools.

The present author [3-6] introduced USIT into Japan since 1999 and further refined it. The main features of refinement are:

- All the TRIZ solution generation methods, which are mostly represented in the principles in the TRIZ KBs, are shuffled and reorganized into the USIT solution generation methods.
- Thus USIT has a unified and simple hierarchical system of solution generation methods, expressed in the form of operators. The five principal methods for solution generation in USIT are: (1) Pluralization of objects, (2) Dimensional change in attributes, (3) Distribution of functions, (4) Combination of solution pairs, and (5) Generalization of solutions. There are 32 sub-methods in total, which are expressed in the form of operators with simple guidelines.

3.2 Problem Solving Procedure in USIT

The whole procedure in USIT is expressed in the flowchart [3] as shown in Figure 3. Problem solving in USIT is done in three distinguished phases, i.e., problem definition, problem analysis, and solution generation. In the problem analysis phase, we have three principal methods, i.e., (a) the Function and Attribute Analysis of the current system, (b) the Particles Method for considering an ideal solution first, and (c) Space and Time Characteristics Analysis. Using either (a) or (b) depending on the nature of the problem is all right, but using both (a) and (b) for any problem is highly recommended from recent practices. Sequential use of (a), (c), and (b) is the typical current practice. In the solution generation phase, the five USIT operators are applied repeatedly onto possible operands in the system or in the solution space.

The flowchart representation of USIT has been used since the initial days of USIT development. It is quite natural because the group work of problem solving in USIT is actually conducted in sessions following this flowchart. Typically, Session 1 for the problem definition phase, Sessions 2 and 3 for the problem analysis phase using the methods (a)+(c) and (b), respectively, and Sessions 4 and 5 for the solution generation phase.

3.3 Overall Structure of Problem Solving in USIT

Now let us consider to map the USIT process onto the basic four-box scheme of problem solving shown in Figure 1. It is important to notice that the four boxes represent not the processes (or methods) but the information (or data) and that the arrows represent the processes. Thus we are going to draw, in terms of information science, a 'dataflow diagram' of problem solving in USIT.

This dataflow diagram of the problem solving process in USIT demonstrates (and claims) the following points:

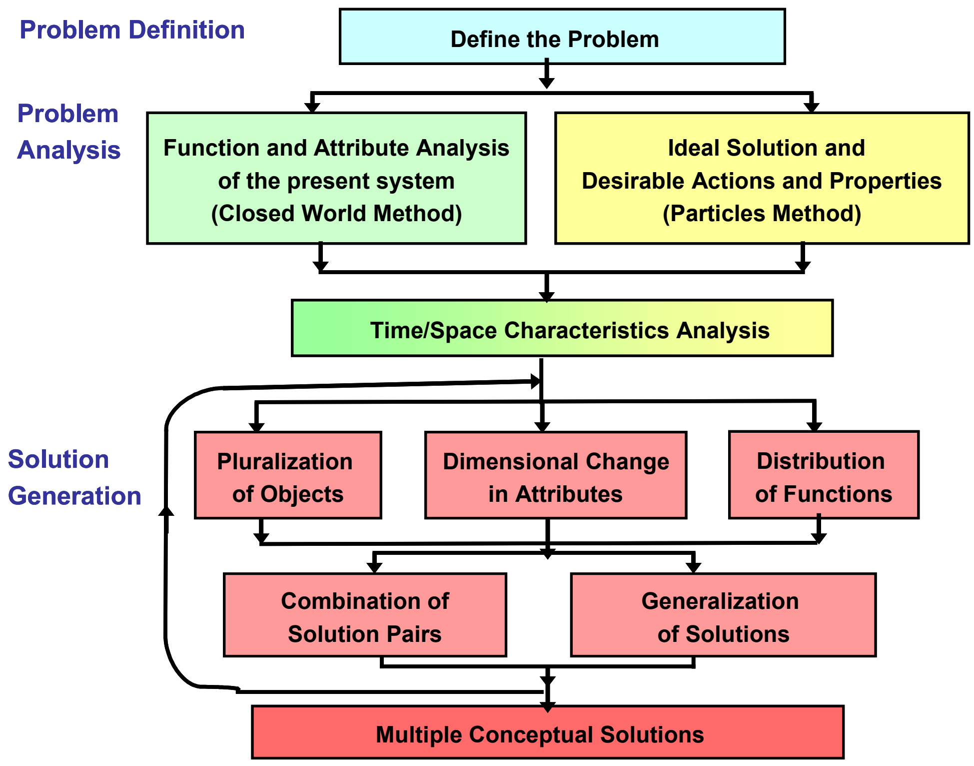

Figure 3. Flowchart of Problem Solving Procedure in USIT

- Abstraction is first performed in the 'problem definition' phase of USIT. A user's specific problem, which is often understood vaguely without a sharp focus by the user him/herself, is converted into a well-defined specific problem having the information stated above.
- Abstraction is further performed in the 'problem analysis' phase of USIT. Understanding of the present system in terms of the basic concepts of objects, attributes, functions, space and time, and also understanding of the ideal system in terms of desirable actions and properties are obtained. The information thus obtained is a generalized problem model (or an abstract problem).
- USIT has the models for problem solving in the forms of 'USIT Operators for Solution Generation'. The guidelines of USIT Operators tell to pick up any possible operands (i.e., objects, attributes, functions, and solutions) in the system/problem and to transform them into modified operands so as to obtain pieces of concepts (or ideas) for a new system.
- Thus, in the solution generation phase of USIT, the USIT solution generation operators convert the operands in the generalized problem model into modified operands which form some parts of concepts in a new system.
- In the solution generation phase of USIT, the pieces of concepts of new system(s) are further built up into conceptual solutions on the basis of background technological capability of problem solvers. This is a part of concretization process.
- The final step of concretization is the implementation of conceptual solutions into user's specific solution(s). This step is usually performed outside the USIT process, by filtering conceptual solutions with technological and business criteria, designing a new system, carrying out experiments, etc.

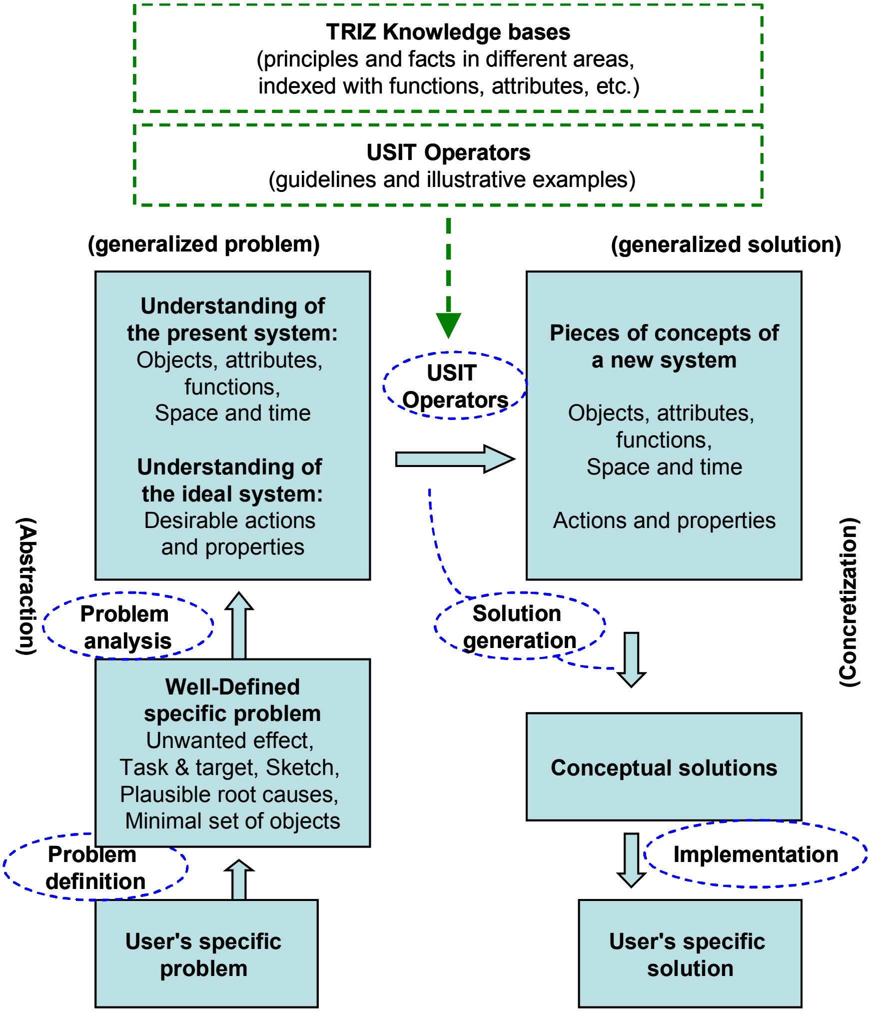

Figure 4. Dataflow Diagram to Show the Overall Structure of Problem Solving in USIT

Since the USIT Operators form the key process in this scheme of creative problem solving, the nature of them is illustrated and discussed some more detail in the following section.

4. USIT Solution Generation Operators

4.1 The hierarchical System of USIT Solution Generation Operators

The USIT Solution Generation Operators [5] form a hierarchical system as shown in Figure 5. There are 5 principal operators which may be further classified into 32 sub-operators in total.

USIT Solution Generation Operators (total 32 sub-operators)

(1) Pluralization of Objects

a. Eliminate
b. Multiply into 2, 3, ..., ∞
c. Divide into 1/2, 1/3, ..., 1/∞
d. Unify
e. Introduce or modify
f. Introduce from the environment.
g. From solid to powder/liquid/gas

(2) Dimensional Change in Attributes

a. Deactivate a harmful attribute
b. Activate a useful attribute
c. Enhance a useful or suppress a harmful attribute
d. Introduce a spatial attribute or vary in space
e. Introduce a temporal attribute or vary in time
f. Change the phase or the inner-structure
g. Attributes at the micro level
h. Properties of the system as a whole

(3) Distribution of Functions

a. Reassign to a different Object
b. Divide the compound Functions and assign them separately
c. Unify multiple Functions
d. Introduce a new Function
e. Vary the Function in space, use space-related Functions.
f. Vary the Function in time.
g. Detection/measurement Function.
h. Enhance adapting/coordination/control
i. With a different physical principle

(4) Combination of Solution Pairs

a. Combine functionally
b. Combine spatially
c. Combine temporally
d. Combine structurally
e. Combine at the principle level.
f. Combine at the super-system level

(5) Generalization of Solutions

a. Generalize/specify
b. Hierarchical system of solutions

Figure 5. The Hierarchical System of USIT Solution Generation Operators

4.2 Illustration of Applying USIT Operators in a Simple Case: Picture Hanging-Kit Problem

Before discussing the nature of the USIT Solution Generation Operators, we better have some illustrative examples in a simple case study [6]. Let me use the Picture Hanging-Kit Problem [8]. Our task is 'To improve the ordinary picture hanging-kit composed of a nail, a string, and two hooks so that the picture is not apt to tilt'. Let us skip the description of the processes of problem definition and problem analysis (see Ref. [8, 3, 6]). As the generalized problem model in this case, we have the following pieces of information among others.

- The equilibrium position (or tilt angle) of the picture frame is determined essentially by the lengths of left and right parts of the string as divided by the nail.
- The functional relationships in the current system may be illustrated in Figure 6.
- When the frame tilts, the string slips on the nail. If the friction between the nail and the string or between the frame and the wall is large enough, the frame may be kept at a non-equilibrium (and possibly the 'straight-up') position temporarily.

- Making the friction between the nail and the string large is desirable for holding the string tightly, but not desirable for adjusting the string (and hence the frame) at first.
- The nail has attributes such as length, diameter, surface smoothness, shape, material, etc.

Focusing on the nail, for example, let us apply various USIT Operators. A part of such application results are demonstrated in Figure 7.

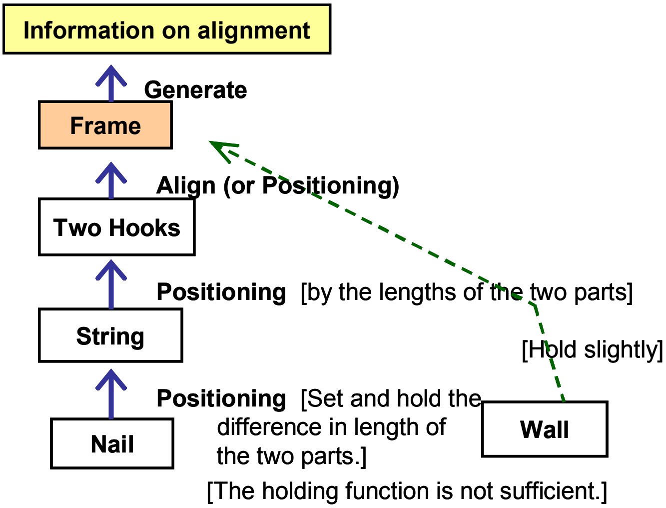

Figure 6. Functional Analysis Diagram for the Picture Hanging-Kit Problem [6]

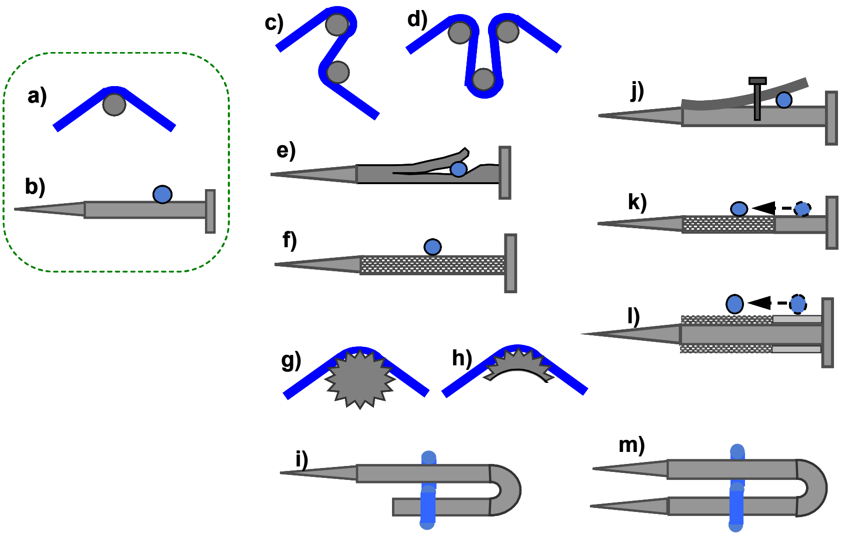

Figure 7. Illustrations of the Results of USIT Operators on the Nail in a Picture Hanging Kit

Figures a) and b) show the original nail with a string. The 'Multiply' operator (1b) is the simplest case of Object Pluralization (1), and gives solutions c) and d) with the intention of increasing the friction. 'Division' (1c) is also a form of Pluralization, and gives an idea shown in e) with the intention of holding the string tightly at the narrow slit. If we want tighter holding function after adjustment, we may attach a screw as shown in j).

The second principal operator advises 'Dimensional Change in Attribute', and f) is a simple response where the smoothness attribute of the nail surface is changed into a much different value, i.e. making the nail surface rough. Since rough surface is not good for adjusting, we have an idea shown in k) where only half of the nail is made rough whereas the other half is left smooth; this guides us the idea of adjusting the string at the smooth part of the nail and holding the string at the rough part. The idea l) is to use a collar having rough and smooth parts around the nail body. The surface of the nail may be changed not just rough but rugged, suggesting to change in the cross-sectional shape as shown in g). Since only the top part of the cross-section is actually used, we may change the cross-sectional shape and size more drastically as shown in h). The operational idea of 'changing shape' of the nail gives us another solution shown in i), which effectively has two nail bodies. When I noticed that the nail i) is apt to be turned by the string tension, the idea of two-footed nail m) came up. This may be regarded as the result of 'Unify' operator (1d) applied on the two nails shown in c).

You may notice in the above explanation that other 3 principal USIT operators have not appeared explicitly. But don't worry. Many of the above solutions are explainable as the results of other USIT operators as well. For example, the idea k) can be explained to have been obtained in different ways as follows:

- Operator (1c): The nail is divided into two parts, and then one part is made rough while the other smooth, and they are used together.
- Operator (2d): The smoothness of the nail surface is changed to be rough and smooth at the two different parts of the nail.
- Operator (3b): The nail's two functions, i.e., to adjust and to hold the string, are divided and assigned to two different parts of the nail.
- Operator (4b): The two opposite ideas of making the nail surface smooth for easier adjustment and of making it rough for tighter holding are combined spatially by using different parts of the nail.
- Operator (4c): The two opposite ideas of making the nail surface smooth for easier adjustment and of making it rough for tighter holding are combined temporally by pushing the string forward to the rough place after the adjustment.

In this manner, different USIT operators sometimes (or often) guide us to the same conceptual ideas. This shows the intended redundancy in the USIT solution generation operators.

For obtaining an idea, these operators may and may not be in mind explicitly beforehand. But it should be noticed that the reflection of any ideas in the general terms of these operators is important for understanding the solutions in its essence. For example, among the five ways of interpreting the idea k), the interpretation with the 'Operator (4c): Combination in time' is found to be most essential in this problem. This operator, in its essence, corresponds to the application of the strategy of Separation in time to a Physical Contradiction, in the orthodox TRIZ terms. Thus recognizing the idea k) in terms of this Operator of 'Combination in time' can lead the user to recognize the Physical Contradiction at the core of this problem and its possible elimination with the Separation in Time. With this understanding, the user will be able to generate many more novel solutions easily.

4.3 Guidelines of the USIT Solution Generation Operators

The USIT Operators for solution generation have their guidelines (i.e., brief instruction accompanied by a schematic diagram) at the 32 sub-operator level and at even more detailed levels. They reflect various TRIZ principles and have been reformulated in a much useful way [4, 5]. By the example, let us discuss about the 'Divide an object' operator (1c) in USIT. This operator has been derived from several TRIZ principles including:

- TRIZ Inventive Principle 1. Segmentation:
  1A. Divide your object into independent parts.
  1B. Divide your object into parts so that some its part can be easily taken away.
  1C. Increase the degree of the object's fragmentation.
- TRIZ Inventive Principle 2. Taking away
  2A. Take away an interfering pat of your object.
  2B. If some property of the object is undesired, find out what part of the object is a carrier of the undesired property and separate it from the object.
- TRIZ Inventive Principles 3. Local quality
  3C. If two functions are to be performed by the same object but this causes problems, divide the object into two parts.
- TRIZ Inventive Principles 15. Dynamicity
  15B. Divide your objects into parts capable of moving relatively each other.
- TRIZ Inventive Standards. 2.2.2 Evolution of SFM.
  Increase the segmentation of the Tool substance.
- TRIZ Inventive Standards. 5.1.2 Introduction of substances under restricted conditions.
  Introduce a new field.

In deriving the USIT guidelines from TRIZ principles, we have chosen the following stand points:

- To use the basic USIT concepts of Objects, Attributes, and Functions in the description.
- To choose a proper level of abstraction consistently, not too abstract and not too specific.
- To describe intentions, conditions of application, applicable cases, specific examples, etc. at the level lower than the guidelines of USIT sub-operators.

Thus the guideline for the USIT Operator (1c) is described as follows:

- USIT (1) Pluralization of Objects
  (1c) Divide the Object (into 1/2, 1/3, ...,1/infinity):
  Divide the Object into multiple parts (1/2, 1/3, ..., 1/infinity),
  modify the parts (slightly, or differently for different parts),
  and combine them for using together in the system.

Some more examples of guidelines in USIT are shown for other four operators which appear in the previous subsection:

- USIT Operator (2d) Introduce a spatial attribute or vary in space: Introduce or enhance an Attribute related to the space, or activate an Attribute (or vary the Attribute's value) depending on different places in space (or different parts of an Object).

- USIT Operator (3b) Divide the compound Functions and assign them separately: Divide the compound/multiple Functions present in the system and reassign the divided Functions to different Objects (already present or newly introduced) or different parts of Objects.
- USIT Operator (4b) Combine spatially:
  Combine multiple solutions in respect to the spatial positions to apply; for instance, at different places (for avoiding the mutual interference), at distributed places, side by side, in front and back (in sequence), on top and bottom, at the same place alternatively, inside of the other, as an inner-structure of the other, etc.
- USITOperator(4c)Combinetemporally:
  Combine multiple solutions in respect to time to apply; for instance, in sequence (one after another), beforehand of the other, simultaneously (in parallel), afterwards of the other, in the reverse order, alternatively, in pulses, periodically, from time to time, interrupting/switching corresponding to the situations, etc.

From these examples of guidelines in USIT, I hope the readers understand that a number of TRIZ principles (including Inventive Principles, Inventive Standard, Trends of Evolution, etc.) are smoothly unified in these USIT Operators, and that the solution examples shown above are easily obtainable by applying these USIT Operator guidelines.

Usefulness and intended redundancy of USIT Operators are based on the USIT concepts of Objects, Attributes, and Functions. The USIT Operators on Objects (as shown in case of (1c)) take some Objects as the operand, apply the specified operation on the Objects, and then further apply modifications onto Attributes and Functions of the operand Objects according to the guideline descriptions. Situations are similar in the USIT Operators on Attributes and on Functions. This type of extension in the USIT guideline descriptions guides the problem solver in a way easier to follow than most TRIZ principles. At the same time, the mentioning of Objects, Attributes, and Functions in each guideline description is the source of intended redundancy, i.e. overlapping, of the USIT Operators.

4.4 Experiences of Teaching and Applying USIT

Experiences of teaching and applying USIT in Japan have been reported in [3, 6]. A lecture of 2 hours can cover the overview of TRIZ and USIT. Typically, two-day USIT training seminar is held in a company with 15-25 participants of engineers. After the overview lecture, 3 real industrial problems are brought in by the participants and are tried to solve in parallel group practice following the USIT procedure. 5 sessions are carried out, where each session is composed of a short lecture of the process, parallel group practice, and presentation & discussion. Usually each group generates 20 to 40 ideas which may be further concentrated into several conceptual solutions worthy of further consideration for implementation. Thus engineers, who were novice of TRIZ/USIT, can have the experience of solving an industrial problem with USIT by themselves, and can understand the full USIT procedure with 3 real case studies. This shows the easiness and effectiveness of learning USIT in comparison with learning TRIZ.

5. Concluding Remarks

In the basic four-box scheme of problem solving, generalized models of TRIZ (and many other scientific/technological theories) are expressed by the generalized problems and their corresponding generalized solutions, and are supposed to be used with analogical thinking. Abstraction is for mapping the user's specific problem to the generalized one in the model, while concretization is for mapping backwards. These mapping processes, however, are often not well explained in the procedural manner.

The present paper proposes a different scheme of problem solving, as summarized in Figure 8.

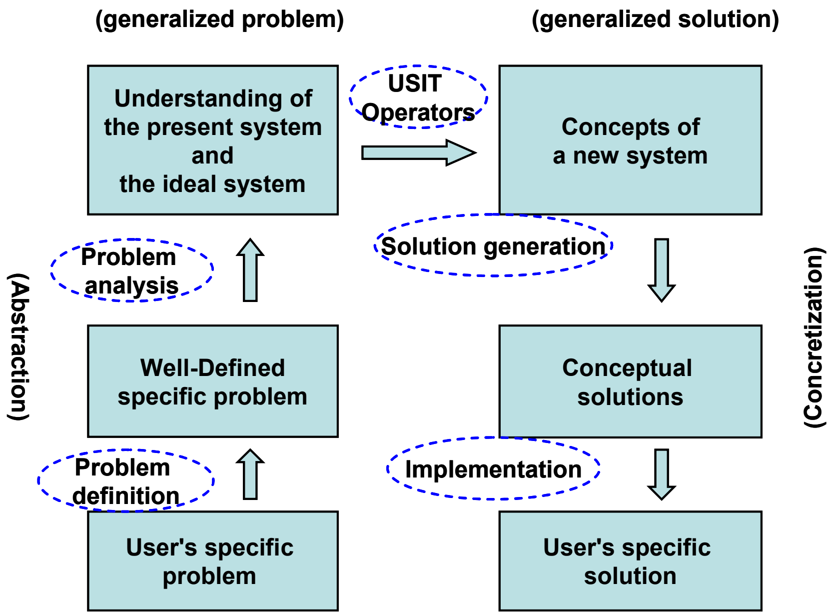

Figure 8. Scheme of Problem Solving in USIT Using the USIT Solution Generation Operators

Abstraction is done in two steps; the problem definition step converts the user's specific but often vague problem into a well defined specific problem and the problem analysis step converts it further into the abstract understanding of the current and ideal systems. This abstract understanding of the system is expressed in the basic terms of objects, attributes, functions, space, time, desirable actions, and desirable properties, etc. and is in place of the generalized problem of the four-box scheme. Then the Solution Generation Operators in USIT transform the elements of the abstract system into modified elements of a new solution system; this is the key step in the whole problem solving. Then conceptual solutions are formed on the basis of technological thinking, and finally user's specific solutions may be designed in technology.

It should be noticed that the vagueness in the analogical thinking disappear in the new scheme. Knowledge expressed in the 'Models' in TRIZ (and problem solving methods in general) has been concentrated into the USIT Operators. And hence all the procedures of creative problem solving are now expressed in much clearer terms and procedures.

This unification and simplification of TRIZ can help people understand TRIZ more easily and widely and apply TRIZ to their real problems, as demonstrated earlier.

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MAPPING THE INNOVATION SPACE ONE: NOVEL TOOLS FOR PROBLEM DEFINITION IN PRODUCT INNOVATION

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Abstract
The following article introduces and describes two novel problem definition tools. The tools include the Concurrent Problem Definition Tool, and the Innovation Hurdle Filter System. The rationale behind the development of these tools is discussed.

1. Introduction

According to Romelaer (2000) the innovation process interacts with numerous contexts and must be framed within these contexts. The various actions of which the innovation process is composed must be co-ordinated with each other. The firm must have competence and resources for each of the actions of which the innovation process is composed.

To do this they need to have at their disposal innovative methodologies that enable them to interact and learn from both within the system in which they operate and also from external factors such as technological, organisational, social, environmental, and intellectual influences.. In effect organisations need to manage technical and economic environments. Padrao (2002) suggests that successful innovations are linked to commercial value. Consequently any innovation activity must ultimately lead to economic success.

2.The Move Towards Systemisation

One of the key tenets to an organisations success lies in the development of a total systematic approach. According to Elfving et al., (2003:1) 'success in manufacturing requires continuous development and improvement of how products are developed and produced. There is a need for new methods, tools and procedures to improve product development especially due to increased complexity and amount of relations between different actors.' One of the main drivers in this 'Innovation Age', is the identification of future consumer needs and demands supported by innovative tools. To maintain this 'innovation advantage' organisations implement a number of methods such as concurrent engineering, axiomatic design, value engineering, QFD, DFM and TRIZ.

3. The Importance of Problem Definition

Problems experienced at the micro level can be the result of improper problem definition at the macro level (Figure 1). Improper consumer product definition at the macro level can often lead to product failure, even though the product has met the technological criteria required. For example a product which is technologically sound can fail at the consumer (macro) level because it has been designed for minimum handling rather that frequent handling through the value chain. This highlights the overriding importance of 'rigorous' problem definition well in advance of product development and commercialisation. The meso level is the enabling link between the micro and the macro levels to help sustain competitiveness.

In TRIZ a ‘problem’ can be technical or managerial, simple or complex, a need for innovation, an opportunity or a perceived need for something to happen. These are expressed in terms of a problem definition. For example, the need for a more comfortable chair is inherently a consumer need. Within the TRIZ approach, however, a more comfortable chair is both a technical problem and a market opportunity.

Essentially problem definition tools need to combine both the technical and consumer aspects of innovation. Consequently the innovation process can be enhanced by interfacing existing innovation philosophies to create a more robust problem definition methodology.

Macro Level	The Market, Usage, Organisational Structure, Environment, Social, Political
Meso Level	Competitiveness, Education, Research, Technology Policy
Micro Level	Technology, Product Development, Process

Figure 1. Elements of Macro and Micro Levels

The problem definition phase is a central activity in the innovation process. In the context of problem definition information is analysed to define the most likely ‘cause of a problem’ or to ‘derive a solution’. Information needs to be gathered in a systematic manner prior to formulating a problem statement. The information gathered is critical and central to helping define the problem, diagnosing and providing an accurate and faster solution to the problem. Moreover, both the problem definition and information gathering should be used simultaneously in order to achieve an accurate resolution.

Once sufficient information is gathered, a problem statement can be created to define the problem in a specific, concise, and accurate manner. The development of a robust problem statement makes it easier to focus and give clarity to the problem and eliminates the risk of solving problems that do not fall within the scope of the problem definition phase.

4. Rationale for a Concurrent Problem Definition Tool

Generally the process for solving a problem will consist of a sequence or structure that fits together in order to ensure nothing is overlooked. Concurrent engineering philosophy is based on the integration of the engineering, marketing and the voice of the consumer. Proulx (1996) suggests that CE is a 'systematic and multidisciplinary approach that simultaneously integrates the different phases of product development and the management of its processes. These processes include the identification of customer needs, specification of product performance requirements, design of the product, manufacturing processes and fabrication of the product, while considering the entire product life cycle, including distribution, support, maintenance, recycling or disposal'. Fundamentally, the key philosophy behind concurrent engineering is the integration of both productionisation and commercialisation concerns in order to achieve a successful product innovation.

In CE projects the voices of both internal and external customers are captured and converted into specific predictable and measurable product characteristics (Hales,1993). Any successful problem definition tool needs to be capable of mapping both the technical and consumer innovation space (Figure 2).

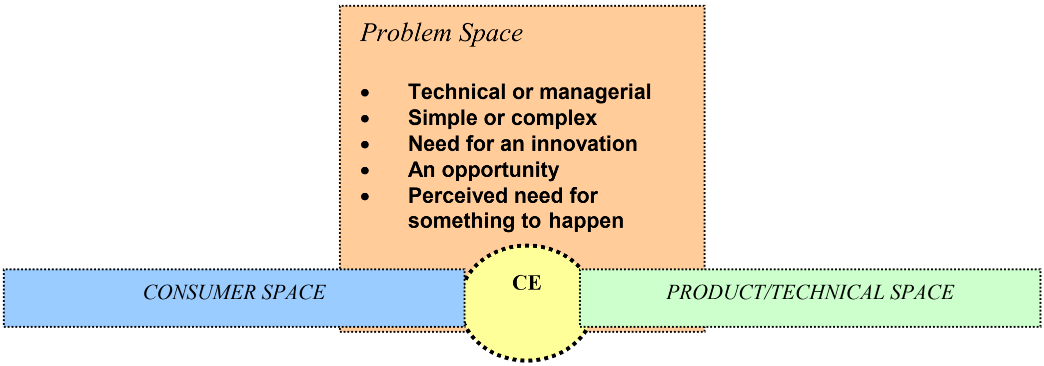

Figure 2. Concurrent Nature of the Consumer and Technical Problem Space.
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5. Description of the Concurrent Problem Definition Tool

The concurrent problem definition tool (CPDT) maps both the product and consumer space. It focuses on both the positive and negative aspects of the consumer and product. This process is carried out in order to ensure that the generic problem is mapped and defined in more specific terms.

The roadmap for utilising the CPDT is described below:

STEP 1

- State problem and enter into the CPDT problem space.

STEP 2

Map the Consumer Space

- Map from a consumer viewpoint. This should include needs and perceptions.

- Map from a generic to numerous more specific definitions.
- Use ‘because’ as a means to question consumer needs.
- Map both negative and positive aspects from the consumer view point.
- Phrase in ‘wants’ and ‘doesn’t want’ terminologies.

STEP 3

Map Product Space

- Map from a product view-point. This should include such factors as materials, shape, colour, ergonomics system, sub-systems.
- Select a product benchmark. The product may ‘be your own’ or a competitors product. It could also represent ‘best in class’.
- Map from one generic to numerous more specific definitions.
- Use ‘because’ as a means to question technical requirements.
- Map both positive and negative aspects from a technological perspective.
- Phrase in ‘is’ and ‘isn’t’ terminologies.

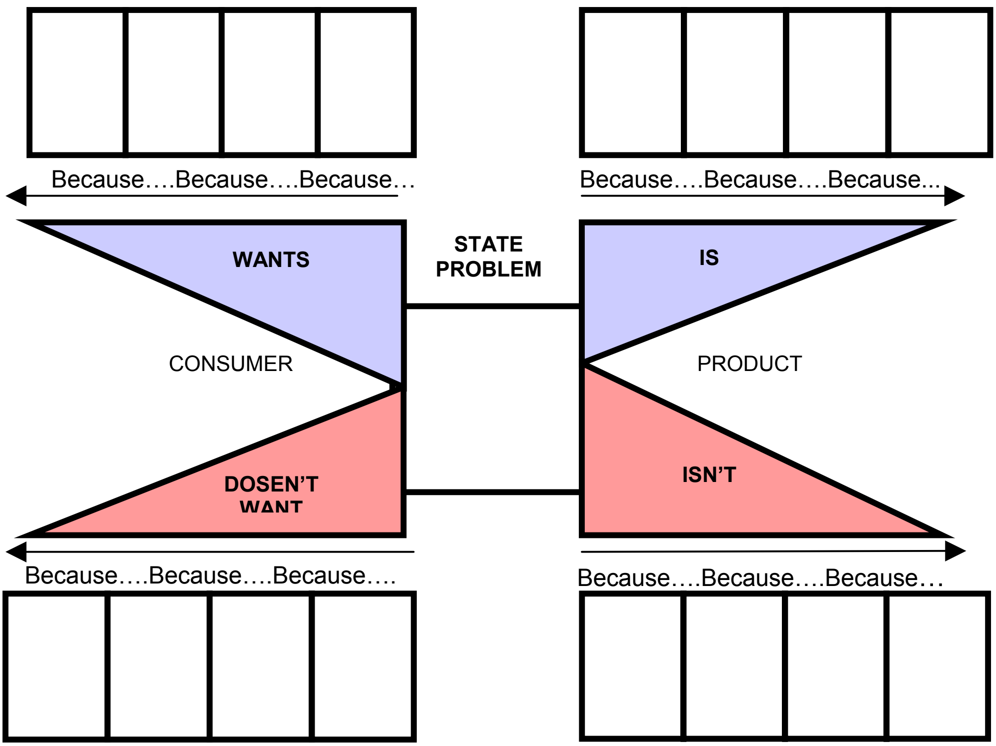

Figure 3. Concurrent Problem Definition Schema.
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6. Barriers and Obstacles to Innovation

Braadland et al (2001) identify a number of innovation barriers for different industry groups. These include economic risk, high costs, finance, organisational rigidities, lack of qualified personnel, lack of IT, lack of market information, regulations, standards and customer responsiveness. It is essential whilst carrying out problem definition analysis that these type of generic obstacles or hurdles to innovation are properly identified and mapped in order to maintain a realistic perspective on what is achievable. Workshops carried out by the authors identified that people engaging in problem analysis have a tendency to under estimate the importance of identifying the innovation hurdles that need to be overcome in order to arrive at a solution for a specified problem. In this regard they tended to adopt the traditional unsystematic brainstorming approach, which is good for creative thought but not for focusing on innovation within constraints.

7. Description of the Innovation Hurdle Filter System

The Innovation Hurdle Filter System (Figure 4) is used to map identified barriers and hurdles within the system. Innovation hurdles can be technological: organisational; political; social (personal, consumer); environmental or informational.

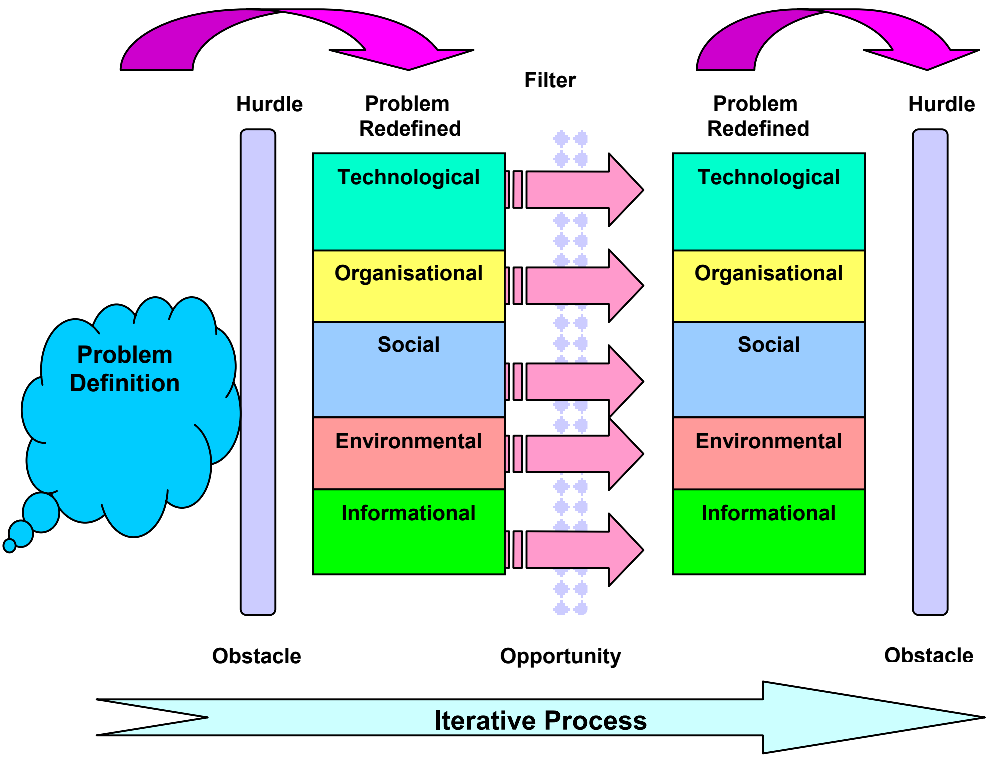

Figure 4. Innovation Hurdle/Filter Schema
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Furthermore, an organisation may experience hurdles that affect: incentives for innovation such as short compliance timeframes: sensitivity to incentives for example, culture of compliance; idea formation such as employees do not appreciate benefits of innovation; implementation for example product quality concerns (Scott et al., 1998).

The hurdles mapped can then be analysed and filtered as to their potential impact on the implementation of identified solutions. The system also enables us to identify the hurdles that do not have an impact on the implementation of identified solutions. The first step in using the Hurdle Filter System is to extract one of the identified specific problems from the Concurrent Problem Definition tool. This specific problem is then entered into the Innovation Hurdle/Filter pro forma.

It is recommended that a small cross functional group from different disciplines carry out this phase of the problem definition process. This will ensure the cross fertilisation of ideas and functions.

The group should focus on applying innovation hurdles to the problem definition. This should enable the team to eliminate those hurdles that are not relevant to further defining the problem space. It should also enable suggestions made by the team members to be eliminated or selected for filtering to the next phase of the problem definition process. This is an iterative process which when exhausted will enable the team to better quantify and identify the problem space

For each hurdle the 5W and 1 H questioning process should be applied in a systematic manner:

1. What is the specific nature of the hurdle?
2. Why does this hurdle exist?
3. Where does the hurdle occur?
4. Who is causing the hurdle?
5. How can this hurdle be overcome?
6. When can we overcome this hurdle?

8. Future Work

The tools described represent part of a suite of novel mapping tools that can be utilised in better defining the innovation space. Further articles will build on this suite of tools and describe their application to actual case studies.

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TRIZ EDUCATION

CASE STUDIES OF TRIZ APPLICATION IN THE DIPLOMA THESIS IN TECHNICAL UNIVERSITIES CZECH REPUBLIC

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Abstract
TRIZ method is taught on Technical Universities in Czech Republic more than 10 years. The efficiency of an engineer's work depends not only on his particular knowledge of his specific field, but also it will depend more on his methodological capacity and ability to think creatively. Thus, the courses of creative technical thinking are being introduced into the process of education as a preparation for creative solution of technical problems that arise in the course of professional life or imply from research and development. The development of creative technical thinking prepares the students better for professional career. Currently, TRIZ is the most complete method of education in this field, which is also being trained on many schools and research facilities around the world. Suitable term of TRIZ application are periods of processing diploma thesis, when student knows all information about a problem and can compare output of the problem solutions using classical methods with output of the problem solutions using TRIZ method. Case study of TRIZ application in diploma thesis will be presented in this article.
Keywords: TRIZ application, Case studies, Technical University, Diploma thesis, Technical system, Contradiction.

1. Introduction

The methods of creative technical thinking have been lectured to students in the Czech Republic mainly at TU Liberec and VUT Brno for more than 10 years. The attention has been focused especially on the TRIZ methodology. A lot of experiences have been gained for this period of time with application of the methodology in the lectures as well as with solving design project and students' diploma thesis, and also partly with applications in innovative technologies of companies.

Students in their final year of their studies at a technical university have passed most of the special courses and, theoretically, they should be able to solve technical problems arising from the real life. However, their first real technical problem, solved within the framework of a semestral design project or their final diploma thesis, is not easy for them to be solved. Most of the students reach a result, which corresponds to usually chosen standard solution procedures. Students have met these standard procedures in the course of their specific field studies. However, we must be thankful at least for these standard results if they are reached.

Within the framework of the optional course „Theory of Creative Thinking“ the students can meet some methods that support creative thinking, help the students to overcome usual stereotypes in reasoning and to solve given tasks as well. They get in touch mostly with the TRIZ method, which is considered by the lecturers as a dominating one among the other methodologies.

While solving an design project and later in the process of solving their diploma thesis students verify particular methods, individual analytical and solving tools of the TRIZ methodology, assess various possible solutions and in many cases propose new concepts of solutions. This brings the students strong heuristic and formative experience from their own creativeness**.**

This article is not able to and even cannot demonstrate the TRIZ methodology in its depth, but only mentions some of the basic elements of the TRIZ method and shows, in a very compressed way, using the methodology while solving a few cases from the students‘ semestral design project and diploma thesis.

2. A bit of theory will kill nobody

It is important that a student should be able analyze given problem situation which is unclear from the beginning. He/she should know how to define the problem system and its important functions and formulate specific typical tasks in the problem. Thus, the target of the above mentioned course is, among others, to teach students understand and use basic terms defined by the TRIZ methodology. Among these terms belong:

- technical system (TS),
- function ,
- trends of technical evolutions,
- technical contradiction (TC) and recommended principles for its solution,
- localization of sources of substances and fields,
- ideal solution (IS/IFR),
- physical contradiction (FC) and recommended separations for its solution,
- S-Field Analysis and recommended models for its solution.

At first, students learn to recognize these terms during the lectures that include presented demonstration cases. Then, they try to apply them on solved cases in the seminars. Finally, students**,** more or less independently, apply these terms while solving their own small project, semestral design project or even diploma thesis.

3. Cases, cases, cases, ... those are TRIZ advantages

The following cases always describe initial problem concept (a) and then subjectively new student conceptions of solution (b,c) using standard or TRIZ methodology.

3.1. Example 1: Hardening by UV lamp during glueing of glass in cold [4]

TS: technical system consists of a transporter, a chamber with UV lamp
Function of TS: harden the joints of glass products glued with transparent glue
Problem: the staff is exposed to UV radiation from the UV lamp

Standard concept of solution: *shading of the chamber by closing equipment* – see Fig. 1a.

While using the TRIZ methodology the following *contradiction* was defined.
TC**:** not to expose the staff by the UV radiation from the UV lamp located in the chamber it is provided shading of the tunnel by a closing equipment, but it increases system complexity
IS: the system itself should be protecting the staff against the radiation.
It is necessary to find a source in the system, which can protect.
FC**:** entrance into the chamber has to be covered so that the UV radiation does not expose the staff and entrance into the chamber has not to be covered so that the products can freely move into the chamber. To be more concrete the entrance into the chamber has to be free for the products and at the same time it cannot let the UV radiation through.
Solution: a simple movable shading near the UV lamp should be provided.
The solution is very simple, practically ideal with a minimal change in the TS – see Fig. 1b.

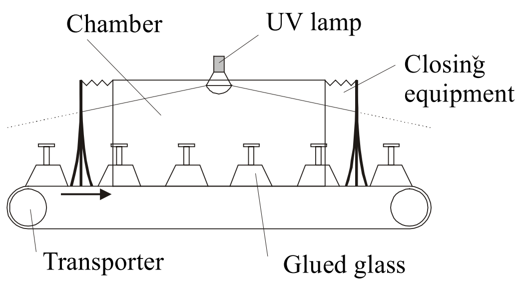


Fig. 1a

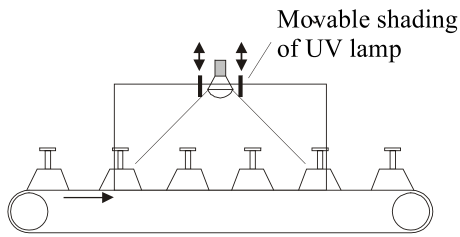


Fig. 1b

4. S-Field analysis

S-Field analysis is another methodology tool suitable for precise defining the model of the problem core and for finding possible ways of model solution. The tool is suitable especially for solving of problems in is necessary to change (strengthen, weaken, cancel) action between two conflicting substances located inside of the operational zone and within the operational time of the conflict.

4.1. Example 2: Moving of glasses to be centered in finishing operation [5]
TS: technical system consists a rotating table, a glass on the table, mechanical force for moving
Function of TS: to move of glasses to be centered on the table in finishing operation
Problem: how effectively moves glass to the axis of the table?
Standard concept of solution: to find a proper material for the surface of the rotating table. It should be compromise between smooth surface (small friction) and rough surface (glasses do not slip) – see Fig. 3a. (commonly graphite is used).
To bring this problem to the FC it becomes more contradicting.
FC: the surface has to be smooth in the moment of moving so that the friction is minimal and it has to be rough so that the glasses do not move
We use *S-Field analysis* looking for solution in this case
Model of conflicting pair: surface of table and bottom of the glass. Moving creates a contradicting situation between the surface of the table and the bottom of the glass. The

surface of the table (L1) insufficiently or badly acts on the bottom of the glass (L2). The S-Field analysis recommends several solving models **(**suggests that there is missing a field (mediator) to complete the function of a minimal system), for example**:** to add a mediator.
Solution**:** If we add substance mediator (for instance air – L3 with controllable pressure field – P) we can get a better controllable system – see Fig. 2. Air is near-by ideal substance. (and is always available from resources)

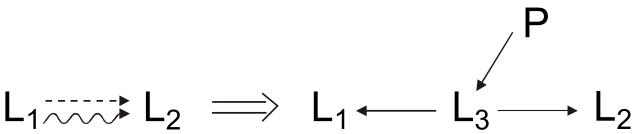
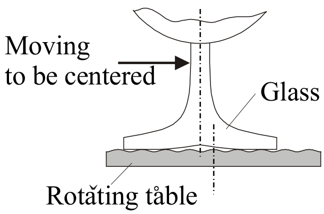
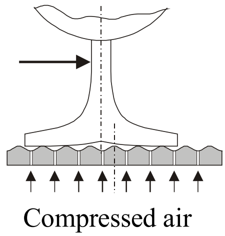


Fig. 2

The air field can be pressure (the roughness is smaller while moving) – see Fig. 3b or underpressure (the glass does not move) see Fig. 3c. Moving the system is more dynamic and more adjustable to the external conditions.





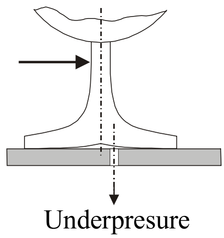


Fig. 3a **Fig. 3b** **Fig. 3c**

5. Ideal solution

Ideal solution does not exist in technology but it is useful to know in which direction can be found this inaccessible point. Within this direction it is recommended to go and *find* real solutions that are more ideal than existing ones. The axiom of ideality within the framework of the TRIZ methodology is applied onto TS, its functions, and its substances as well as for solving of contradictions.

For instance, the ideal TS should fulfill functions but it should not exist. The function should be accomplished with minimal costs. Similar, a contradiction in TS should be solved/overcome especially due to using own resources of the TS *itself*. The keyword is ITSELF, which is significant for a direction towards the ideal solution.

If a student understands the content of the axiom of ideality and its practical effect then he/she gains a powerful tool for evaluation of advantages and lacks of existing technology as well as a directive tool for finding perspective technical solutions because he is able to eliminate no-perspective, complicated and ineffective directions way in advance. Of course, gaining of such a tool is connected with serious work of the lecturer as well as the student.

5.1. Example3: Hand feeding of molten glass with a blowpipe from a pot furnace [6]
TS consisting of a pot furnace, molten glass and a blowpipe
Function of TS: hand feeding of molten glass by blowpipe from the bottom of pot
Problem: during the process of hand feeding of molten glass a problem often arises from the situation that it is not possible to feed the rest of molten glass from the very bottom of the pot. It is caused by a limited entrance into the pot furnace – see Fig. 4.
Standard solution: various solutions were designed especially concerning lowering the pot, changes entrance into the pot furnace and creating a modified blowpipe with joint. However, these solutions are technically and economically ineffective.
For better understanding of the problem the *contradiction* can be defined as follows:
TC : blowpipe with a joint enables hand feeding the rest of the molten glass from the bottom of the pot (see Fig. 4a), but makes the realization of the TS more complicated (design, price).
IS : the blowpipe needs to be preserved but it is necessary to feed the molten glass to the very bottom. The system itself must provide the feeding of the molten glass to very bottom. A word ITSELF leads to a finding the ideal solution. With minimal changes of the technical system (in ideal case with no changes) fulfilling of the function should be reached. It is necessary to use sources within the system that are in hand to be used. To reach an ideal solution we have to overcome a contradiction, which can be formulated between parts of the system.
FC**:** the front side of the pot must exist so that the molten glass does not go away from the pot and the front side of the pot have not exist that should enable the blowpipe to feed the molten glass from the very bottom. This definition, even though it seems very absurd, enables us to better understand the problem and find the best solution.

Solution: *The contradiction can be overcome by a simple transformation. In the moment when the pot is full the front side of the pot must be vertical so that the molten glass does not go away and in the moment of feeding from the bottom the front side of the pot must be inclined so that the pipe can reach the bottom and the rest of the molten glass should still stay in the pot. To solve this problem the pot must be inclined. This inclination should be provided by the system itself. It means that the inclination must be provided by an element, which is a part of the system. This element must change in time. Changing element in time will provide the inclination by itself. This element is a changing amount of the molten glass.*
Technical idea – see Fig. 4b. The center of gravity T1 of the full pot 1 is located in front of the edge of inclination of the pot. If the amount of the molten glass decrease the center of gravity T2 moves behind the edge of inclination and causes inclination of the pot into the position 2. This can be reached by increasing the weight of the front side of the melting pot. By inclining of the pot the rest of the molten glass becomes available for the blowpipe.
This solution fulfils the law of increasing the degree of ideality of the TS when fulfilling of the function (feeding of the molten glass to the very bottom) is reached *itself* without any significant changes.

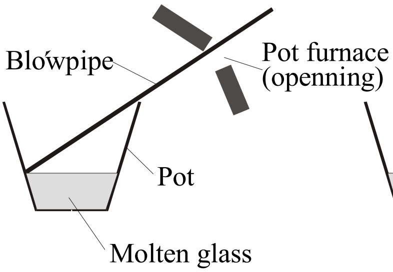


Fig. 4

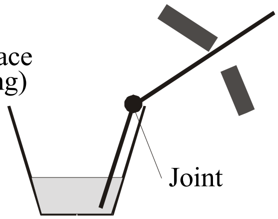


Fig. 4a

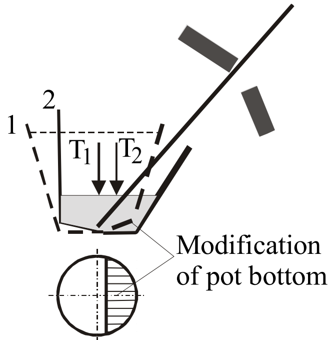


Fig. 4b

6. Support of the TRIZ lectures

Methodical references [1], [2], [3], [7] have been prepared for the students as well as for the lecturers. A great amount of additional texts suitable for studying can be found on the Internet. Students use software support for the TRIZ methodology created by IMCorp. after acquiring basics of the method.

The ability of a student to apply newly gained recommendations for solving a concrete technical problem depends on his ability of creative thinking. The software does not replace the ability to think but it is rather a tool which helps to focus and concentrate while analyzing a problem and also inspire the synthetic creative technical thinking.

7. Conclusion

The class work within the framework of optional courses „Theory of Creative Thinking“ consists of lectures, seminars and small solved projects. The lectures are definitely conducted as problem based. It means after short theoretical explanations some of cases are included.

It has been proved during the lectures that the attention should be concentrated only to some methods and also only to a few essential elements of the creative method that change the traditional thinking in the greatest way. These elements are desirable to be repeated in various cases. In the TRIZ methodology these elements are especially analytical steps, terms of TS, Function, TC, sources, operational time and zone, IS, FC and SA as it is demonstrated in this text.

A repetition is necessary especially because of that the students as well as engineers in companies need to inventive experience passion on many various cases to understand the essential partial conclusion that a progress procedure towards a creative solution is relatively the same (methodically), only the technical facts are always different, but the result may be very inventive, creative, new, surprising and thus formative.

It is effective during the lectures and seminars to use cases from the very close surrounding of a man and try to improve things that students use in everyday life (keys, glasses, thermometer etc.) Cases are desirable to be changed every semester. This puts a heavy demand on the lecturer. It is suitable to use cases from practical life of the lecturer so that the lecturer can answer every question about the problem. Using the software tool for the support of any method is effective only after acquiring the basics of the methodology. It is similar to a tool of Stradivari, which produces the quality only in hands of those who know the melody.

During the seminars the school cases are discussed first and then students solve given open practical problems. From the view of acquiring the methodology the most effective way seems to be independent solving of small projects, semestral design project and final diploma thesis in case these contains open technical problems and students have sufficient amount of required knowledge. Then students must prove independent analytical and synthetical work.

The authors do not suffer from illusions that all students are prepared and willing to devote spare time to inventive activity (passion) and prepare themselves to future innovative solutions. For more than 10 years of lecturing „ The Methods of Creative Technical Thinking" it has been agreed upon a fact, that aprox. 10 – 20 % of the students are willing and able to conquer untraditional creative solutions.

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TRAINING COURSE SUPPORT: FOSTERING METHODICAL PRODUCT- AND PROCESS-DEVELOPMENT BY COMBINING TRIZ-TOOLS AND SUSTAINABLE DEVELOPMENT

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Abstract
Strengthening innovation power in European companies as well as encouraging sustainable development are two of the main future goals of the EU (see Lisbon goals, European Council 2000).
The training course SUPPORT has been developed in the framework of the European Leonardo da Vinci programme and shows companies different ways to build up several parts of an environmentally sound innovation management system.
The approach combines "cleaner production" tools with tools of the TRIZ method which form the main part of the training course. To complete the course programme it has been complemented with tools for the assessment of ideas in respect of their environmental compatibility.
This paper deals with the course targets, the target groups, the project partnership for the elaboration of the course manuals, the modular structure of the course, the course materials (project products) and the contents of the individual course modules.
Furthermore, the paper gives a first short description of experiences made during the test training courses and presents current ideas for the further development of the training course and its further distribution at an European level.
Keywords: Training, EU-Project, Innovation, TRIZ, Sustainable Development, Creativity

1. Introduction

Innovation is one of the most strained words in companies and society. It is mostly associated with the topic product development (new products rsp. constitutive product improvements) and thus with creative processes as well.

Another keyword gaining more and more strength in enterprises is the direction of the corporate strategy towards economic design of products and services. The holistic consideration of these ideas is strongly connected with the notion of sustainable development, in both, a political and a scientific way.

Subject of the SUPPORT-project was to methodically support these two main topics of a modern company: innovation and ecological awareness.

As in most enterprises there are no structured documents available for these phases, especially the early phases of problem handling (which are problem analysis, generation of ideas, evaluation of ideas) take a major role when considering innovations.

The tools considered in this course almost all originate from the TRIZ-methodology. This methodology has perfectly proved itself in numerous major enterprises and offers new rudiments for designing creativity and analysis tools which are interesting for operational use.

The topic ecological awareness will be worked out through the presentation of successful and established tools out of projects for cleaner production. Furthermore the economic benefits for single enterprises as well as macroeconomic impacts of a sustainable economic system will be taken into consideration.

2. The Project SUPPORT

Grants: The Project SUPPORT was granted and co-financed by the Leonardo da Vinci programme. The European initiative Leonardo da Vinci is the profession support programme of the European Union. Within the scope of this measure, the EU supports the development, testing and dissemination of new learning contents and materials.

Partnership: The Project was executed in a project partnership composed of 16 project partners out of 6 European countries. The project started at the end of 2002 with a duration of 24 months.

The following project partners were involved in the development of the course:

- University of Leoben, Austria
- Joanneum Research, Graz, Austria
- CREAX, Ieper, Belgium
- Fraunhofer IPT, Aachen, Germany
- AREA Science Park, Triest, Italy
- University of Maribor, Slovenia

The project comprised the development, testing, and dissemination of the project idea and results.

3. The course goals and targets groups

The most important goals of (the training course) SUPPORT are:

- To highlight the advantages of a methodical approach to innovations
- To convey new tools for problem analysis and idea generation.
- To anchor the ideas concerning sustainable development
- To arouse interest for creative methods (with emphasis on TRIZ)

The main target groups are enterprises with (entrepreneurs, who have got) their own production plants and R&D departments. The course is designed to help these companies to improve the cooperation between innovative (R&D) and environmental departments (environmental or generic management). Additionally, the course aims at students or potential start-ups.

4. The products and the course structure

The main products of SUPPORT are:

- Written materials and CD-ROMs for the course participants
- Presentation materials for the course trainers and

- Videos (sequences) of the whole project and its individual modules

All written materials are available in English and German.

In addition to that the participants are given other dissemination materials and can consult on the project's homepage → www.leonardo-support.com.

SUPPORT currently consists of seven modules:

1. Introduction module: Innovation / creativity & sustainable development
2. Aspects of Cleaner Production for products and processes
3. TRIZ- tools for problem analysis
4. TRIZ- tools for idea generation I
5. TRIZ – tools for idea generation II
6. Tools for idea evaluation
7. Project Management Tools

The modules can either be taken individually (one module a day) or combined to form a whole training course.

5. Overview of the contents of each module

5.1 Introduction Module 1: Innovation / Creativity & Sustainable Development

The introduction module is divided into two half a day seminars given a short and precise overview of the topics innovation / creativity on one hand and of the meaning and goals of sustainable development on the other hand.

In the first short introduction

- the terms innovation and creativity
- the phases of product development or rather the "innovation process"
- the individual demands in the creative process
  (the 4 roles: explorer – artist- judge – warrior) -> Figure 1
- the possible contribution of the Theory of Inventive Problem Solving – TRIZ – within the scope of a product innovation strategy of a company
- an allocation of terms / tools of the course modules to the creative roles

are examined and illustrated.

Figure 1. The 4 Creative roles (Roger von Oech, 1986)

In his books Roger von Oech suggests that in an creative process all 4 roles have to be supported.

1 – The explorer, who searches for interesting and useful details → analysis

2 – The artist, who sees connections where others do not → development of ideas

3 – The judge, who discards, balances up and makes decisions → evaluation and choice

4 – The warrior, who has the temperament of a lion and who never rests → realisation

During this module it is noted which suggestions and tools are offered by SUPPORT regarding all these roles.

The goal of the second introduction part is to introduce the participants to the fundamental physical laws of sustainability, and, building on this, to show that sustainable development is an imperative of nature and that no other form of development is possible in the long-term.

A look at the history of industrial environmental protection shows that Innovation (rethinking) is needed as a next level of environmental protection (Figure 2).

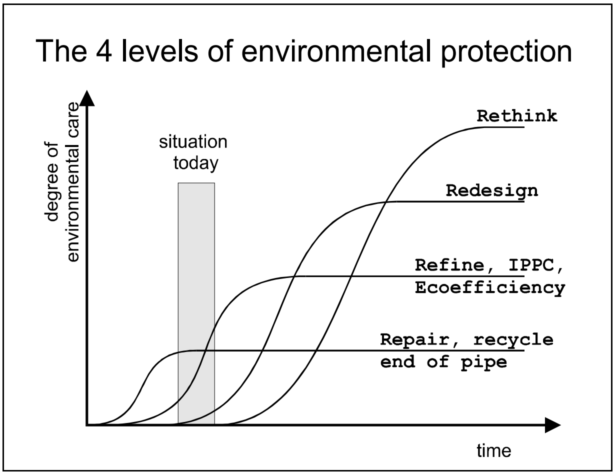


Figure 2. The 4 level of environmental protection

5.2 Module 2: Aspects of Cleaner Production for products and processes

The objectives of the second module is to answer the question, what does the requirement „sustainability" mean for product development and producing enterprises and show the participants simple tools for the acquisition of economic impacts.

The presented tools for cleaner production are the input/output analysis, material flow analysis (Sankey diagrams) and material flow accounting.

Using material flow analysis – for example – give a comparison with the best available technique and can show the weak points of the current production process. (Figure 3) The material flow analysis also provides information on costs of manufacturing of wastes and emissions.

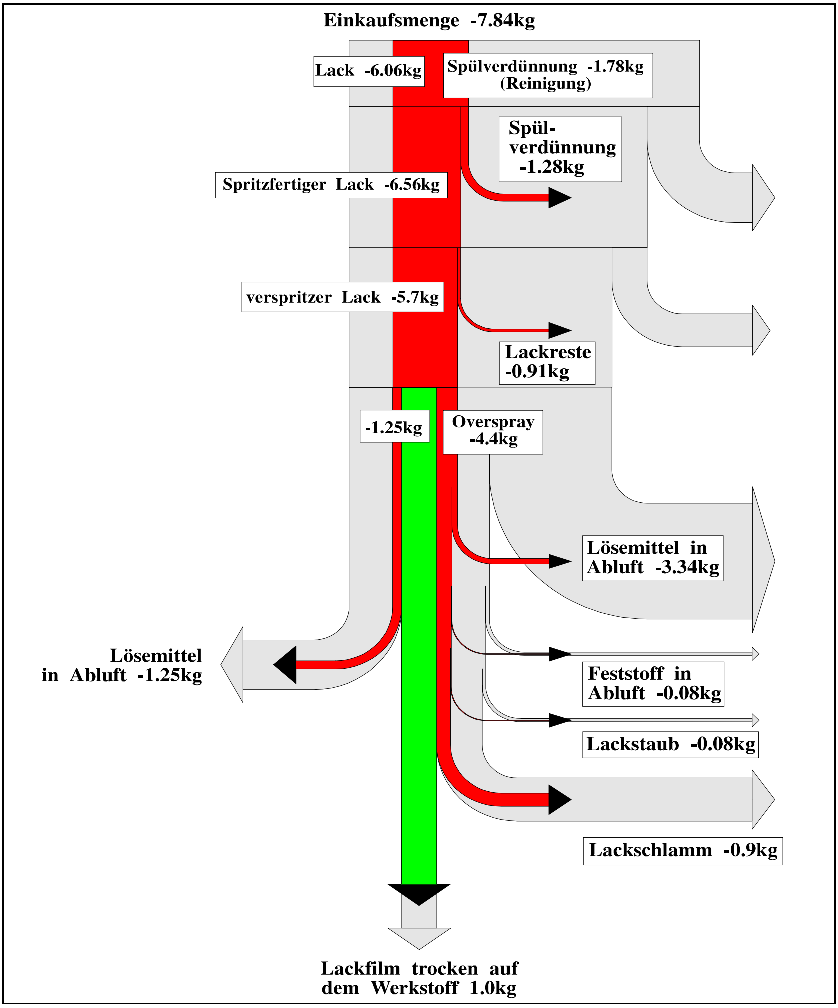


Figure 3. Material flows of paint and solvent in a spraying plant - comparison

5.3 Module 3: TRIZ- tools for problem analysis

The primary objective of the module "Problem Analysis" is to provide an understanding of the problem. Furthermore, by analysing the problem situation and the interconnections between aspects of the problem, initial solutions can be developed.

This main objective and the tools used to do this give rise to other sub-objectives:

- ❖ Defining task, problem and optimisation potential.
- ❖ Identifying useful and harmful functions.
- ❖ Analysing system and system surroundings; describing interconnections between various aspects of system
- ❖ Eliminating expensive, harmful and environmentally damaging components.
- ❖ Using available resources.

At the beginning of this module it is shown again that the decisive leverage effect for reducing harm to the environment is in the first phase of the lifecycle of a product. (Figure 4) A minimal increase in expenditure during development results in a noticeable decrease in expenditure in later phases. Potential optimisations that have been recognised at an early stage can be efficiently implemented here. This applies to ecological as well as to economic aspects.

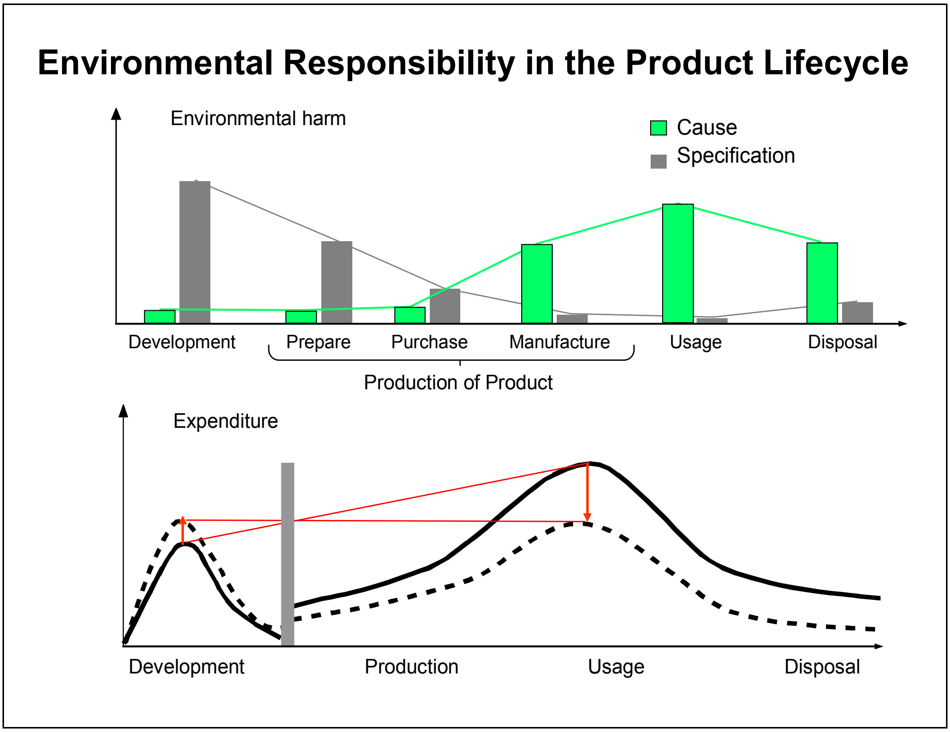


Figure 4. Environmental Responsibility & Leverage Effect of Expenditure

The TRIZ methodology provides a variety of tools to efficiently support product development and to thereby both promote sustainable environmental protection and the success of a company.

In this module the following TRIZ tools are presented:

- The Innovation Checklist
- The Resource Checklist
- The System Operator (9 Windows)
- Ideality (incl. useful and harmful functions)
- The Function Analysis
- Trimming

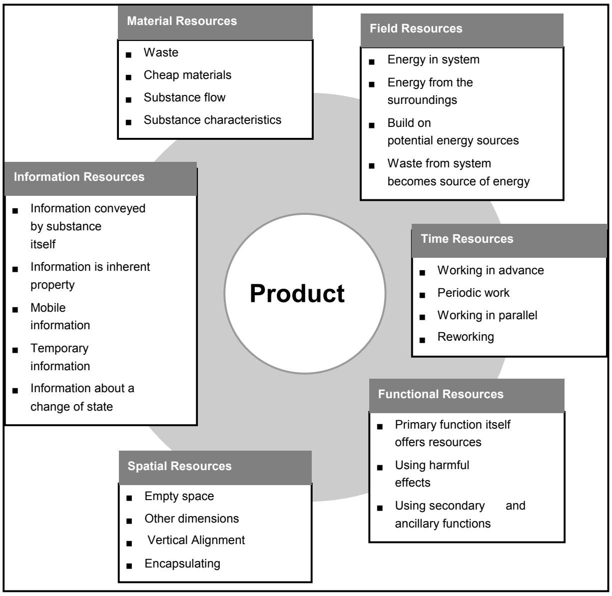


Figure 5. Resource Checklist

5.4 Module 4: TRIZ- tools for idea generation I

This module shows how:

- ❖ projects benefit from the ‘ideality’ concept by focusing on increasing overall benefit whilst decreasing costs and harmful effects.
- ❖ to actively seek and define contradictions within a system
- ❖ Contradictions and the 40 Inventive Principles can be used to speed up problem-solving and innovation.
- ❖ sustainable design practise can be improved by resolving conflicts within the system.

At the beginning also the S-curve analysis is presented as a tool to identify a promising problem solving strategy. (Figure 6)

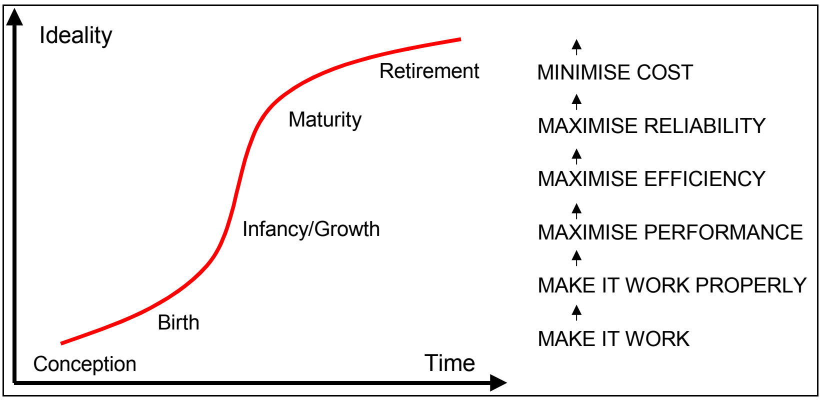


Figure 6. Typical product life-cycle S-Curve

For example, if the S-curve has reached its maximum height the system has reached a fundamental operational limit of capability. No amount of optimisation of the system parameters will produce any further increase in performance. Also, if the performance target is above this limit of capability described by the S-curve then the current system will not be able reach that target and the system will have to be changed. The next figure shows how when a new system is introduced, it is described by the start of a new curve. (Figure 7) These 'S-curve jumps' are characteristics of step-change innovation processes.

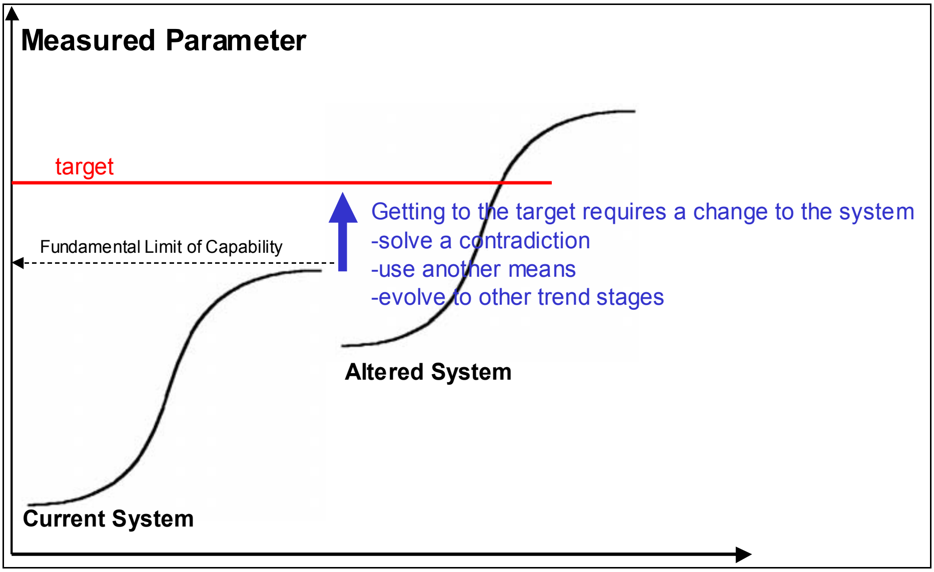


Figure 7. Altering the system is required to reach the performance target

The TRIZ methodology states that there are three different ways of making these jumps:

1. Find another means of delivering the function
2. Solve a contradiction or conflict
3. Move to next stage along the evolutionary trend

In the materials step by step instructions are specified to help the participants in the first attempts using the concept of the ideal final result and the concept of technical contradictions and the inventive principles.

5.5. Module 5: TRIZ – tools for idea generation II (evolution lines)

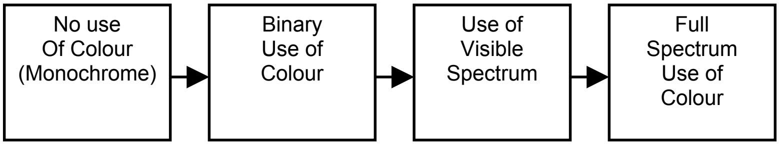
This module

- ❖ introduces the Trends of Evolution from TRIZ.
- ❖ provides many different examples of products and systems that illustrate how the Trends of Evolution work. This section includes examples of more sustainable products and systems.
- ❖ provides a step-by-step way to use the Trends of Evolution in problem solving.
- ❖ discusses the use of the trends in strategic decision-making and introduces a new tool 'Evolution Potential'.

As one appendix to this module a detailed description of each trend with possible reasons for jumps on these trend is added.

Example:

<u>*INCREASING USE OF COLOUR*</u>



Examples: Photography, film, thermal management on space systems, manufacturing inspection systems, pressure/temperature sensitive paints, active camouflage systems.
Reasons For Jumps

Evolution Stage	*Reasons for Jumps*
Monochrome to Binary	*- ability to make simple yes/no measurement* *- warning indicator* *- improved aesthetic appearance* *- improved radiation heat management*
Binary to Visible Spectrum	*- increased flexibility of measurement* *- improved aesthetic appearance*
Visible to Full Spectrum	*- eliminate interference with human interfaces* *- add new function through employment of effects present (e.g. use IR to achieve heat-seeking capability)* *- increased range of measurement possibilities*

Notes: Full spectrum includes infra-red and ultra-violet - both of which are increasingly being used to achieve previously untapped benefits. Colour is rarely viewed as a resource in many engineering systems; the trend shows that someone, somewhere has found an advantage in making use of colour.

5.6 Module 6: Tools for idea evaluation

The aims of this module are to:

- ❖ Explain the role of evaluation within the innovation process
- ❖ Give a general introduction into indicators and their functions within evaluation and analysis processes
- ❖ Present an overview of sustainability indicators within the three dimensions of sustainability
- ❖ Provide examples of generic tools to assist in the evaluation stages of innovation processes, describe their strengths, when and how they should be applied.
- ❖ Provide specific examples of each of the evaluation tools (→ Figure 8)
- ❖ Discuss how they can be used to evaluate the potential sustainability performance of new ideas and innovations.

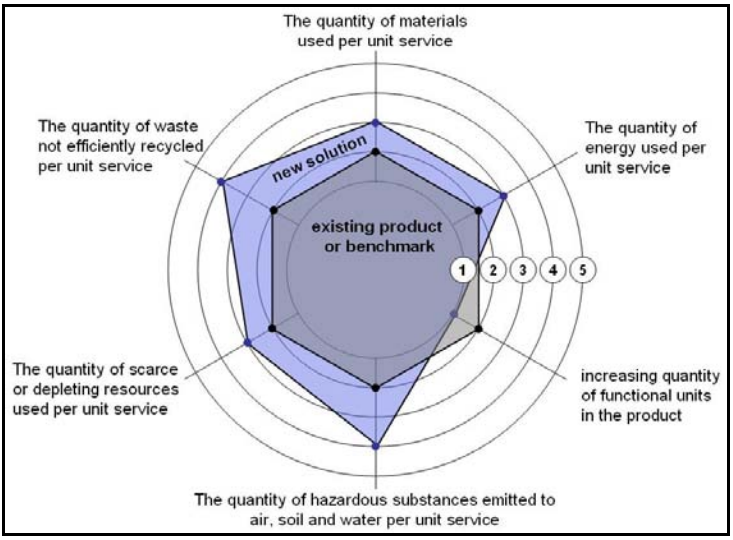


Figure 8. The eco-compass after Fussler and James (1996)

5.7 Module 7: Project management

The last module of the training course SUPPORT has the two objectives to:

- Becoming familiar with the theoretical background and the “philosophy of project management”
- Becoming familiar with certain project management techniques and tools in order to be able to carry out and complete projects, as well as actively taking part in them and playing a part in their success

In this module the participants get information (and learn) what are projects, what is project management, which phases are included in the project lifecycle? which planning tools are available in the individual phases of the project, what sort of project organisation is available, how does project controlling work and how do complete a project?

5.8 Video Sequences

The Videos are available on a CD-Rom and on the Web and are composed of

- an introduction sequences about the project idea
- two introduction sequences about sustainable development and the TRIZ method
- a short sequence for each module (incl. theory and practice)

5.9 Final remark to the project and the tools

The idea of the project was not to develop new creativity- or cleaner production-tools but to combine them in a manner, that both concepts find new entrance opportunities to companies and the public. The project should help both the idea / tools of sustainable development and the ideas / tools of TRIZ to increase their number of followers.

6. Experiences Test Training Courses

Status 2004 09 02:

Due to the fact that not all test trainings are finished at the moment a final conclusion is not possible. Basically the participants were highly interested and the previous feedback is encouraging. → *Report Conference in Florence.*

7. Further development of the training course

In two calls for related projects at European level following-up projects have been handed in:

A) Leonardo da Vinci: Call „Transfer of Innovation“

B) Marie Curie Conferences and Training Courses: Call „Series of Events“

One of theses proposals were evaluated positively.

The project "European SUPPORT" – Leonardo da Vinci - with new transfer partners from Sweden, Estonia, Bulgaria, Cyprus, Rumania and Slovenia will start in October 2004.

References, Project Partners

Project & Training Materials SUPPORT

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NEW OPPORTUNITIES & FIELDS OF APPLICATION

MONITORING INNOVATION:
AN INTEGRATED INSTITUTIONALIST APPROACH (COMPARATIVE FRAMEWORK)

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Abstract
The European golf industry faces sharp, yet ambiguous legal regulation of pesticide use. Regulations are formally banning traditional technological conventions without specifying alternative conventions. Will the industry merely keep switching to other, not yet prohibited, toxic pesticides, or will it rethink the functional ecology of golf courses, taking advantage of potential eco-innovations? The paper offers an analytical framework for understanding and facilitating change, focusing on how collective agreements (formal rules) co-evolve with more individual practices (informal rules). After discussing how two leading New Institutional Economics authors (Williamson, North) integrate various institutional levels, I turn to the French Economics of Conventions. I examine how Thévenot's three engagement regimes (justification, intentional action, familiarity) can provide empirical indicators of institutional levels. Three main variables are introduced: degree of collectiveness, nature of perceived environment, level of reciprocity. Their articulation results in an original learning concept. This comparative framework is open for examining, in a future step, the potential complementarity and contradictions with the TRIZ approach.
Keywords: Innovation, Pesticides, Golf, Institutions, Keynesian Conventions, Learning.

1. Introduction. How do individuals understand collective agreements?

1.1 Greening the golf industry

Regulations force a technological change in pest management on golf courses. Golf putting greens are traditionally heavily treated with toxic pesticides. Estimated quantities of active ingredient used in the UK (1994 to 1997) amount to 15 kg/ha of green (orchard: 12.5 Kg/ha; potato crop: 11.7 Kg/ha) [Garthwaite 2003]. Active ingredients applied are causing widespread health and environmental concerns, responsible for their progressive ban.

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1.2 Examples of disputed technological conventions

The 3 most important insecticides used until recently on golf courses in the British Isles (against the leatherjacket, larvae of the European crane fly *Tipula paludosa*) are now obsolete or near-obsolete:

- **Hexachlorocyclohexane** (HCH, e.g., lindane): highly persistent organochlorine, neurotoxic (disrupt flux of cations across nerve cell membranes), endocrine disrupter, likely carcinogen, found in human breast-milk across the world. Most common insecticide used on golf until its ban in 2002.
- **Carbaryl** (e.g., Sevin™): Carbamate nerve toxin, highly toxic (causes irreversible nerve impulse disruption), mutagen, toxic to aquatic invertebrates and fish (bioaccumulation). Common in golf until its ban in 2002.
- **Chlorpyrifos** (e.g., Durban™): broad-spectrum chlorinated organophosphate; the most widely used insecticide worldwide. Cholinesterase inhibitor, with wide adverse environmental effects (synergy with other molecules, bioaccumulation in fish). Under review, **ban expected**.

Pesticide use is getting increasingly restricted in the EU.

Regulatory constraints to pesticide use in Europe are escalating dramatically and include:

- Commission Regulations 2076/2000/EC and 1112/2002/EC (4th Review) and Commission Decisions 2002/478/EC, 2002/479/EC and 2000/817/EC.
- REACH: Registration, Evaluation and Authorisation of Chemicals.
- Rotterdam Convention on Prior Informed Consent (PIC, 2004).
- Stockholm Convention on Persistent Organic Pollutants (POPs, 2001).
- Commission's 6th Environmental Action Plan (2001-2010).

Change is required, however the industry is increasingly worried because no alternative is specified: **a change to what?** (see Fig. 1)

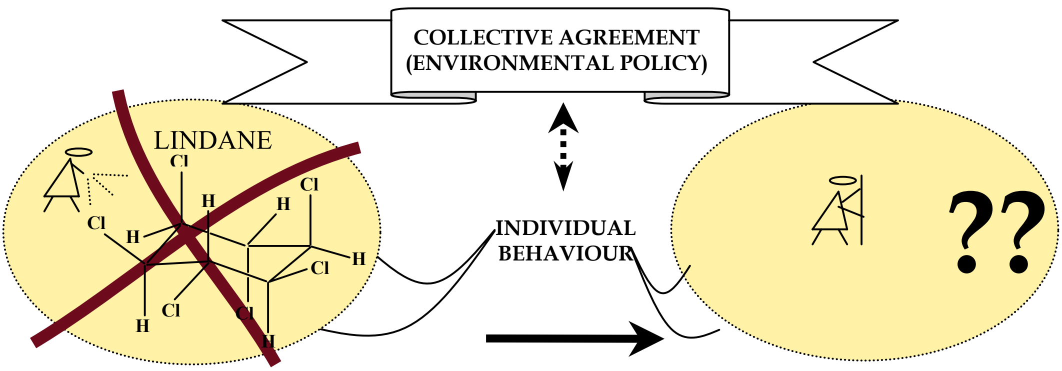


Fig. 1. What is green then?

1.3 How is a collective rule translated for and understood by users?

If alternative technologies (e.g., eco-innovations) can be identified, are there obstacles to the technological switch? Can research on institutional change contribute to removing those obstacles? Policy change isn't sufficient for behavioural change. Consistency between policies and behaviours is crucial to sound policy-making. In other words, vertical integration of institutions matters to institutional design. How do theories of institutions integrate institutional levels? Once reformed and agreed upon, policies and other formal rules still have to be *complied with*, i.e., to result in effective change. In this last point lays a major challenge facing 'humanity today: to make the transition from international agreements to local action' [Juma 2002: 11]. In other words, policy-makers, at all levels, face the difficulty of transforming agreements (which often emerge as formal rules) into practice (informal rules, routines) [OECD 1999, 2000, Seri 2001, Juma 2002]. Addressing this challenge requires understanding the interaction between agreed principles on the one hand (one institutional level), and actual practice and behaviour on the other hand (another institutional level). How do theories of institutions conceptualise this interaction? Put another way, how are institutional levels integrated in theories of institutions? The goal of the present Section is to initiate a comparison between approaches of institutional change with regard to this question.

2. Two New Institutional Perspectives on institutional integration

2.1 Preliminary definitions

The following definitions are submitted on a preliminary basis:

Institutions are approached through rules. **Institutions** can be broadly defined as 'any system of rules with some coherence (manifested in different ways)' [Favereau 2002: 312], or as 'shared concepts used by humans in repetitive situations organised by rules, norms and strategies' [Ostrom 1999: 37].

Formalness varies. Both **formal** and **informal rules** will be considered here as *institutions*. Knowledge and institutions can be diversely formal as we will see through Section 3.

2.2 Williamson develops the Transaction Cost Theory

How does Williamson integrate the analysis of institutional levels? Williamson [1975, 1985] extends the Coasian concept of transaction cost into a general theory of institutional arrangements. Institutional arrangements are conceptually discontinuous blocks: either I transact, or I integrate my partner. He nuances this concept by stressing that in the 'real' world, organisations and markets are embedded in an institutional framework, and they overlap, giving birth to 'hybrid forms'. Williamson postulates that economic agents choose the institutional arrangements that minimise their transaction costs. This transactional analysis is the means by which agents optimise their contracts. 'A transaction occurs when a good or service is transferred across a technologically separable interface. One stage of activity terminates and another begins' [Williamson 1981: 552].

The institutional arrangements are only one part of the institutions. Williamson [1998] distinguishes four institutional levels (see Table 2):

- **(L1) Embeddedness**. This level encompasses institutional forms such as 'traditions' and other 'non calculative' rules, norms, customs, mores, traditions, religion, etc, gathered in the broad category of 'informal constraints' (ibid: 27). They are taken as given by most economists. They influence the long-run character of economies (measurable at the scale of centuries or millennia).

- **(L2) Institutional environment**. The structures observed here are the product of politics and provide the **rules of the game** within which economic activity is organised. The polity, judiciary and bureaucracy of government are all located here. The laws regarding **property rights**[2] – their definition and enforcement – are prominently featured.
- **(L3) Institutional arrangements**. The third level contains the institutions of governance. The legal system (L2) does not guarantee the enforcement of the rules and this is the role played by the institutional arrangements (also called governance structures). L3 analyses the **play of the game** by alternative modes of organisation: markets, hybrids, firms, bureaus.
- **(L4) Resource allocation**. Adjustments in price and output are made in a (more or less) continuous way in response to changing market conditions (neo-classical decision). Decision-making by risk-adverse agents (efficiency of incentives) are analysed by agency theory.

Table 1. A Williamsonian integration of institutional layers

Level	Change (years)	Purposes	Theory
Resource allocation (L4)	Continuous	Get the marginal conditions right	Neo-classical, agency theory
Institutional arrangements (L3)	1-10	Get the IA right	Transaction cost
Institutional environment (L2)	10-100	Get the IE right	Property rights
Embeddedness (L1)	100-1000	Often non calculative; spontaneous	'Social' theory

Adapted from Williamson [1998: 24, 2000: 597]

2.3 Discussion

Williamson focuses essentially on L2, and on L3 to a lesser extent. Correspondence and integration between the four levels pose problems for several reasons. First is the lack of analytical attention paid to 'embeddedness'. This blackboxing of L1 is acknowledged by Williamson himself: 'The study of 'informal organization' poses a continuing challenge (…). Our understanding of informal organization is still primitive (...). Simon (1991) avers that considerations of identity and docility are important, but these arguments need to be worked out more fully' [Williamson 1998: 52].

[2] Between the various categories of property rights, the right of ownership – which consists of the right to use an asset, the right to appropriate the returns from an asset, and the right to change its form, substance, or location – is the most important.

Second, separate theories are mobilised for explaining each of the institutional levels. This leaves unanswered important issues such as the evolution from one level to another, or the existence of some institutions at several levels simultaneously. For example it can be argued that some formal institutions can also perfectly fall into the 'embedded' category. In many cases indeed, a calculus rule, a market transaction, or a legal law, are institutional environment items that are *at the same time* embedded as a 'tradition' or a 'social norm'.

Third, the timeframe at which change may occur doesn't seem to be as rigid as in Table 1. Examples are numerous of significant embedded social norms dramatically affected by change within about a decade or less (e.g., food, health, sexual habits). Conversely, it could be asked whether some institutional arrangements are not able to persist significantly longer than a decade (even when their transaction-cost minimizing properties are being questioned).[3] These issues are part of the new NIE research program 'that is transforming our understanding of how market economies function, and even of what 'markets' are. To develop this program, we must better understand how the rules governing institutional arrangements such as markets and organisations are created and changed, i.e., how institutions emerge and are stabilized' [Ménard 1995: 179]. In that regard, North is pointing to interesting avenues.

2.4 North casts light on' informal institutions'

How does North integrate institutional levels? Douglass North, one of the major authors of the New Institutional Economics, has contributed considerably to the introduction of history, institutions, and more recently cognition, into economic analysis. In a much quoted sentence, he defines institutions as 'the humanly devised **constraints** that structure political, economic, and social interactions. They consist of both informal **constraints** (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights)' [North 1991: 97, emphasis added].

North is explicitly aiming to take into consideration diversely formal institutions. If one attempts to capture the essence of the formality and of the informality as expressed in North[4], the following characterization may be obtained.

Formal institutions (constraints, rules) 'are formal written rules' (p. 4); 'may change overnight as the result of political or judicial decisions' (p. 6); 'make up a small (although very important) part of the sum of constraints that shape choices' (p. 36); 'underlie informal constraints, but are seldom the obvious and immediate source of choice in daily interactions' (p. 36). They include (p. 47) political (and judicial) rules: define the hierarchical structure of the polity, its basic decision structure, and the explicit characteristics of agenda control; economic rules: define **property rights**, that is the bundle of rights over the use and the income to be derived from property and the ability to alienate an asset or a resource; contracts: contain the provisions specific to a particular agreement in exchange. They 'at least in good part, are devised in the interests of private well-being rather than social well-being. (…) as a first approximation, are derived from self-interest' (p. 48).

Informal institutions (constraints, rules) are 'typically unwritten rules that underlie and supplement formal rules' (p. 4); are 'embodied in customs, traditions, and codes of conduct

[3] Thus we need to integrate the time dimension into the empirical indicators. This is not so simple since even the timeframe is quite variable from an institution to another. In other words, we need to introduce multiple timeframes and to distribute them properly according to the institutions (how??).
[4] say, in North [1990], where the subject is most extensively treated.

are much more impervious to deliberate policies' (p. 6). They 'defy, for the most part, neat specification and it is extremely difficult to develop unambiguous tests of their significance' (p. 36). They 'are pervasive[5]' (p. 36), 'define overwhelmingly the governing structure' in 'our daily interaction with others, whether within the family, in external social relations, or in business activities' (p. 36); 'come from socially transmitted information and are a part of the heritage that we call culture' (p. 37); 'are not directly observable' (p. 43); are 'persisting', do not 'change immediately in reaction to changes in formal rules' (p. 45).

2.5 Discussion

North's categories overlap but do not match perfectly the categories assembled by Williamson and represented in Table 1. First, North defines institutions as the 'rules of the game of a society', i.e., the institutional environment [Denzau and North 1994: 4]. Hence he doesn't seem to emphasise the 'play of the game' (institutional arrangements) as much as Williamson does. Second, institutions include both informal constraints and formal rules [North 1991: 97]: for North, the 'embeddedness level' (L1) is thus not as distinct from the institutional environment (L2) as it is in Williamson. According to these definitions, the *rules of the game* (i.e., the institutions) apparently encapsulate the *embeddedness* level. For North the formal institutions are the rules and constitutions produced by the state authority that guarantees compliance. Informal institutions fall into three categories [North 1990: 40], see Fig. 2: Conventions, extensions and amendments to formal rules; Behavioural norms (socially sanctioned); Internally enforced codes of conduct. Even though legal and constitutional rules are associated with normative power, they are subject to interpretation when used within particular contexts. Reversely informal rules are not independent from legal rules. In short, both categories (formal and informal) are entangled. However, the modalities of the interaction are not easy to identify.

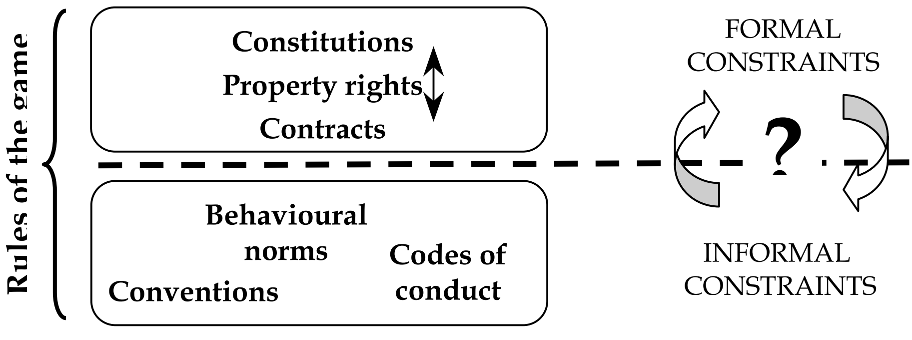


Fig. 2. Articulation between North's institutional categories is not straightforward

North defines **ideologies** (an old subject of interest) as the 'shared frameworks of mental models that groups of individuals possess that provide both an interpretation of the environment and a prescription as to how that environment should be structured' [Denzau and North 1994: 4]. For North, mental models come from 'minds', institutions come from

[5] I.e., they extend their activities, presence, influence, etc, throughout.

'groups. However, the distinction collective/individual is not clear, and is even put on the table as an open question: 'What is the relationship between formal and informal constraints? How does an economy develop the informal constraints that make individuals constrain their behaviour so that they make political and judicial systems effective forces for third party enforcement?' [North 1991: 111].

2.6 Conclusion

The conceptualisation of the 'continuum' between and within institutional levels is far from being stabilised. North himself doesn't hide his dissatisfaction when it comes to the operational use of NIE concepts, e.g., in economic development and decision-making support: 'The way in which a society changes is a mixture of changes in formal rules, informal norms of behaviour, conventions and their enforcement characteristics. But (…) the only thing we have direct control over is the formal rules. Now changing the formal rules is a very blunt instrument for trying to change the way a society works, and indeed the formal rules are only one element. In Russia, for example, many of the formal rules were changed (…) and the norms of behaviour that evolved over time were inconsistent with these formal rules, producing the chaos and results that are apparent today. Finally, how do formal rules change? We live in a world of dynamic economic change, but our theories are static. (...) We do not know the process of change' [North 2000: 8-9]. The lack of conceptual articulation between institutional levels is also explicitly acknowledged by Williamson. Compared to Williamson, North gives informal institutions some analytical content. However, the relation between institutional levels is not elaborated. A more solid bridge is needed.

3. Conventions theory bridges formal and informal institutions

How are institutional levels integrated in the French Convention theory? The French Economics of conventions is recent and not very well known outside France. This is why we will first introduce its epistemological position. We will then present Thévenot's institutional levels, and examine their integration.

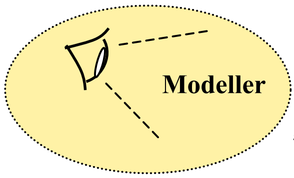
3.1 Lewisian conventions are speculative

Let's start by distinguishing between two concepts of conventions: a Lewisian one and and Keynesian one. For David Lewis [1969], a convention is a solution to a recurrent coordination problem. It is a regularity R in behaviour (or in behaviour and belief) that, in a population P, satisfies the six following conditions[6]:

- Everyone conforms to R.
- Everyone expects everyone to conform to R.
- This expectation that others conform to R give everyone a good and decisive reason to conform to R.
- Everyone prefers a general conformity to R rather than a less-than-general conformity (coordination equilibrium).
- R is not the only possible regularity satisfying conditions 3 and 4 (conformity is arbitrary).

[6] The version given here is updated as in Lewis [1983: 165-166], quoted in Dupuy [1989: 371].

- Conditions 1 to 5 are common knowledge[7].



A

	denounces	doesn't denounce	B
denounces	(Xi,Yi)	(Xii,Yii)	
doesn't denounce	(Xiii,Yiii)	(Xiv,Yiv)	

Fig.3. Modeller predicts, players execute

Deriving from this definition, conventions are used to solve coordination problems in classic non-cooperative game theory [Schotter 1981, Young 1993]. Conceptually, they rely heavily on the common knowledge hypothesis and the underlying paradigm of complete rationality [Aumann 1992]: all players (i) are rational (i.e., know and don't play dominated strategies), (ii) know that all are rational, (iii) know that all know that they are all rational, (iv) know that all know that all know that all know that they are all rational, *ad infinitum*. Lewisian conventions are assumed decided, understood, and agreed upon. In fact, players execute, they hardly *decide* (the game modeller does), see Fig. 3.

3.2 Keynesian conventions are interpretative: players predict (and proceed)

It is rational to mimic others in situation of uncertainty because others might be better informed [Orléan 1995]. Practical, 'real life' coordination relies on this **mimetic rationality**, as observed by Keynes in his analysis of the relation between mimetism and convention. Keynes introduces the concept of **conventional judgement**: 'Knowing that our own judgment is worthless, we endeavour to fall back on the judgement of the rest of the world, which is perhaps better informed. That is we endeavour to conform with the behaviour of the majority or the average. The psychology of a society of individuals each of whom is endeavouring to copy the others leads to what we may strictly term a conventional judgment' [Keynes 1937: 217]. Adopting conventional coordination mechanisms limits the play of reflexive anticipations (specularity). Because they institute stable benchmarks, these mechanisms reduce the uncertainty contained in the environment. Conceptually 'conventions are interesting because they suppress the need for specular anticipations. Actors don't have to be indefinitely sceptical at each other's behaviour. They conform directly to the convention' [Orléan 1981: 298, our translation]. This of course doesn't imply that they always agree on conventions.

Borrowing from Keynes, the French Economics of conventions [Dupuy et al. 1989, Favereau and Lazega 2003, Runde and Mizuhara 2003] acknowledges the paradoxes of common knowledge[8] and views conventions as partially endogenous, partially exogenous

[7] Infinite specularity: an information X is common knowledge between you and me if we both know X, and both know that each other know X, and both know that each other know that each other know X, etc.

[8] Perfect (complete) information is not the limit of imperfect (incomplete) information; ii) perfect information leads to indecidability and indeterminacy. As a result, the rationality paradigm is radically incomplete (practically and logically) [Dupuy 1989]. On irrationality, see Aumann [1992].

(bootstrapping). Interpretation replaces common knowledge. A convention is then defined as a 'regularity resulting from social interactions but that individuals take as objectified' [Dupuy, et al. 1989: 145]. The epistemological position adopted is that of **complex methodological individualism** [Bessy 2003]: the social world is viewed as autonomous from individual actors (autonomy of the collectives), but individuals are the only actors, the only subjects of intention. The Keynesian convention is the concept that will be dealt with here. We will concentrate on the following point: Thévenot's regimes of engagement integrate distinct institutional levels. This will enable us to achieve a closer definition of this concept.

3.3 Thévenot integrates institutional levels according to three continuums

Laurent Thévenot, an influential, founding author of the French convention school, builds a theory of human coordination drawing on the 'cognitive turn' that has characterised the social sciences in the 20th Century, and according to which cognition is of essential importance to coordination[9]. Thévenot distinguishes three main types of social interaction, which he calls 'regimes of engagement' (see Table 2). Thévenot's institutional levels (from formal to informal: justification, intentional actions and familiarity), represent a framework of interpersonal interaction characterised by three criteria (or related by three continuums): collectiveness, interaction and environment perceived. When moving from one regime to the next, each of these three criteria changes.

Table 2. Thévenot's regimes of engagement in the world

REGIMES \ CRITERIA	Collectiveness	Reciprocity	Perception
Justification	*Collective conventions of the common good*	*High and very general (allow distant interaction)*	*Conventional 'qualified' objects (code, benchmark)*
Regular planned action	*Successful conventional action*	*Functional interaction*	*Ordinary semantics of action*
Familiarity action at several	*Routines; personal and local convenience, within a familiar milieu*	*None*	*Usual and used surroundings providing a distributed capacity; close by. Local and idiosyncratic perceptual clue*

Adapted from Thévenot [1998, 1999]

[9] E. Durkheim and M. Weber have brought founding elements for theorising human cognition. Social constructivists and cognitive psychologists further developed this exploration [Boltanski and Thévenot 1991, Livet and Thévenot 1994, Thévenot 1995, Thévenot 2001].

3.4 Toward a measurement framework

Empirical target: Actors concerned by the pesticide ban in the golf industry: Golf Greenkeepers, Professional organizations, including the consultants, Golf Federations including the golfers (end-users), Environmental organisations including the industry's. Each level can be investigated with a proper set of indicators (N.B.: in progress):

- Justification (why):*Are you aware of the pesticide ban? Where does the ban come from? Who decided the ban? Do you know the reasons for the ban? What is your general opinion about the ban? (is it fair/efficient/costly/good for the environment-public health/good for the quality of the courses/etc) (…)*
- Intentional action (How): *How are you going to control pests in your golf course? How can you replace the banned pesticides? Do you know alternatives? Can you use them in your course? Have you heard of biostimulants? Have you been trained to replace the banned pesticides? (…)*
- Familiarity (What): *Is the Leatherjacket an issue for you (main pest insect)? What do you do when you see an attack of Leatherjacket? Are you acting preventively against the Leatherjacket in a routinely way? What works best against the Leatherjacket? Have you ever used biostimulants? (…)*

More work is needed for designing proper indicators for and proceed to a systematic analysis of, each institutional levels. This will help analyse how a formal rule (e.g., pesticide regulations) exist for field users (greenkeepers and their immediate socio-economic sphere: golfers, consultants). This will also help identify the diversity of formalnesses: from judiciary and non judiciary origin (habit, morale, aesthetic, technical, renown, market…), and the associated diversity of codification. This will also allow to measure the 'completeness', or 'integrity', of institutions relevant to sustainable development, to assess a relevant institution is not complete, why, and how to make it complete (are the rules of a particular institution consistent across institutional levels, within and across users' groups?).

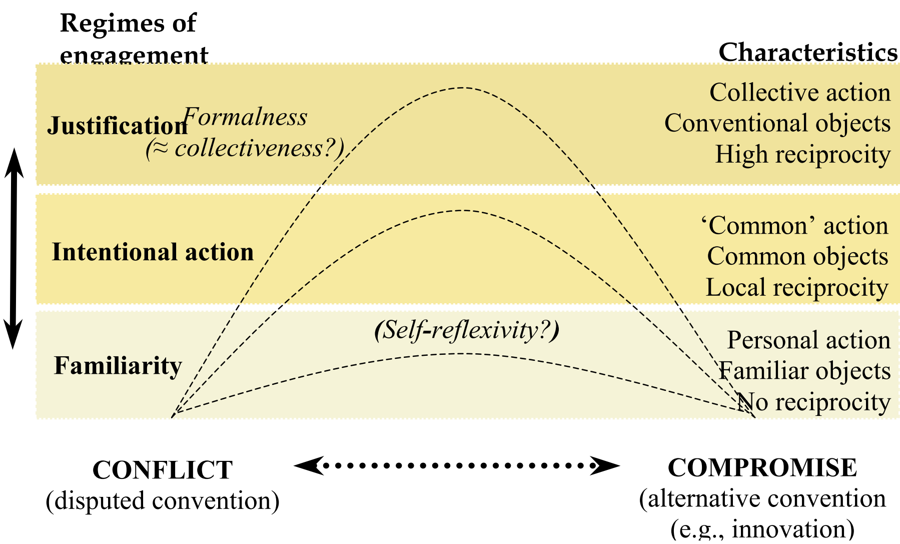


Fig. 3. Learning involves reflexivity at varying levels

4. Conclusion

Empirical data will feed into a learning model built on the articulation between three institutional levels (Fig. 4). This conceptual model tentatively articulates several institutional levels, which is arguably of interest to the understanding and facilitation of innovation. Even though the empirical framework is not yet fully fledged (empirical application not completed to date), the conceptual comparison above enables a few provisional conclusions:

- The latter learning model is extremely scalable in terms of time, space, collectiveness.
- It is likely to encompass several traditional conceptualizations of institutions, e.g., Williamson's 'embeddeness' and transaction costs (see Table 1), North's conventions and social norms and property rights, the rational choice theory (see Morand [2005]);
- Thévenot's convention theory is hermeneutical (rather only speculative), is not enclosed in the mental ability of humans but pays attention to their perception (phenomenological), admits a vertical pluralism (formal/informal)[10];
- The analysis of conflicts (between and within institutional levels) offers promising avenues to the identification of compromises to those conflicts (innovations, either products, processes, or organizations);
- The above learning model, emphasizing the dynamic, spiraling and critical process between practice (familiarity, informal) and principle (justification, formal), seemingly offers dialogue opportunities with the TRIZ approach.

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[10] as well as an horizontal one not addressed here (several types of formalnesses).

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TRIZ AND MARKETING

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Abstract

In the given work the methods used in marketing are analyzed: life cycle of the goods, Ansoff's matrix , segmentation of the market and consumers, matrix BCG, a matrix "Quality - price", Porter's scheme and the SWOT-analysis. It is shown, that the general law of S-shaped development of systems is used only for system "goods", and that in incomplete treatment (life cycle of the goods). For the analysis, the prediction of development of firms and the markets the simplified circuits in part reflecting the law of S-shaped development of systems as two-dimensional models and matrixes are used. It is shown, as the law of S-shaped development of systems and the system operator (SO) have been used for the analysis and forecasting of development of the commercial enterprises. The author offers the algorithm of marketing actions allowing effectively to move ahead in real conditions. The principle of concrete situation is used in algorithm. This principle is frequently ignored in modern methods of marketing. The maximal economic benefit of application of such approach - increase in volumes of manufacture (sales) at 7-10 time within 6-10 months. There is the scheme showing dependence of the goals of firm from a stage of its development according to the law of S-shaped development is resulted. Application of algorithm of marketing actions allows each organization to have priorities in the decision of problems according laws of development of systems. Use of laws of development of systems and methods of TRIZ will allow to increase a theoretical and practical educational level in business, to take terminology and to enter uniform conceptual space on importance fields of business.

Keywords: TRIZ, marketing, S-curve, system operator (SO)- the 9-screen Diagramm , Ansoff's matrix, matrix BCG, a matrix "Quality - price", Porter's scheme and the SWOT-analysis.

Nomenclature:

TRIZ - Theory of inventive problem solving
SO - the 9-screen Diagramm for developing system
SWOT-analysis – Strength, Weakness, Opportunities, Threats
S-curve – the low of system's development

1. Introduction

At present time we have plenty of methods and schemes for forecasting the volume of sales and marketing strategies planning. Marketing specialists employ usually a combination of the existing methods. The choice of these or those methods normally depends on personal experience of the consultant. More of that, the consultants unconsciously prefer to deal with problems of the same kind, which they had solved successfully before. What is the most difficult in analysis and forecast on the market? – The market situation is always unique, but some regularities had been already discovered and described.

2. Observation of existing methods and TRIZ for forecasting of a developing

The Goods. One of the most well known regularities is the life cycle of the goods. Fig.1 displays the dependence of the goods dynamics in time.

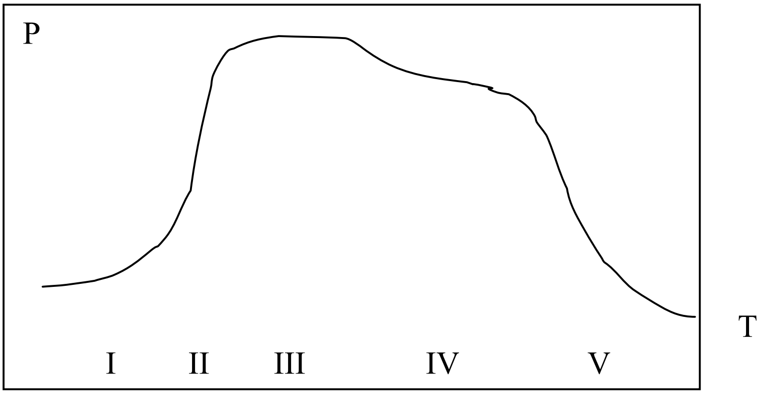

Fig.1. The life cycle of the goods P- quantity of goods, T – time, I, II, III, IV, V – stages of development of the goods.

This happens with the most successful products, but the very mechanism and causes of this regularity are still not discovered. That is why the forecast of market situation and success of the concrete product are so difficult to predict. The map of a company positioning can serve as an addition to this description. This map contains indeed only 2 parameters – the quality and the price of our product. It is definitely one of the characteristics, but first of all the characteristics of the product and not the characteristics of the firm.

	High quality (II, III)	Low quality (I)
High price (???)		
Low price (???)		

Tabl.1. The map of a company positioning
I, II, III – stages of development of the goods (Comments of the author of this paper).

Let us consider this approach from the viewpoint of S-curve of system's development.

This method supposes describing the products according to the suggested parameters and with the help of this make positioning of the company. This approach comprises consumers' survey and has very subjective character. Further development of this method resulted in making behaviour market strategies matrix.

	High quality (II, III)	Medium quality (II, III)	Low quality (I)
High price	Bonuses ("Skimming the cream off")	Overestimated price	Robbery
Medium price	Profound penetration	Medium level	Glow for show
Low price	Increased significance	Good quality	Decreased significance

Tabl.2. The matrix of strategy of behaviour in the market.
I, II, III – stages of development of the goods (Comments of the author of this paper).

In this table we have the situations taking place on the market, but to employ it for forecasting is difficult. Which price one should employ and what will be the dynamics of it? Fig.2 shows the law of S-curve systems development, which is widely applied in TRIZ.

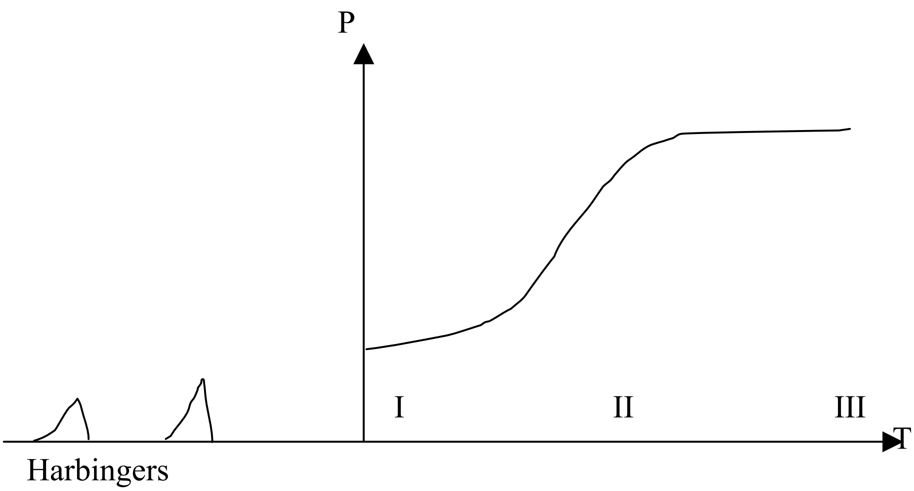

Fig.2. The law of S-curve systems development.
P – the main useful function, T – time, I, II, III – stages of development of the system.

Let us compare these two figure (1 and 2). Fig.2 gives possibility not only describing, but also forecasting the successful operations on the market. The search of precursors of the system is the important step of our analysis. The new system (the goods) appears really only when the first copies of it are sold. In the middle of the second stage (A) the new opportunities for diversification of the product or the methods of its selling appears. This point (C, Fig.3, (2)) can be calculated as maximum of the first derivative P. Transition to the second and the third stages (E,G) is possible to obtain from the second derivative P (1). The concrete decisions about the product can be accepted only taking in account the situation within the firm and the market.

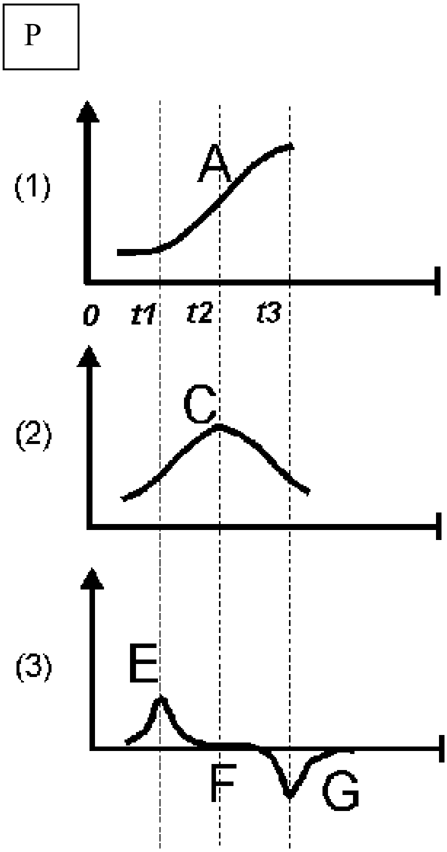

Fig.3. Determination points of changes.
P - the main useful function, 1 – S-curve, 2 - the first derivative P, 3 - the second derivative P, t1,2,3 – time

A firm. There are no definite recommendations how to analyse the operation of the firm in the contemporary marketing studies. The activity of the firm is presented on the market via developing its products and percentage of market occupation. Meanwhile, products and technologies (which the firm possesses) determines its peculiarity and success. Very often psychological inertia makes us estimate the effectiveness of a firm due to its product or to the situation on the market, but the very inner mechanism of firm's operation and management is underestimated. The closest to TRIZ is the method of SWOT-analysis, which is displayed here as a table 3.

	Strength. Opportunities.	Weakness. Threats.
Internal		
External		

Tabl.3. SWOT-analysis

This table gives the mode of analysis, which lets us describe the current state of business. But this approach does not give "a key" to forecast the development pathways.

We managed to describe the development of a firm within the S-curve terms. Number of features indicating different aspects of the firm's development allows determine fairly precisely the stage of the firm's evolution, distinguishing it from the stages of product's or market sectors evolution.

A sector of the market. Normally sectors of the market are characterised by distribution of the main participants along with the volumes of selling. The percentage of the product and dynamics of growth of selling serve as the main criteria for decision-making, e.g. BCG matrix (Tabl.4):

Relative percentage of the market	Relative percentage of the market	Relative percentage of the market
Dynamics of growth of selling	Low	High
High	"Buds", "Kidneys", "???" (I)	"Stars", "Pearls" (II)
Low	"Lame ducks", "Over-ridden horses", "Dogs". (???)	"Milch cows" (III)

Tabl.4. BCG matrix

Let us compare the conventional parameters of this matrix with the shape of S-curve.

Each cell of this matrix contains the stage of product's evolution. It is obvious that the analysis (???) of the column is difficult, because these parameters are not sufficient to make the decision.

A bit different approach is suggested by Ansoff (Tabl.5):

Market / Product	New (I)	Old (III)
New (I)	Diversification Di-version [Sabotage??]	Development of the product (Linear expanding). Technological risk
Old (III)	Expanding of the market (Devouring of segments). Commercial risk	Penetration (Occupation). Marking out claims

Tabl.5. Ansoff's matrix

This method is workable in the restrictions of the first and the third stages of the development. There are no determinative features of new and old product and new and old market. The most realistic is the Porter's scheme (fig.4).

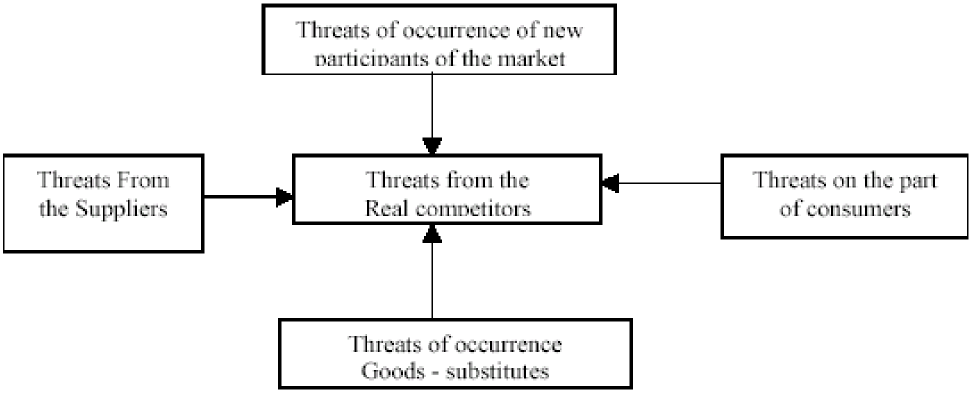

Fig. 4. The Porter's scheme

The Porter's scheme gives some directions for reflections but as the analysis is made without taking into account the last experience and laws of development of systems accuracy of such forecasts is insignificant. Moreover, the given method fixes an existing situation, but does not offer a solution business problem.

2. Forecasting with TRIZ-method

We have developed the set of features (which reflects the concrete situation on the concrete sector of market) to determine the position on the sectors of the market.

Fig. 5 shows our approach for analysis of the business.

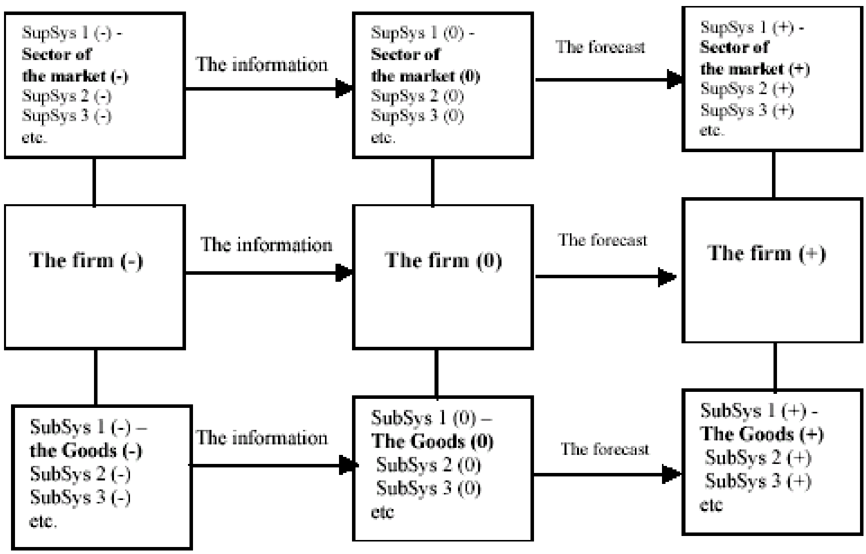

Fig. 5. System operator (SO) "Development of business"
SupSys 1,2,3 – Supersystems (aria for firm's activity), SubSys – Subsystems of the firm, (-) – Past, (0) – Present, (+) - Future.

System analysis with the help of TRIZ gives us the systemic coordinates Product-Firm-Sector of the market.

Products, a firm, a sector of the market are also the systems with their features. We can describe their evolution from the viewpoint of S-curve (Fig 6) and the principle of concrete is used.

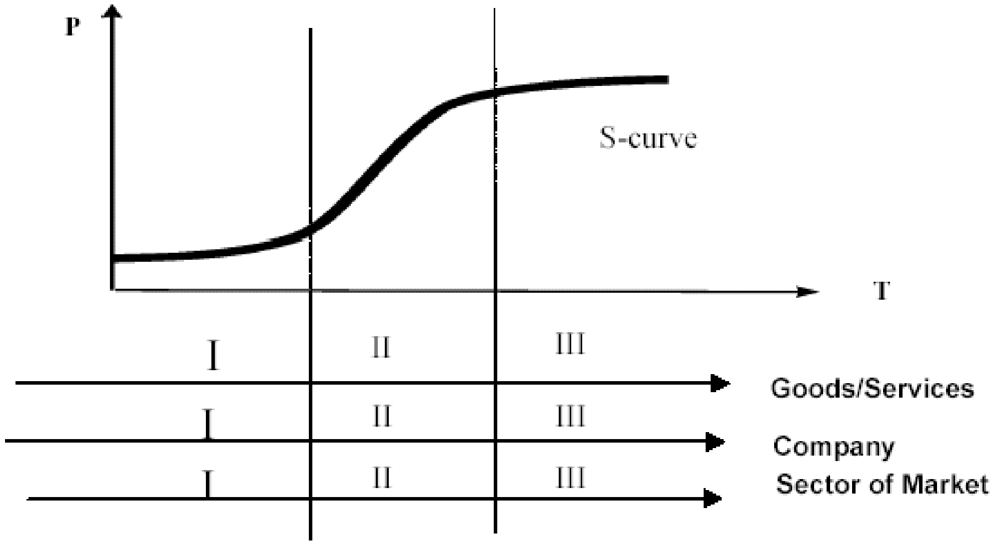

Fig. 6. Formation of three-dimensional space
P – the main useful function, T – time, I, II, III – Development steps of the system (Goods/Services, Company Sector of Market)

A product has its own features, depending on the stage of development (e.g. number of copies, variety, quality, manufacturing technology, raw materials, popularity, etc. – 20 features in total). And namely the complex of all these parameters gives possibility to determine the stage of development of the product, but not the single parameter.

A firm and a sector of the market also possess their features, dynamics of which allows determining their stage of development. Concerning a firm it will be number and qualifications of the personnel, existence of branches, methods of management, processing of documents, decision making process methods, organisational structure, etc. – more than 20 parameters in total. A sector of the market comprises such kinds of parameters as dynamics of turnover within this market, capacity, state of infrastructure, relations with the state, etc.

And only the set (the complex) of all these three parameters gives us the diagnostic description of the business (Fig 7).

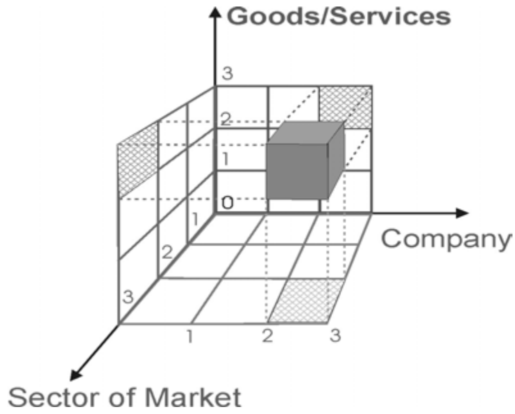

Fig 7. Business cube - of three-dimensional space of business
0, 1, 2, 3 – stages of development of the system (Goods/Services, Company Sector of Market)

We have analysed more than 300 successful business situation from Russian and references from literature (Russian and foreign companies). As a result of this analysis we obtained and tested "the ideal" strategies for every position from the 27 possible business-states (Fig. 8).

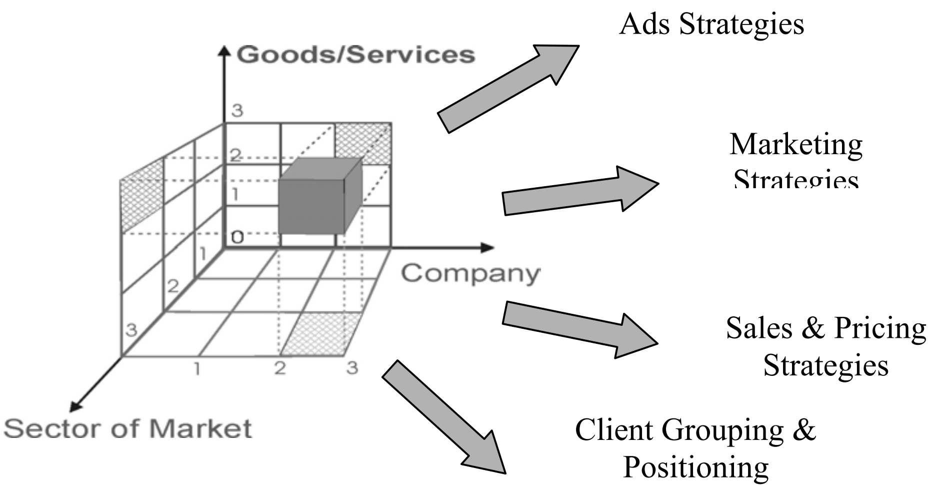

Fig. 8. Strategies of "ideal" business

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A CONTRIBUTION TO HISTORY OF TECHNOLOGY: ANALYZING LEONARDO'S TEXTILE MACHINES AND HIS INVENTIVE PROCESS BY TRIZ METHODS

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Abstract

In a previous work the authors have presented a novel methodology to compare historical machines according to the TRIZ patterns of evolution in order to support History of Technology studies [1]. Such a methodology, mainly dedicated to homogeneous machines analysis, was applied to the cranes designed by Brunelleschi for the construction of the S. Maria del Fiore Cupola in Florence.

The interesting results obtained with such a method induced to further develop the methodology and its applications. The goal of the revised method is enriching the information extracted from technical drafts or detailed designs dating back to the Renaissance Period.

An exemplary application is presented analyzing a comprehensive set of textile machines designed by Leonardo da Vinci from the end of the XV century until the first half of XVI century.

The core of the revised method is still based on TRIZ patterns of evolution but integrated with a system operator analysis; crossing the technical and evolutionary information extracted by means of these two tools, an important breakthrough has been performed to evaluate a machine in a larger technological and philological context. This method allows to approach the genius world of Leonardo and to understand his own contribution to the general process of Renaissance technology.

The studies has been performed in cooperation with the historical experts of the Leonardo's museum in Vinci; their task was to check the reliability of the achieved results.

Key words: Patterns of Evolution, System Operator, History of Technology, Leonardo da Vinci, TRIZ.

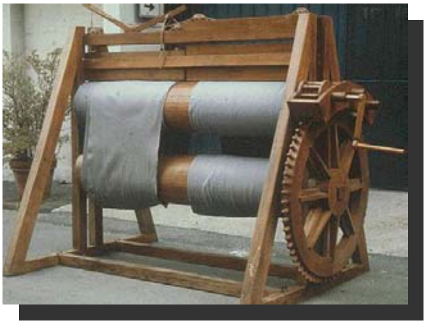
1. Introduction

The work presented in this paper starts from the results published in a recent article [1] where TRIZ patterns of evolution have been applied to compare the cranes designed by Filippo Brunelleschi to build the S. Maria del Fiore Dome, in Florence; as a result, an innovative application of TRIZ tools as a means for aiding History of Technology researchers was presented. More specifically, the aim of that work was defining a set of criteria to compare historical inventions in order to provide a temporal classification as well as an evaluation of their subsystems functionalities without using historical data.

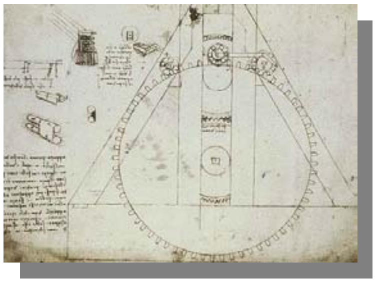
Now the goal is to enlarge the cluster of technological and historical inventions to be analyzed, by introducing some criteria for studying non homogeneous machines developed by a same inventor, i.e. machines with different functionalities and/or layout.

Moreover, it is possible to make a thorough investigation by using a complementary analysis technique based on System Operator [12], in order to define the intervention level of Leonardo's design.

More specifically, such a method is aimed at realizing when Leonardo intended to improve an already tested and working machine (product innovation) or when his goal was to integrate the machine in a wider manufacturing cycle (process innovation) or at least when his efforts were aimed at introducing a new technology to substitute a low-productivity process (i.e. domestic manufacture). By crossing the results obtained with the two analysis



Discontinuous Raising Machine



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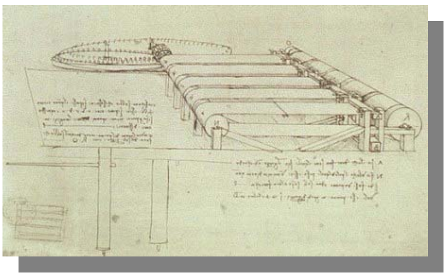

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Continuous Raising Machine

Figure 1 Exemplary drawings and models of Leonardo textile machines

techniques it is possible to evaluate the innovation level of each machine and to suggest hypotheses about the position of this machine inside a productive spinneret; moreover, enlarging the number of examined machines, the Leonardo's design approach to generic problems can be appreciated.

2. Previous works

The core of the method for homogeneous machines presented in [1] is constituted by a new application of Triz knowledge base. The diagram shown on the left side of figure 2 represents the classical path followed according to Triz methodology. In this case the flow is partially inverted in order to compare different embodiments in terms of position on a set of relevant S-curves and so to identify an evolutionary classification of the examined machines.

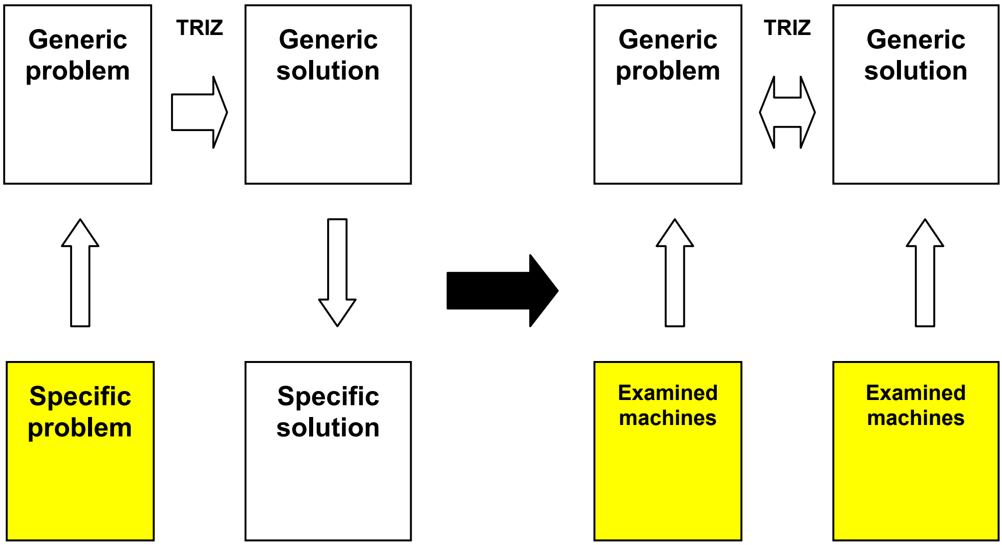


Figure 2 - Triz traditional path diagram (left) and historical researches Triz path (right)

The first step of the method consists in selecting the comparison features, i.e. functional aspects, structural and technological elements owned by the whole set of examined machines. Since these are all cranes, therefore sharing the same functionality, it is possible to proceed by means of a functional analysis of their parts. Four features were identified as relevant for the comparison: load positioning/degrees of freedom, load lift/stop mechanism, internal structure/frame, external stability.

The next step is the selection of the Triz operators (principles and evolutionary trends) adopted for the comparison of the examined machines; in such a study case the selected operators were:

Integration, Segmentation(1), Dynamization(15), Trimming, Self-service(25), Shape(17), Inversion(13), Separation in time/space/condition, Increasing Ideality, Dynamization, Building bi- and poly-systems, Increasing Controllability .

2.1 Comparison matrix

Basically the method consists in performing a one-to-one comparison between the selected machines; the basic features representative of the machines characteristics are compared on the basis of the relevant principles and patterns of evolution.

The comparison is operated by means of a set of N x N square matrices, each corresponding to one of the above defined basic features, where N is the number of the examined machines.

The (i, j) cell in the right-top half of the matrix contains the result of the comparison between the i-th and the j-th machines: an exemplary content is represented in figure 3 .

The principles/evolution patterns not concerning any difference between the two machines under comparison are omitted. Besides, a “+1” value means that the i-th machine of the first column is at least a step forward in the evolution than the j-th machine of the first row; vice versa for a “-1” value.

The result of such a comparison is reported in the left-bottom half of the matrix, in the (j,i) cell: such a value is determined as the sum of the partial values in the (i,j) cell and it represents the evolution balance of the pair of examined machines.

Feature X	**1**	**2**	**…**	**i**	**…**	**j**	**…**	**N**	**SCORE**
1									
2									
…									
i						Integrat. +1 Segmen. +1 Control. -1			
…									
j				+1					$\sum \mathbf{v_{ij}}$
…									
N									

Figure 3 - Comparison matrix exemplary definition

Once the analysis for a given feature has been completed, an evolution score is evaluated for each machine by summing all the corresponding evolution balances. Such a score can be adopted as a ranking function of the machines in terms of technical evolution of the examined features. The analysis can be repeated for all the above defined features (figure 3) and an overall result is provided by summing the evolution scores associated to each comparison feature.

3. Method extension

When the set of machines to be compared is not homogeneous whether for functionality, or for layout, the method previously proposed can't be applied and an extension of the above summarized criteria must be defined.

In such a case the attention must be focused on the features and/or the elements shared at least by a subset of the selected machines apart from the functions they perform. Constructive solutions and basic mechanisms can suitably play this role.

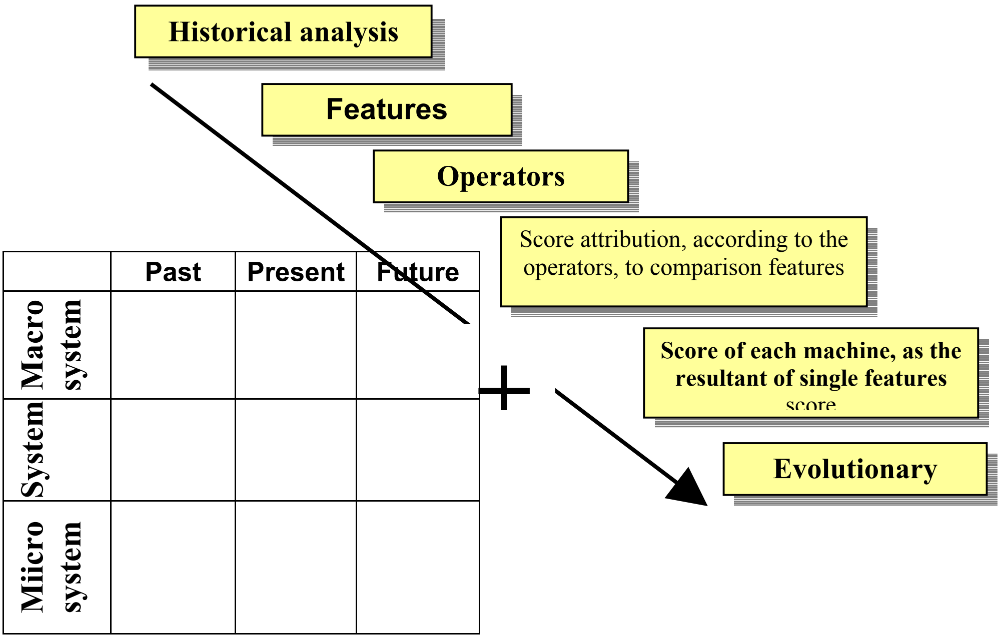


Figure 4 Updated methodology, basic steps

Hence, the first part of the method is a simple extension of the methodology to non homogeneous machines; such an implementation allows the comparison even among inventions with different functionalities. A new analysis technique, based on the "system operator", has been added to mostly increase the amount of information extractable from the selected pictures.

A detailed explanation of the updated methodology (figure 4) will be presented in the following paragraphs by comparing a set of textile machines designed by Leonardo.

3.1 Historical introduction

Leonardo da Vinci produced an impressive series of drawings datable from about 1495 until the first decades of '500; while his engineering activity is mainly known for war, building and flying machines, it's worth to note that his interests involved also almost all the activities of a textile production spinneret. In his Florentine period and even more in Milan

[7], Leonardo studied in a thorough way a whole of textile procedures [11]: ”cardatura” (carding), “filatura” (spinning),” tessitura” (weaving), “garzatura” (raising), “cimatura” (cutting), “battiloro” (goldblating), etc.

Moreover, Leonardo dedicated big efforts to the study of means capable of replacing human force (hydraulic mill, animal force) and he developed several techniques to distribute mechanical power from a primary shaft to several secondary shafts [2, 3]. From this point of view it can be said that his studies virtually anticipated the first industrial revolution by almost 2 centuries, even if XVI century technology was not offering the means to realise it. This is probably the reason why no examples of his activity in the textile field survived and his inventions were practically forgotten for two hundred years.

3.2 Machines selection

A variegated set of textile machines (figure 5 a, b) has been chosen in order to give evidence to the above presented historical notations and, most of all, to describe the proposed classification method.

For practicality only the most representative pictures [13, 14, 15] of the large selection are showed and classified by manufacture typology.

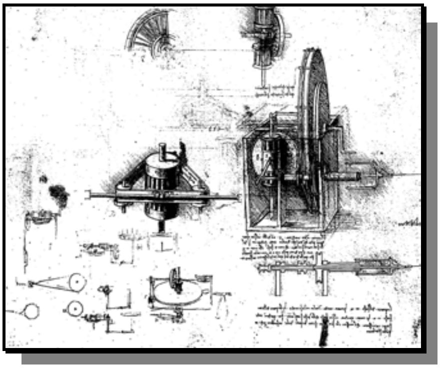
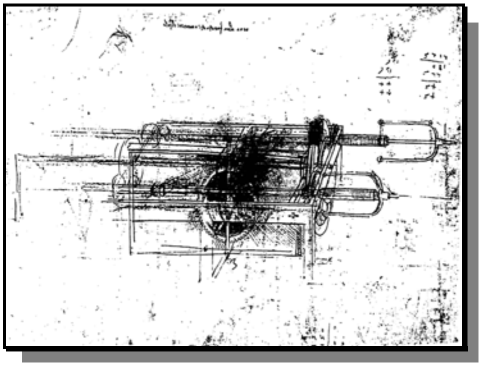
3.3 Comparison features selection: “Constructive solutions and mechanisms”

As stated above, due to machines’ heterogeneity, the “evolutionary” comparison must be applied to the features and/or to the elements shared at least by a subset of the selected machines, apart from the functions they perform.

Since the method consists in performing one-to-one comparisons of the examined inventions, it is assumed that it is not necessary to select just features belonging to the whole set of machines: in facts, it is preferable to take into account the maximum number of details just leaving a blank cell where the elements to be compared are missing. Of course, as described below, the resultant evolutionary score of each machine must be independent by the number of comparison terms.

Two main classes of objects have been chosen as comparison features: constructive solutions and basic mechanisms. The first class is constituted by components or structural details like gears, joints, beams shape etc. The latter is focused at a larger scale and takes into account the mechanisms adopted as a solution to given kinematics problems. In the following figures these two classes are named “COMPONENTS” and “KINEMATICS” respectively.

The whole list of comparison elements is not compatible with a conference article; nevertheless, in order to give a clearer idea of the above classification, some exemplary features of the loom are here presented.

1 	**2** 
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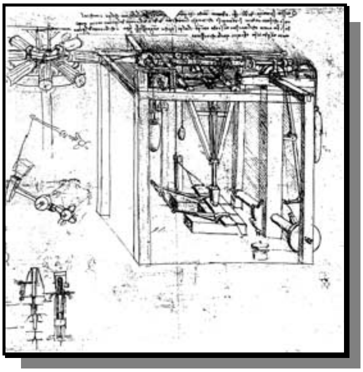
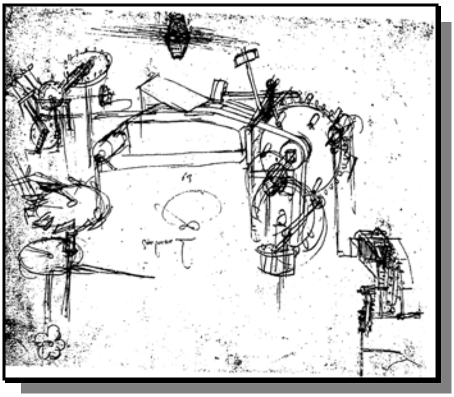
3 	**4** 
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Figure 5a – Leonardo’s textile machines under comparison (part a).

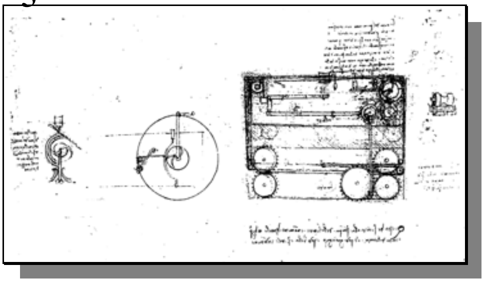
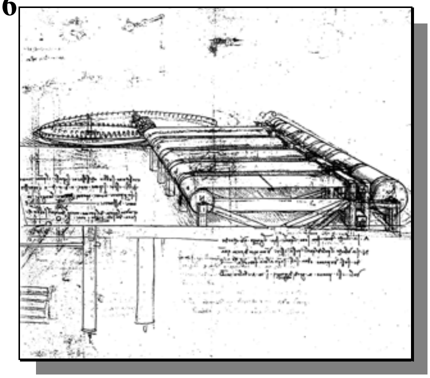
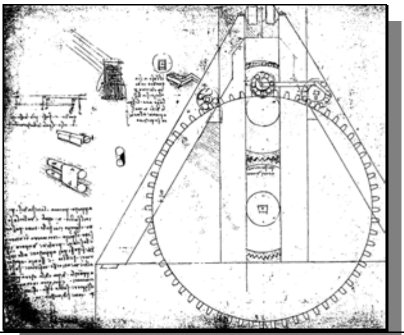
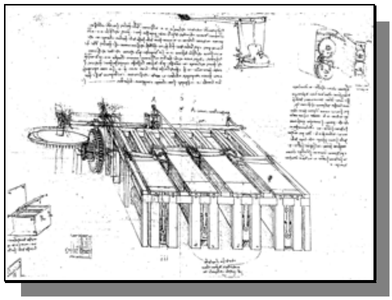
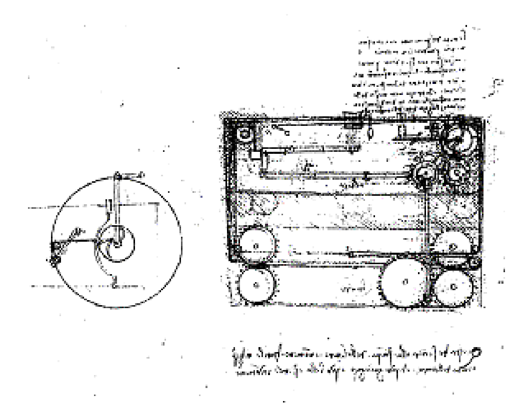
5 	6 
WEAVING MACHINE (TELAIO) C.A. f 985r Other ref. C.A. ff. 753r, 872v, 884r v, 892r v, 985 v.	CONTINUOUS RAISING MACHINE GARZATRICE CONTINUA C.A. f. 106r
7 	8 
DISCONTINUOUS RAISING MACHINE GARZATRICE INTERMITTENTE C.A. 435v Other ref. C.A. ff. 435r e 814v	CUTTING MACHINE (CIMATRICE) *C.A. f. 1105r* Other ref. C.A. ff. 1024r v, 1056v, 1105v, 1107r v.

Figure 5b – Leonardo's textile machines under comparison (part b).

3.4 "Weaving machine" comparison features

The weaving machine is a very complex and fascinating machine that gives a strong idea of Leonardo's capabilities: it is sufficient to give motion just to a primary shaft on a side of the machine and all the weaving tasks (distribute the tread, lift up and move down the heald , guide the shuttle, roll up the tissue etc.) are automatically performed by an impressive combination of mechanisms. In figure 6 the "assembly" drawing of the loom (C.A. f.985r) is shown together with a virtual model reconstructed by the authors according to the studies of Boldetti [18].



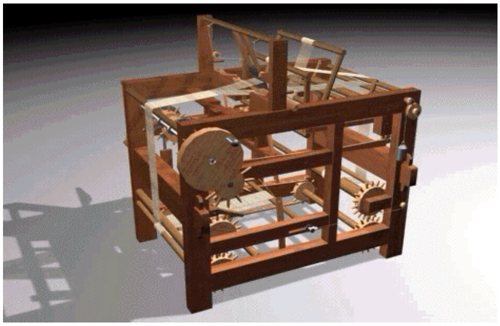


Figure 6- Leonardo da Vinci –"Weaving machine" Cod. Atl. f.985r (left picture) and a Virtual model of a weaving machine according to the studies of Boldetti [18] (right picture).

3.5 Components matrix:

For example are below showed some features selected for the loom :

- "COLLEGAMENTO SOLIDALE AD UN'ASTA": is the joint that allows the warp beam rotation at the connection between the vertical axe and the lever, connected to the warp beam, that drives the stake wheel.
- "COLLEGAMENTO SNODATO TRA 2 ASTE": connections between linkages that drive the heald rise.
- "CAMME": cams driving treadle motion
- "FULCRO": pivot on the machine frame that rotatably holds the linkages for the heald rise.
- "SISTEMA DI ARRESTO": in the high right part of the machine there is a stake wheel and a sheet spring that limits the movement of the shaft holding the cams.

3.6 Kinematics matrix

- "ROT→ALT": is the mechanism that drives the shuttle; more generally, is a mechanism to transform a rotation into a rectilinear alternate motion.
- "TRASMISSIONE MOTO TRA ASSI //": power transmission between parallel shafts (i.e. belts, gears etc.)
- "REGOLATORE AVANZAMENTO CIRCOLARE": mechanism that drives the warp beam; more generally, a system to transform a continuous rotation into a discontinuous one.

3.7 Comparison operators selection

Once that the machines features have been identified, the attention is focused on the selection of relevant Triz operators (principles and evolutionary trends) to be adopted as a comparison means. In facts, it is suggested to reduce the number of comparison criteria in order to limit the analysis time consumption; at the same time it is necessary to take care in order to avoid information loss. This is a critical task that requires a systematic approach, as represented in figure 7.

As a result, the following TRIZ operators survived as criteria for the following comparison.

Principles : 1.Segmentation (seg),2.Extraction (ext),3.Local quality (lql), 4.Asymmetry (asym), 5.Combining (comb), 6.Universality (univ), 7.Nesting (nst), 13.Inversion (inv), 14.Curvature (cur), 15.Dynamity (dyn), 24.Mediator (med), 28.Replacement of a mechanical system (rms);

Trends of Evolution: Space segmentation (sps), Geometric evolution of linear/volumetric constructions (gev), Reducing energy conversion (rec), Mono-bi-poly similar/various objects (mbp), Degrees of freedom (dof), Design point (dpt).

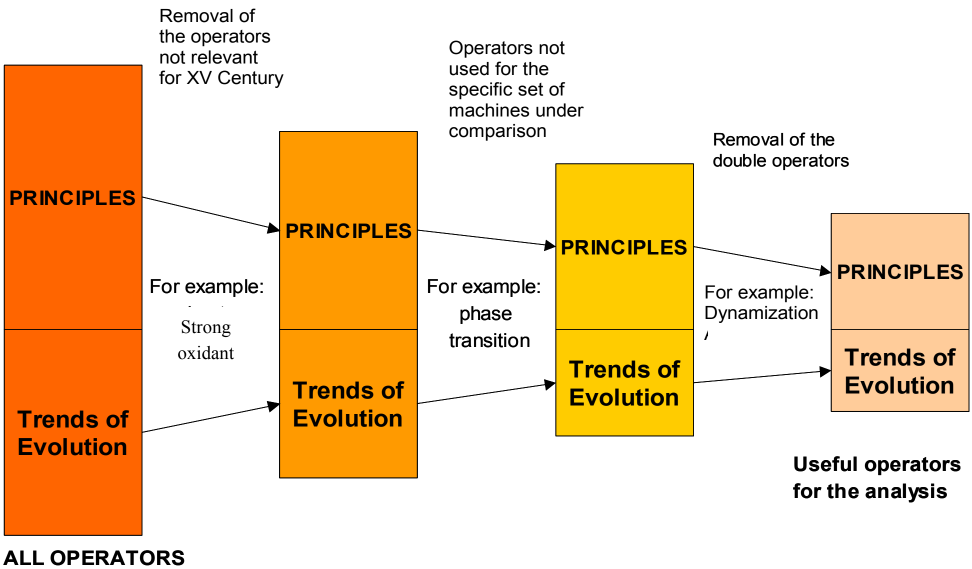


Figura 7 Operators selection path

3.8 Comparison score

Once that both the objects to be compared and the criteria for the comparison have been defined, the method summarized in section 2 can be applied even to heterogeneous machines and the right-top half of the matrix shown in figure 3 can be filled.

Figure 8 reports an overview of its application. Compared with the previous method matrix, in this case each column is further divided into 3 sub-columns containing the comparison elements, the relevant comparison operators and the results of the comparison respectively.

4. Evolutionary score evaluation

The transition from homogeneous to heterogeneous machines requires also an update of the algorithm adopted to elaborate the results summarized in the right-top half of the comparison matrix in order to fill its left-bottom half.

Since each cell (i, j) of the matrix contains all the comparison features shared by the pair of machines i and j, and for each feature all the relevant comparison operators are listed, several different approaches could be adopted to evaluate a resultant score representing an evolutionary balance between the machines i and j:

- Features priority: by summing all the values assigned to each comparison element, it is possible to evaluate the features of the machine *i* that are better/worse than the corresponding features of machine *j*; therefore it is possible to establish the most advanced machine among *i* and *j* by counting the "winning" features.
- Operators priority: in order to identify whether machine *i* is more advanced than *j* or not, the number of principles/trends so that *i* is better than *j* is counted, apart from the comparison elements they have been applied to.

Furthermore, a second choice must be made about how to sum up features/operators score, apart from their priority:

- Algebraic mode: the sum of "winning" features or operators is assigned to the (*i*, *j*) cell.
- Binary mode: a "+1" value is assigned to the (*i*, *j*) cell if the sum is positive, "-1" if negative, "0" otherwise.

By analyzing different practical implementations that could have been suggested by the same principle/trend it emerges that the operators priority technique would neglect relevant improvements applied to a same machine just counting them once, therefore the features priority approach has been preferred. Nevertheless such a choice could misevaluate more complex machines due to the greater number of comparison features (when there is a homogeneous subgroup of machines in a larger set). Therefore, eventually a binary value is assigned to the cell.

The resulting features priority, binary mode algorithm works as follows:

1. in the cell (*i*, *j*), for each comparison feature belonging both to machine *i* and machine *j*, the relevant operators are listed and a score is assigned as described in section 3 (figures 8, 9);
2. the number of comparison features so that the *i*-th machine is more/less advanced than the *j*-th one is evaluated by summing the operators score;
3. by summing the comparison features score, it can be evaluated whether the whole *i*-th machine is more advanced than the *j*-th one or not;
4. in the first case a "+1" value is assigned to the (*i*, *j*) cell, "-1" in the latter, "0" otherwise.

It is worth to notice that the resulting matrix is anti-symmetrical: $a_{ij} = -a_{ji}$. The same procedure can be applied both to components/structural details (COMPONENTS MATRIX, figure 9), and layout/mechanisms (KINEMATICS MATRIX). Eventually, the two matrices are summed in order to evaluate the final evolutionary score of each machine (figure 10). The resulting evolution rank is shown in figure 11.

4.1 Sensitivity analysis

In order to check the sensitivity of the proposed method, the same study has been performed even according to the operators priority approach, both summing the results in algebraic and binary mode. The evolutionary ranks obtained by adopting these different criteria are almost unchanged, therefore confirming the reliability of the method. The only difference is constituted by the discontinuous raising machine “relegated” to the last position, mainly due to the recurrence of the same principles/trends in different components with opposite score.

COMPONENTS

	goldblating	hammer goldblating	spinning	4 speedle spinning	weaving	cont.raising	disc.raising	cutting
goldblating		ruote dentate: gev 1, dpt 1 fulcro: dyn 1 camme: med -1, nst -1, gev -1	ruote dentate: seg 1 colleg snodato tra 2 aste: seg 1, nst 1, univ 1, gev -1 combinazione di + forze: comb 1 n° campi di forze utilizzati: rms 1	ruote dentate: seg 1, nst -1, dpt 1 collegamento solidale ad un albero: dyn 1, cur 1, med 1, nst -1 incastri: med -1, gev 1, univ 1 combinazione di + forze: comb 1 n° campi di forze utilizzati: rms 1	ruote dentate: sps 1, mbp -1, dpt 1 fulcro: dyn 1, med 1, cur 1, nst 1 camme: gev -1 colleg snodato tra 2 aste: med -1, nst 1 collegamento solidale ad un asta: dyn -1, med -1, gev -1, nst 1, dpt -1 sistema d' arresto: inv -1, gev -1, univ -1, dof -1 combinazione di + forze: comb 1	incastri: gev 1 n° campi di forze utilizzati: rms 1	ruote dentate: seg 1, gev 1, dpt 1 sistema d' arresto: nst -1 incastri: gev -1	ruote dentate: seg 1, sps -1, gev 1, dpt 1 collegamento solidale ad un asta: dyn 1, med 1, cur 1, nst -1 n° campi di forze utilizzati: rms 1 camme: med -1
hammer goldblating	-1		ruote dentate: seg 1, lql 1, gev -1, dpt -1 combinazione di + forze: comb 1 n° campi di forze utilizzati: rms 1	ruote dentate: seg 1, sps -1, gev -1 combinazione di + forze: comb 1 n° campi di forze utilizzati: rms 1	forze di richiamo: gev 1, dpt 1 ruote dentate: sps 1, gev -1, mbp -1 fulcro: dyn -1, med 1 camme: med 1, nst 1, gev -1 combinazione di + forze: comb 1		ruote dentate: seg 1, lql 1, gev 1	ruote dentate: seg 1, lql 1, sps -1, gev 1 camme: nst 1, gev 1 fulcro: dyn -1 n° campi di forze utilizzati: rms 1
spinning	-1	-1		ruote dentate: seg 1, lql -1, nst -1, dpt 1	ruote dentate: seg -1, lql -1, sps 1, mbp -1, dpt 1 colleg snodato tra 2 aste: med -1, gev 1 n° campi di forze utilizzati: rms -1	combinazione di + forze: comb -1	ruote dentate: seg 1, gev 1, dpt 1 n° campi di forze utilizzati: rms -1	ruote dentate: seg 1, sps -1, gev 1, dpt 1 n° campi di forze utilizzati: rms -1
4 speedle spinning	-1	-1	0		ruote dentate: seg -1, nst 1, mbp -1 collegamento solidale ad un albero: dyn -1, med -1, nst 1, dpt -1 n° campi di forze utilizzati: rms -1	incastri: med 1, univ -1 combinazione di + forze: comb -1	ruote dentate: gev 1, nst 1 incastri: med 1, univ -1, gev -1 n° campi di forze utilizzati: rms -1	ruote dentate: gev 1, nst 1, sps -1 incastri: med 1, univ -1, gev -1 n° campi di forze utilizzati: rms -1
weaving	0	-1	1	1		combinazione di + forze: comb -1	ruote dentate: seg 1, lql 1, mbp 1 sistema d' arresto: inv 1, univ 1, gev 1, dof 1, nst -1	ruote dentate: seg 1, lql 1, sps -1, mbp 1 camme: gev -1, med -1 collegamento solidale ad un asta: dyn 1, med 1, nst -1, dpt 1 fulcro: dyn -1, med -1, nst -1 sistema d' arresto: inv -1, gev -1, univ 1, dof -1

Figura 8 Components matrix

	goldblating	Hammer goldblating	spinning	4 speedle spin.	weaver	Continuos raisning	Discont. raising	cutting	TOTAL
goldblating	X	0	1	2	-1	1	-1	1	3
Hammer goldblating	0	X	1	0	0	1	2	0	4
spinning	-1	-1	X	-1	-2	-1	0	-1	-7
4 speedle spin	-2	0	1	X	-2	-1	-1	-1	-6
weaver	1	0	2	2	X	0	2	0	7
continuous raising	-1	-1	1	1	0	X	-1	0	-1
Discont. raising	1	-2	0	1	-2	1	X	**-1**	-2
cutting	-1	0	1	1	0	0	1	X	2

Figure 9 Overall matrix

4.2 Results

In figure 10, the evolutionary rank obtained by the features priority binary mode method is shown, according to the results reported in figure 9. The evolutionary rank defines the innovative content of each process phase vis-à-vis with the other process of a textile spinneret.

Arguing about if it can be stated that a more "ideal" machine has been conceived after than another machine with a lower evolutionary score is the object of the authors work in progress; nevertheless it can be certainly claimed that new relevant information are available in terms of inventor's approach and innovative contribution brought.

In order to simplify the data presentation in fig. 10 the textile processes are clustered by homogenous type ignoring further subdivision.

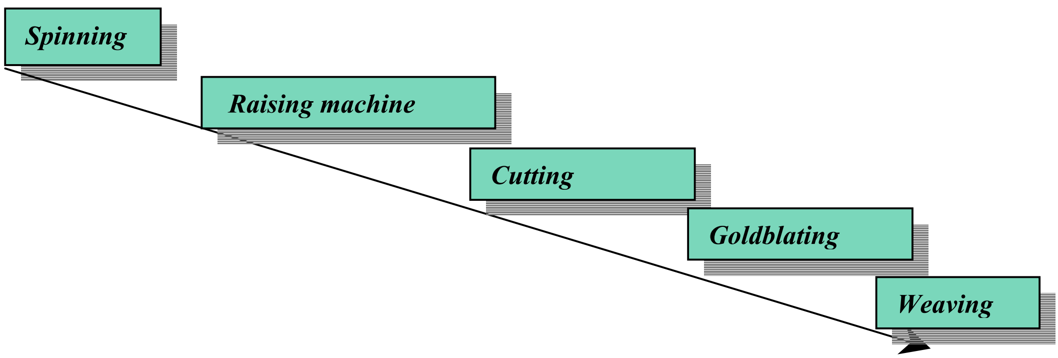


Figura 10 Final evolutionary rank

5. System operator

Once an innovative level is assigned to each process of a whole productive spinneret by means of the previous method, it is possible to introduce a new analysis: “the system operator” allows a deep investigation about the information readable from historical technical drafts.

The System Operator ‘tool’ hints approaching the analysis of a system taking into account the variables TIME and SPACE, by means of 3x3 screen. The central box of the nine screens – system, present – is the one the brain naturally migrates to whenever a problem is to be solved. The System Operator is useful throughout the problem solving process, problem analysis, opportunity finding, exploiting creativity spectrum; it is a useful means to help looking for resources, identifying constraints, specifying the design requirements during the problem definition process; it is used during idea generation when connecting TRIZ solution triggers to the given problem situation .

In this case the system operator is proposed to frame each textile activity.

Each machines is analyzed as below showed:

SPACE ANALYSIS

Macro system (M): machine environment, from the physical place where the machine was positioned to the human factor (workers, social and technical environment).

System (S): the machine and its products

Micro system (m): Machine components and their contribution.

TIME ANALYSIS

It should be observed that the proposed classification is slightly different from the usual System Operator approach

Past (p): The first column contains what existed before the ideation of the machine, inventor’s experience, studies, analyses, potential sources of inspiration.

Present (P): The second column contains all design aspects, more specifically about the proper function of the machine.

Future (F): The third column contains information about the practical realization of the machine: reliability, efficiency, product business etc.

The idea is to frame each machine in a wider context to obtain a schematic vision of the whole work of the inventor and to quantify his innovation domain. Crossing these data with the information derived by the evolutionary score classification, it is possible to clarify if, in the inventor’s mind, there was the idea to perform the same function by means of a more efficient process or to develop a brand-new system.

More specifically, each screen can potentially provide suggestions about the inventor’s intention, about the aim of the intervention, the maturity level of the solution etc.

6. Results

An exemplary study by means of the 9 windows method is reported in figure 11, where it is examined a Leonardo’s design of a Goldblating machine.

The machine has been detailed as a whole in its environment and in terms of its constructive details, and the motivation for each characteristic has been evaluated in terms of the machine working (present), its manufacturing (past) and its long-term usage (future).

In this case it is easy to deduce from the resulting table that Leonardo's intention was to ameliorate a pre-existent machine (in facts he was studying a lot of aspects concerning maintenance).

His action has been aimed at improving several functional areas of the machine at different detail levels, as demonstrated in the plurality of drafts regarding a Goldblating machine.

It is worth to observe that the most interesting interventions have been found at the Macro level, with several studies aiming at the adoption of a primary motion source. As a consequence it can be suggested that Leonardo used to have a vision of a whole textile spinneret totally independent by manpower.

	past	present	future
Macro system		Primary motion source + Max autonomy + Parallel Production + Manpower cost +	
system		Different design + Rectangular slab +	
Micro system		Counterweight value +	
		Thread interchangeable + Maintenance Indication + Replaceable parts +	

Figure 11 Result table about the Goldblating machine analyzed by the System operator method

The whole textile process has been analyzed with the System Operator and the results combined with those obtained at the end of the evolutionary rank analysis, but only partial conclusions will be reported in this paper, since the whole research will be presented in a monograph for the new building of the Leonardo's museum in Vinci.

According to the above conclusions, Leonardo was the first to attempt the development of such a technology with the aim of "textile automation", therefore anticipating by almost three centuries the combination of steam power and textile machines as developed in United Kingdom with the First Industrial Revolution.

The studies about the history of textile processes are quite difficult since at that time innovations were opportunely hidden in order to preserve industrial secrets: in facts no rules were available for protecting Intellectual Property, apart few not relevant exceptions. According to an accredited tale, at the beginning of the XVIII century an industrial English spy brought in England the secret of the mill and thanks to skilled Italian native workers he built in Derby a big bristle mill. In accordance with several researchers studies, it could have been the first modern industry in England.

7. Conclusions

In this paper a TRIZ based analysis method of Renaissance machines has been proposed to aid historians classification. The methodology has been applied to textiles machines with a low degree of homogeneity. The combination of evolutionary score and 9 window analyses allows a deep and novel retrieval of historical information to be extracted from technical drafts of Renaissance engineers as demonstrated with a set of Leonardo's sketches.

The reliability of the method has been further checked by comparing the obtained results with the historical data provided by the experts of the Leonardo Museum in Vinci. It must be mentioned that there are few data available; at the same time such a situation gives a greater relevance to the proposed method.

The work is still in progress and further results will be published in the next future in conjunction with the Leonardo Museum in Vinci.

Acknowledgments

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SYSTEM APPROACH TO FAILURES OF TECHNICAL SYSTEMS

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Abstract
This work is devoted to the TRIZ-based analysis of the technical systems failures. The basic reasons have been revealed. The ways of preventing accidents and catastrophes were looked at. A TRIZ-based approach to the enlarging the assortment of insurance services was proposed.
Keywords: TRIZ, systems, evolve systems, breakdown, destruction, "sabotage analysis", application in business
Nomenclature:
SAT - System Analysis Technique.
TRIZ - Theory of inventive problem solving.
TS - technical system.
MATCEM: Mechanical – Acoustic – Thermal – Chemical – Electrical – Magnetic.

1. Introduction

Theory of inventive problem solving (TRIZ) basically investigates only evolving systems, accumulates only successful experience of several hundred thousands of inventors. Nevertheless, terrorist activity, accidents and catastrophes on the ground and underground, in the air, on water and under water which occur more and more often lately, are the threatening notification for mankind. Something is wrong here…How to understand – what is wrong exactly? Is it possible to understand? If it is so, then how to do this? How can we prevent accidents and catastrophes?

2. The system analysis of refusals of technical systems

We think in many different ways when we look at the same problem. Everyone takes into consideration his own context of examination.

Example 1.
- For a designer a bicycle is a new technical system..
- For a manufacturer a bicycle is a kind of production.
- For a transport company a bicycle is a kind of cargo.

- For a storehouse a bicycle is an object of storage and loading-and-unloading work.
- For a retailer a bicycle is an article which is to be sold.

…

- And for a customer a bicycle is an object to satisfy his needs.

Obviously, each participant of the "life cycle" of the "Bicycle" system has its own point of view at this system, takes into consideration his own context. These different contexts are often not coordinated between each other.

Example 2.

Let us assume, that our country needs a new submarine to be constructed.

- The government will place order at different plants,
- Constructors will search solutions of many technical problems,
- Technologists will rack their brains over the question how to accelerate the process,
- The military will desire to fit out the submarine as better as possible to defend it from enemy attacks.
- Psychologists will think over the future crew…

That means each participant of the construction will be looking at his own narrow piece of the common project. Each specialist thinks within "his own context". It is not so easy to join all these pieces at the final stage… Any divergence when constructing a complex technical system (TS) may result in future accidents.

Like new systems, new knowledge, new concepts arise at the junction of different sciences, hazards and emergencies occur at the junctions of different branches of technology, different contexts of existence or different contexts of examination and modeling of technology and the same system. In either case something new springs up often by chance. With the only difference that in the former case the consequences are estimated positively, while in the latter case – negatively.

Wise Bernard Shaw said: "Narrow specialization in a broad sense lead to a broad idiot making in a narrow sense." How to avoid this "idiot making"?

To evolve systems (technical, social, economic, etc.) we need to know – what "a System" is. Here is a classic definition of "a System" by Alexander Bogdanov: **A System is the aggregate of elements and bonds between them which possess properties not limited to the sum of the properties of the elements.**

In other words, the entity is more than just the sum of parts. Elements are "the bricks" that make up "a System", bonds between them – are "the grout" that join them. "A System" must comprise two combined and interacting with each other elements (sub-systems) at the minimum, which develop a new "system property". This new "system property" is often called an extra net effect or synergy. If we add the third element E3 to the existing system and organize new interaction giving new extra net effect, we'll get a new, more complicated system "SYS2" , which will be a super-system for SYS1 and E3.

It should be pointed out that a system property – is a new property of an aggregate of elements which were independent at first, combined in a new "System" with their new bonds. The elements may be material, and then we make up machines, gearing, devices. The elements may be non-material (ideas, concepts, etc.), then we build up mental models, create scientific theories, knowledge systems.

If "a System" comprises people as elements, then we make up teams, groups, firms, political parties and public organizations…And a human being is fundamentally a non-linear element of a system. His behaviour , especially in emergencies, is often non-predictable.

On the 11^{th} of July, 1910, the USA's submarine "C-4" during exercise had to attack their own ship-base "Carstine". The captain commanded to the first mate officer "to cut "Carstine" through", that means the SM had to go through under the ship's bottom. Nevertheless, the first mate officer understood the command literally. In some time the periscope cut into the planking of the ship and made a big hole in it…

How to analyze emergencies and accidents?

Obviously, three possible reasons cause the loss of a system property by the system:

1.Breakdown, destruction (even partial) of Element 1;

2.Breakdown, destruction (even partial) of Element 2;

3.Breaking of bonds between elements E1 and E2;

If a system comprises three elements the following reasons should be added to the list:

4.Breakdown, destruction (even partial) of Element 3;

5.Breaking of bonds between elements E1 and E3;

6.Breaking of bonds between elements E2 and E3;

7.Initiation of unforeseen (parasitic) bonds between the elements of the system.

Obviously, as the complexity of the system increases, the number of possible failures increase non-linearly. If we take into account only failures of N elements and breaking of only pair bonds, the number of all possible failures W will be proportional to N + N!/2 (N-2)!

However, the bonds may be not only arranged in pairs, but more complicated. Then the number will still further increase.

But this is not the whole story! As the complexity of the system grows, the side system properties which are undesirable and harmful may arise (and almost always arise!). These "parasitic systems" are usually left out of consideration by the creators of the system when making up a new system. Who thought about automobile-exhaust pollution when the automobile was built up? Who considered the emergence of the destructive flatter when the supersonic plane was built up?

Example 3.

The electric power system is a necessary component of a "Submarine" system. Power cables run through all the compartments of a submarine. When emergency occurred at the "Komsomolets" submarine (on the surface!), one of the compartments caught a fire. The crew had hermetically sealed the damaged compartment rapidly. Nevertheless it appeared, that power cables perfectly conduct not only current, but… flame as well! In a few minutes the whole submarine was enveloped in flames and had sunk. In terms of TRIZ the existence of a “Chemical field” in the cables’ isolation was left out of consideration.

It would seem, this sad experience is to be taken into account. On the contrary! Flames still travel through power cables of submarines! And not only submarines! Remember, why the Ostankino television tower in Moscow was burnt down…

And the story is not complete! It is not enough that when the number of elements grow, the number of bonds sharply and non-linearly increase, and consequently the probability of failure rise too. One more effect hidden for the time being, that is till emergency, shows itself. The more complex is a system, the greater number of elements has it, the more is its dependence on super-systems. The most simple technical system - “a hammer” is not affected by earthquakes. A complex system “a city” depends on a super-system resources: water supply, heat supply, electric energy delivery, etc. Shortage or absence of some of these resources leads to the disruption of normal operation, that causes emergencies and accidents. Besides, the builders of the city must take into account the possibility of earthquakes and take the appropriate precautions.

Moreover: human activity sometimes unpredictably affects super-systems.

Example 4.

A case is known, when making a huge reservoir in the USA brought to the settling of its bottom. A real earthquake struck! The dam was destroyed. The water flow wiped several settlements off , people died…

From the above analyses follows that the probability of failures in a system dramatically grows, when the complexity is added. The absence of risks is possible only if the system has lack of energy supply, chemically and biologically active components. So:

1. It is impossible to make absolutely reliable TS;
2. The possibility of the human operators mistakes must not be ruled out.
3. It is impossible to take into account all external factors affecting the accident rate.

It turns out that all possible reasons even impossible to enumerate.! Yes, it is so. And that is why accidents and catastrophes occur. Obviously, it is impossible to prevent them completely… But we can and we must reduce the probability of their occurrence!

In order to reduce the probability of accidents, to decrease the level of “idiot making” it is necessary to thoroughly analyze elements of systems and bonds between them. How to analyze systems? How to make system properties to manifest themselves and use them properly? How to avoid accidents and catastrophes?

A powerful tool for analysis of TS was worked up in TRIZ: System Analysis Technique (SAT). SAT allows to see possible “harmful systems” beforehand, at the design stage. A special “sabotage analyses” was also developed in TRIZ.

From some common considerations it is seen how we can reduce the probability of failures in any system:

1. The enhancement of reliability of separate elements of a system. TRIZ shows the transition to the more reliable, more “ideal” systems. This is the line of evolution “mono-bi-poly-“.

   Example 5.

   Separation of a submarine into hermetically sealed compartments drastically increased their stability.

2. The enhancement of the reliability of bonds between elements of a system. More often it is duplicating of systems, especially control systems. (It is very expensive and not always a help).

   Example 6.

   The control system of the space shuttle “Challenger” had six reserve systems. However a stream of plasma forced its way through the seal of the solid-state accelerator, cut the pylon of the fastening off. Together with six reserve systems. All the mankind knows what happened further.

3. Simulating of a system’s behaviour in emergency is one more powerful tool. The use of SAT at the design stage, taking into consideration already happened failures, allows to reduce the probability of emergency. It is necessary to test tolerance of all elements of a system and bonds between them for sharp changes of external or internal influences. This is a known sequence of fields in TRIZ: Mechanical – Acoustic – Thermal – Chemical – Electrical – Magnetic (MATCEM).

   Example 7.

   The power cable in a submarine is intended for conducting the flow of electromagnetic energy (EM). And it must be mechanically strong (M), hermetically sealed and resistant to great pressure differentials and vibrations (acoustic – A), stable to thermal (T) actions (cooling off, heating, burning), neutral to chemical (C) attacks (chemical reactions, oxidation, combustion, decomposition, etc.)

   Until such simulating is not carried out or is carried out by the trial-and-error method, accident rate will grow. It is necessary to carry out system analysis of the former accidents and catastrophes.

4. It is necessary to count up or even to forecast the appearance of non-linearity in models of physical phenomena and processes.

   Example 8.

- Everyone knows the Ohm’s law. However it doesn’t work when currents are too weak – non-linearity comes into action, caused by fluctuation of electron density in conductors. When currents are too high it doesn’t work as well – conductors fuse and convert into plasma – into detonating short wires. And at extra-low temperature the resistance of the conductors disappears completely – the phenomenon of super-conductivity appears.

- At high-powered laser emission “self-focusing” phenomenon appears – medium refraction factor becomes non-linearly dependant on the power of emission. In that case the medium converts into plasma at a point of a laser beam focusing. Even air does it!

Basing on this, a very clear procedure for analysis of elements of systems and bonds between them may be suggested.

In rows of theTable 1 all possible fields (MATCEM) of interaction between elements (sub-systems) of the system are listed to be examined. Each of these lines may be divided into several ones, in accordance with different types of possible interaction between elements.

Example 9.

We can examine a mechanical field in a following way:

- Constant field;
- Gradient of the field in vacuum;
- Overfall of the field;
- Variable field;
- Impulse field (push, stroke);
- Etc.

Example 10.

Let us assume that “element 1” is a power cable. It is evidently intended for transmitting electromagnetic energy from a generator to the user. However, it is not apparent that it will be heavy-duty. And what about pressure drops? And temperature rising? Will it burn? What products of burning will be emitted? Will they be toxic? And so on.

Element Field	Element 1	Element 2	Element 3	Element 4	Element 5	…	Element N
Mechanical	?						
Acoustic	?						
Thermal	?						
Chemical	?						
Electrical	+						
Magnetic	+						

Table 1. The morphological table of elements and fields in system

Elements (sub-systems) of the system to be examined are in columns. All the existing and possible interactions of the elements with the fields are to be shown in table cells. This easy method of analyzing possible interactions allows to examine and forecast if only apparent for TRIZ phenomena in a system way. By this means the probability of failures of a system sharply comes down.

3. Application of MATCEM… in business

Any accident, emergency or catastrophe may be considered as an “insured accident”. We have carried out a systematization of a great number of possible physical and biological influences on different objects (“elements” in Table 1): on a human being, movable and immovable property, industrial objects, etc.

This work has resulted in a table, containing more than a thousand possible variants of insured cases. It is to be noticed, that even big insurance companies in Russia very rarely propose more than 70 kinds of insurance…

Example 11.

Where can the risk of influence of the mechanical field in a form of differential pressure upon human’s life or health arise? One of the Novosibirsk insurance companies has found a small group, about 30 persons, for whom this risk exists every day. It appeared to be a group of divers, repairing piers of the bridges across the river Ob, monitoring the condition of the dam (hydro power station), repairing under-water parts of ships, laying underwater pipelines and so on. All of them were insured against caisson disease. The company has got a great profit.

4. Conclusion

Besides, we have developed a method for analyzing and designing systems, including all basic TRIZ components: system and functional analysis, contradictions of different levels, ideality, laws of evolution, resources, etc. We have designated it “Solvers Technology”. It helps to solve the problems of reducing an accident rate of any systems in a system way. The foundation of this approach was already presented in our report at the conference ETRIA-2001 [1].

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MEDICAL EDUCATION OPTIMIZATION BY NEW PIONEERING TRAINING

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The most powerful obstacle to self-improvement is an assurance in own correctness.
Hans Selye

If the sabre is short,step forward it will be lengthened.
The Georgian proverb

Abstract
Diagnostic skill of practitioners' optimization has direct impact on the health of population worldwide. Traditional professional medical education deficiency due to Didactic training problems, and Diagnostic decision-making problems.
Didactic Training Problems**.** There is a great methodological difference between general and professional education. However, medical professional learning for disease diagnostics use the same levels of knowledge and didactic systems that are used in a general school education. Therefore, a real professional mastering cannot be forming.
Diagnostic Decision-Making Problems. Traditional medical education has been based on the nosolo-gical intellectual system, which is oriented to maximal memorization of special information. It starts with disease diagnosis and goes to symptoms/signs. In real life, the opposite situation takes place - from revealed symptoms/signs to diagnosis, i.e. vice versa.
The objective is the development and testing of the most effective original Self-Learning Expert Systems/Tools (SLEST) for optimal professional training of medical diagnostics to every learner.
Methods: Innovative intellectual approach to medical diagnostic decision-making has been suggested.
Results. Comparative evaluation of conventional and offered innovative methods of diagnostics and professional training shows significant advantages of the innovations.
Conclusion: Mentioned problems can be solved successfully by computerized diagnostics based on algorithmical syndromic disease recognizing, and` mass professional education based on eLearning.

Keywords: Professional training, Didactic systems, Diagnosis, Algorithm, Self-learning.

Used abbreviations: **DS** - Didactic system; **DDA** - Differential Diagnostic Algorithms; **AES** – original Aesculapius Medical Diagnostic Expert System; **s/s** - symptoms and/or signs; **SLEST** - **S**elf-**L**earning **E**xpert **S**ystems/**T**ools; **ES** - Educational System.

Nomenclature:
1. The term ***"diagnosis"*** has two definitions: 1. The intellectual process for a disease recognizing; 2. The nosological meaning - determining the nature of a case of disease. To distinguish between

these meanings, we use two different terms: Diagnostics - an intellectual process, leading to diagnosis. Diagnosis - the result of diagnostics.
2. ***Differential diagnostic algorithm (DDA***) is a determination step-by-step operations for establishing diagnoses of all diseases, based on leading syndromes, major s/s, such as chest pain, fever, jaundice, round shadow on chest x-ray, etc.
3. In western medical literature the term ***"syndrome"*** means usually a disease named by the author describing it first, e.g. Reiter's syndrome, etc. Here the term "syndrome" used in it classical meaning as "A group of symptoms that collectively indicate or characterize a disease" (On-line Medical Dictionary, © 1997-98 Academic Medical Publishing & CancerWEB). Then "syndromic reasoning", "decision-making by syndrome" means a certain intellectual actions with diseases manifested by this given syndrome, e.g. a chest pain, jaundice, etc.
4. ***Didactic system (DS)*** is a certain complex of methods and tools of the management by cognitive activity of every several learner in given learner group.
5. ***eLearning, e-Learning, elearning.*** Below the definition from the Internet presented (http://www.idc.com Document #: 23283, Publication Date: October 2000, Published Under Services: Corporate eLearning).
eLearning is a well-used word these days. A good, working definition for "e" - anything is "electronic" or "Internet-enabled." Internet-enabled learning, or elearning, strictly means learning activities on the Internet. Those events can be "live" learning that is led by an instructor or "self-paced" learning whose content and pace are determined by the individual learner.

1. Introduction

Among many hundreds of professions, there are some of them, which have been considered as dangerous due to an effect upon life and health of many people of the activity of such professionals. Professions of pilots of passengers' airliners, captains of marine, river passengers' ships, locomotive drivers of passengers' trains, and even bus' drivers. A profession of a physician could be assigned to the category of dangerous professions. Life and health of hundreds of million of people directly depend on diagnostic skill of practitioners. Therefore, a diagnostic skill of practitioners' and medical professional training significant optimization has a direct impact on the life and health of the population worldwide. It is obviously that representatives of dangerous professions need in the highest level of professional education, constant improvement of their skills during their entire professional activity. What is a real situation? If it is not optimal, then how it could be solving the best?

The author had worked out 15 original scientific and methodological ways, trends, branches, and 70 methods of professional medical education optimization (150 publications, including many books, textbooks and guides). This article, and obtained outcomes (Table 3) based on of many years comparative evaluation between of the traditional learning, and several the most effective original optimal methodologies.

2. Didactic and training problems of medical education

Dissatisfaction by the existing diagnostics level is the cause why ways for improvement of healthcare and medical education seeking for permanently. Great hopes are put on modern medical equipment and contemporary communications. Among various technical innovations, special attention has been attracted to computerized distance learning, i.e.

eLearning. Last years enormous literature dedicated to distance education appears. Strong attention and efforts has been applied to initial and continuing medical education improvement, including eLearning. Here almost all technical modern tools are used - remote telephone- and video-consultations of very skilled experts, video-conferences, video-discussion groups for complicated patients diagnostics and treatment, presentation to users of appropriate special medical information on CD-ROM, via Intra-net and Internet, computer-assisted instructions, etc. Local and international networks have been developing, and improved constantly.

Distance medical education has a high practical meaning. Near 80% of physicians are internists, mostly family doctors. Majority of them works in remote medical establishments located far from large university clinics and medical centres. For example, over 50 million people in the United States (about 20% of the population) live in rural areas, but only 9% of the nation's physicians practice in rural communities

Enormous number of researches in the fields of distance education and large funding of these innovations allow expecting clearly manifested outcomes, demonstrating significant improvement of medical skill in professional activity caused by eLearning. Meanwhile, study of enormous new worldwide literature receiving from Internet and Medline-Express shows quite unexpected and surprising situation. However, in reality better professional skill of remote medical learners did not achieved. Why?

The following caused a lack of success. **1)** Ineffective nosological approach to given information had been remained. **2)** Mentioned numerous researches were dedicated to improvement of various simple medical procedures but not to diagnostics and treatment optimization. **3)** eLearning was addressed not to intellectual activity of learners but to better fulfilment various manual procedures. In other word only I-II levels of training was used. **4)** Real strong testing of the existing learners' skill before and after eLearning did not performed.

However, between visible manual and invisible intellectual professional activity of a physician is the greatest difference in principle. Effective diagnostics and treatment are the products of intellectual activity. Therefore, for effective learning, must be used different methodologies and technologies. Short theoretical outline needs for deeper penetrate to this problem. It is presented below.

Thus, modern technical achievements cannot to optimize independently of a diagnostic intellectual activity. What is the matter? Where is the main cause of such situation?

The causes of medical education inefficiency are the following. **1)** Use the same levels of knowledge and didactic systems that used in general school education; **2)** Use the I-II Levels of Learning cannot provide of a professional mastering; **3)** Use ineffective Didactic Systems cannot provide a professional mastering to every learner; The most difficult in medical education are diagnostic and training problems.

The Table 1 reflects modern didactic concept. In the Table 2 the Classification of the Didactic Systems (DS) has been presented.

Study level	Name of study level	Specification of the learning activity (characteristics of the level)
I	**Knowledge-acquaintance**	**Identification, recognizing, distinguishing**
II	**Knowledge-copying**	**Reproductive activity (reproduction of Information by memory or meaning)**
III	**Knowledge-Mastering**	**Productive activity using knowledge for practice related to known objects and situations**
IV	**Knowledge-transformation**	**Innovative and creative activity**

Table 1. The levels of a learning/knowledge

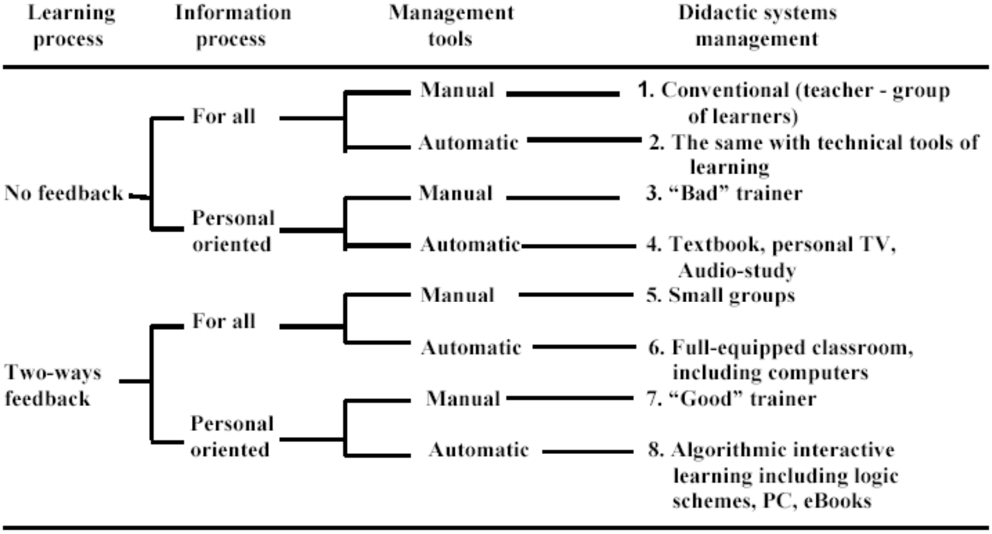


Table 2. Classification of the Didactic Systems (DS)

So, the Table 1 shows that only the III level, which differs methodologically from the I-II levels in principle, can obtain a professional mastering in any field of a vocational training. A difference between of professional and general school education and, control is clear and simple. A principle of professional work is "A professional task or problem – correct solution". A school principle is "A question - answer". IV level (creative activity) is not required in mass professions training, because here a decisive significance has a personal creative abilities.

The main objective in medical education – to provide a professional mastering to every learner. A success in this problem completely depends from the Didactic System.

It is clear from the Table 2 that ineffective DS "A teacher - many students" has providing to EACH student only I-II levels of knowledge. Effective intellectual diagnostic doctor's work, i.e. knowledge mastering of III level cannot be formed by methods of I-II study levels in principle, even theoretically. Among of eight existing Didactic Systems there is the only DS (#8) ensuring of optimal professional training to every learner, i.e. Two-ways feedback

Personal Oriented Automatic Algorithmic Interactive Learning, including logic schemes, PC, programmed eBooks. Just this DS is optimal.

Thinking is tragically invisible.
D. Miller, Yu. Galanther, K. Preebram.

3. Diagnostic problems

Hundred of millions of patients visit physicians daily. One out of four people in the USA suffer from heart or blood vessel disease, i.e. 68 million Americans. Half a million people dies from heart attacks yearly and nearly half of these people are younger than 65 [13]. More than 3 million patients are hospitalized yearly in the US for chest pain [31].

The cost is over $3 billion just for those found to be free of acute disease [30]. However, many diagnostic errors have been encountered in outpatient clinics, emergency departments, and even in large medical centres. From 25% to 87% diagnostic errors have been described at various diseases in various medical establishments [7,11,32]. Enormous financial expenditures take place for superfluous medical examinations. E.g., among patients with chest pain suggestive of Myocardial infarction who are referred for coronary arteriography, up to 30% have no detectable major vessels disease (300,000 normal coronary arteriograms annually!) [8].

The main cause of unsatisfactory state of disease diagnostics has been explained below.

Define meaning of words, and you
save the world from half of its mistakes.
René Descartes

4. Important conception "Algorithm"

There are various wordings of the term ***"algorithm",*** in particular, presented in Internet. ***"The term "algorithm" is a procedure or formula for solving a problem". "The algorithm is a set of rules for solving a problem in a finite number of steps".***

It is very surprisingly, but majority of publications dedicated to various algorithms for diagnostics and treatment of diseases has not true algorithms. Only schemes, containing trees with "yes-no" elements have been presented there without solving of a final problem. These schemes contain of recommendations to execute of certain exams, to define the presence or absence of certain signs, etc. However, the solving of the main diagnostic or treatment objective – the final diagnosis establishing or the most effective treatment of considered diseases is absent.

The first and the most difficult problem is a diagnosis of the disease establishing among several, or even many of probable diseases. Just only for the solving of this problem the algorithm needs. In other words, a true algorithm, and the term "Diagnostic Algorithm", "Differential-Diagnostic Algorithm" must be only use for differential diagnostics between several similar diseases.

Meantime, majority publications have just such senseless headings as **diagnostic algorithm** where the "algorithm" is used for the only disease diagnosis, e.g. myocardial infarction [28], aspergillosis [9], anorexia nervosa [6] traumatic aortic injury [9], gastric cancer [29], and many other.

Taking into account the practical importance of the conception, on the one hand, and the ambiguous serious situation with the term and the meaning of the “algorithm” the author’s wording below significantly differs from other ones.

"Differential Diagnostic Algorithm (DDA) and Algorithmization of Diagnostic Decision-Making is the exact comprehensible prescription for stepwise fulfilment of elementary intellectual operations and actions in the optimal sequence for establishing of diagnosis of all or majority of the most important diseases, manifesting by given leading syndrome” (See Fig. 1a-1c).

5. Principles and features of Differential-Diagnostic Algorithms

It is necessary to consider the four main characteristics of the true algorithm. This task has not a theoretical or terminological sense but very important practical clinical meaning.
The true Differential Diagnostic Algorithm (DDA) has the following main features:

1. Definiteness, i.e. ***simplicity and having a single meaning*** of its intellectual operations step-by-step.

2. Mass character, i.e. given algorithm should be ***applicable to all diseases manifesting by given leading syndrome.***

3. Efficiency i.e. ***obligatory establishing*** of the ***diagnoses*** of all diseases, for which the given algorithm is designed (under the condition of correct recognizing of symptoms/signs contained in the algorithm).

4.Partition of process of diagnostic thinking on elementary clear intellectual diagnostic operations located in an optimal sequence.

Listed features of an algorithm required of some explanations.

1. Medical information is not simple and ***has not a single meaning***. If several students or doctors will carry out the auscultation of a heart the same patient, then various members of the group will present usually different diagnostic interpretation of the heard signs.

Such situation is observed frequently in practice of medical group consultations when even experienced doctors have detected different s/s and establishing the different diagnoses at the same patient.

2. Nosologic classification of diseases is unsuitable for universal mass diagnostics of the whole class of diseases. It is impossible to create a DDA for diagnostics of the e.g. acute MI (AMI), although, as mentioned above, just this surprising situation has been present in the literature.

For this reason, the syndromic principle of diagnostics is the only basis for development and use of DDA. Each class of diseases is precisely designated by concrete syndrome. The different classes of illnesses are precisely differentiated (inter-syndromic differential diagnostics, Fig. 1a). Then the same task for diagnostics of the AMI looks completely differently. ***Not as the DDA for the AMI diagnostics*** *but as the “****Differential diagnostics of diseases manifested by acute chest pain"***. At such decision-making of a diagnostic problem by means of algorithm will be recognized ***all diseases, accompanying by this syndrome including of the AMI as well.***

3. It is generally known, that the diagnostic efforts of a doctor can remain without result, i.e. the diagnosis is not established (zero result) despite of spent efforts, time, many of different examinations, etc., or the diagnosis is wrong (erroneous result). In any case a required result (correct complete diagnosis) has been not achieved.

ADD provides the efficiency of a task decision, i.e. ***establishment of the final correct diagnosis of all diseases***. The only basic requirement is a correct detecting at a patient of the s/s, which are presented in the algorithm. It is clear, if the s/s are detected incorrectly then the diagnosis will be erroneous.

4. The partition of a complex process of diagnostic thinking to the elementary consecutive operations is one of the most important conditions of the successful decision of typical tasks. The diagnostic decision process has been divided up to such small simple elementary steps-signs, that the opportunity of a mistake at the decision of every of them is very small. On the whole the successful decision of very complicated intellectual diagnostic task is reached step by step in optimal sequence.

A DDA is not something completely new in clinical medicine. Its creation is based on the well-known standard examinations, symptoms and diagnoses of diseases. However, a DDA is the qualitative new achievement of a clinical thinking. That is why the use of the algorithm for practical diagnostics of diseases gives the new unusual results in principle.

So, any logical design, which was planned as an algorithm, but is inadequate to these four principles is NOT a true Differential Diagnostic Algorithm (DDA), and cannot be use for disease differential diagnostics.

The knowledge of some principles easily
compensates ignorance of some facts.
Claude Adrien Helvetius

6. Innovative intellectual approach to medical diagnostic decision-making

It is well known that diagnostics of diseases as a branch of science is based on three trends:

1. Medical diagnostic technology (engineering, equipment, etc.);
2. Symptoms/signs of diseases, their significance and value in a diagnostic process;
3. Peculiarities of clinical decision-making in intellectual diagnostic process.

1) Medical diagnostic technology. During the past few decades greatest achievements have been obtained in this branch (various X-ray applications, US, CT, MRI, various laboratory tests, biopsy, etc.). All these discoveries and inventions allow obtaining directly the most convincing signs of diseases. As a result a great improvement in the quality and accuracy of diagnosis was achieved, on the one hand, but significant increasing of the number of diagnostic examinations, their duration, and costs of diagnosis, on the other hand. A delay of the final diagnosis, many social problems, many difficult psychological problems both of patients, and of physicians, a general increase in the cost of health care, etc. is caused by this circumstance.

2) Symptoms/signs of diseases, their significance and value in a diagnostic process. This branch gives slow results, and is not effective enough, because medical literature describes all diseases traditionally: first a diagnosis (the disease's name) and then its description, in particular clinical manifestations (symptoms/signs). Herein lies the greatest problem because many different diseases manifest by the same or similar symptoms and signs (chest pain, abdominal pain, headache, fever, arterial hypertension, etc.). So, the real work of the physician is doing the opposite. Clinical reasoning moves not from diagnosis to signs as in textbooks, monographs and lectures. It moves from the patient's revealed signs through differential diagnosis of all probable diseases with the same or similar manifestations to the most probable diagnosis, i.e. vice versa. Conventional diagnostic methodology assumes that each physician has in his mind a catalog of all diseases, all their manifestations, and all criteria for fast and precise differential diagnostics. It assumes as well that a physician has unlimited time for intensively analyzing of every patient's problem.

Thus in this branch, there are many unknown factors. The most valuable (decisive) signs of each disease must be identified for discriminating between of each clinically similar disease.

3) ***Peculiarities of clinical decision-making in intellectual diagnostic process.*** This branch is not highly developed in practice. However, these 2) + 3) two branches allow to realize the revolutionary optimization in the most complicated intellectual field of clinical decision-making.

The optimization of clinical thinking is based on very important transformations. The first transformation is moving from a conventional clinical reasoning to much more effective and more economical evidence based decision-making. The second one is a selection of minimum decisive s/s for each disease. The third stage is a DDA developing using selected s/s for algorithmical decision-making. There is also very effective and promising the fourth stage - the transformation of previous three innovations into a computerized diagnostic or/and training expert system.

Thus, three optimal principles of diagnostic decision-making used for the most effective diagnostics. This approach essentially differs from traditional diagnostic decision-making and provides optimal diagnostic outcomes [15-25].

a) Syndromic based diagnostic decision.

b) Minimum decisive symptoms and signs detection.

c) Differential diagnostic algorithm for shortest **and fastest differential diagnostics of ALL or majority diseases having given manifestation (syndrome). Only the combination of all three principles (a+b+c) provides the best results in the intellectual diagnostic process diagnostics by syndrome) is very important and promising because many various diseases with different pathologic processes have the same or very similar clinical, laboratory, etc. manifestations. Moreover, the same disease may be present with different syndromes or large symptoms/signs e.g. chest pain, arterial hypertension, fever, cough, chest X-ray picture, etc. Therefore, in each case it is very important to select a so-called leading syndrome, for example, a chest pain, arterial hypertension, etc. From such leading syndrome starts a differential diagnostic process as evidence-based thinking. Of course, it is possible to begin the process of evidence based diagnostics with a combination of two or more manifestations, e.g., chest pain + ECG disorders, arterial hypertension + pyelonephritis + retinal changes, etc.**

The classical nosological and three optimal principles are ***not antagonistic, but are synergistic***. The integrated clinical diagnostic decision-making is the basis for optimal diagnostics of diseases manifested by any the same leading syndrome and for appropriates algorithms development.

1. ***Recognition of leading manifestations (evidence based principle of DDM use);***
2. ***Detection of decisive signs and symptoms (principle of optimal diagnostic expediency use);***
3. ***Differential diagnostics and final diagnosis of a disease (differential diagnostic algorithm use);***
4. ***Confirmation of the disease diagnosis (nosological approach use)***

On the view the Table 3, it needs to take into account the following. The author's methodology of comparative evaluation between usual diagnostics and by means of

DDA and AES always was the same according to the principle "The other equal conditions". On the first stage conventional diagnostics was performed, on the second stage - diagnostics by innovative method. The time interval between both stages was several minutes. The other equal conditions were always observed, i.e. the same examinees, only written diagnostic conclusions, the same patients or their equivalents (clinical, X-rays, ECG and other diagnostic tasks, problem situations, training games etc.), Below some results are presented.

All these results, presented in the Table 3 were obtained under quite unfavourable conditions. All learners were used the separate DDA and AES, and only once during of various comparative experiments. In the SLEST the most effective components will be incorporate to the same united system, and a self-training efficiency will be the best.

Key integral and rigorous criterion of the training quality is decrease of errors number. The less errors, the higher quality of professional skill, and vice versa.

Therefore, for count of results of a comparative evaluation, the author use of the very simple and available to all method.

Number of introduced errors at the training $\dfrac{\textbf{by the old method}}{\textbf{by the new method}}$ **in % or in a reduction ratio**.

It is very important that the management by intellectual activity by means of DDA and AES is an universal tool independently from a profile of the activity, level of the IQ, etc. (similar outcomes had been obtained at the highest skilled medical instructors, and the pupils of the trade school). It is the demonstrative illustration of the TRIZ ideas, principles, and methods universality and efficiency [1-5].

The SLEST will include: 1. Innovative Intellectual Approach To Medical Diagnostic Decision-Making; 2. Programmed Self-Training with a feedback; 3. Differential Diagnostic Algorithms; 4. Original Aesculapius Medical Expert System; 5. Programmed Self-Testing with a feedback; 6. Training on the best III level of Knowledge Mastering; 7. Training with the best Didactic System.

The SLEST will ensure optimal diagnostics of diseases in the most important fields: 1.Cardiology; 2. Pulmonology; 3. Gastroenterology; 4.Hepatology; 5.Infectious diseases; 6.Traumatic injuries.

The Table 3 demonstrates that the aphorism below is really true.

The various outcomes obtained during of the comparative evaluation between traditional, and author's optimal methods of professional training presented in the Table 3. The most objective criterion is decrease a number of errors at the training by the DDA or AES. The column 5 reflects of the increase of the full correct diagnoses using he DDA or AES. The column 6 shows decrease of the errors and other criteria by means DDA/AES.

Participants of experiment	Independent diagnostics	Diagnostics with DDA or AES	Independent diagnostics after the work with DDA	% of diagnosis improvement with DDA	% of number errors decreasing	
					in the time of work with DDA	after the work with DDA
1	2	3	4	5	6	7
Russian data						
The solution of written diagnostic problems for the heart auscultation (1054 diagnoses)						
Students III year	+26/ ±25/-49	+69/ ±14/-17	+45 ±35/-20	265	290	245
Students IV year	+24 ±24/-52	+70 ±12/-18	+55 ±18/-27	292	290	193
Students VI year	+49 ±24/-27	+98/±0/-2		200	13,5 times	
Practitioners internists	+40 ±23/-37	+90/±3/-7		225	530	
Medical teachers internists	+25/-75	+100/±0/-0	+75/-25	400	75–0	300
Internists of top skill	+49/-51	+89/-11		182	464	
Diagnostic interpretation of phonocardiograms (127 diagnoses)						
Internists of top skill	+32/-68	+97/-3		303	23 times	
Pulmonary X-ray diagnosis 21173 diagnoses)						
Students IV year (both groups below)	+37/±42 -21					
Finished of X-Ray diagnostics course		+93/±7/-0	+83/±10/-3	251	21–0	700
Not started of X-Ray course		+93/±6/-1	+78/±13/-9	251	21	233
Students VI year	Errors 71–100%	Errors 6–0			71–100% 6–0%	
Learning game "A patient with acute chest pain" 12 students V courses						
Operations of thinking	220	4			55 times	
Hints of the teacher, carrying the game	104	In DDA 4 signs			26 times	
Time of the students	1704 sec	10 sec			170 times	
Time of the management	422 sec	DDA - 10 sec			42 times	
The pupils of trade school. Recognition of a kind of the wiring wares (cables, wires)						
General results	+24/-76	+71/-29	+76/-24	296	262	317
The weakest pupils	+0/-100	+71/-29	+71/-29	0–71	345	345
The strongest pupils	+40/-60	+70/-30	+80/-20	175	200	300

I^st year	+0/-100	+67/-33	+50/-50	0–67	303	200
III^rd year	+40/-60	+80/-20	+100/-0	200	300	60/0
Solving of technical written problems based on the industrial safety regulations (Deputy of superintendents on a large plant, accountable for the industrial safety)						
Outcomes of the solution	+44/±25/-31	+100		227	31–0	
Israeli data						
Conventional and computerized diagnostics (Fever-AES) of reasons of a fever with clinical and laboratory signs (number of signs demanded for diagnostic 4 diseases)						
Total of signs	313	15		21 times		
Clinical si gns	183	11		17 times		
Laboratory signs	130	4		33 times		
Family doctors. Pulmonary X-ray diagnosis (400 conclusions)						
The diagnoses	+23/±24/ -43/0 10	+72/±16 -12		+313 ±67	358	

Table 3. Comparative evaluation of independent and algorithmic or computer diagnostic (%)
+ Full correct diagnosis; ± Partial correct diagnosis; - Wrong diagnosis; 0 – Diagnosis absent
/ Variants of various data «from–to»

If it is necessary to pass at the night on twisting path, not seeing the future bends, it is necessary to go, groping the path by a leg. In the daytime the man will run along on this path rapidly, since the forthcoming route is seen to him.
Ishikava Kunigiko

7. The SLEST advantages

The strategy of the SLEST will be providing by the principle ***"To spend minimum for receiving a maximum".***

The most effective professional self-training will ensure the most reliable diagnosis for medical professionals in the most efficient way, using minimum medical examinations, symptoms/signs, efforts, time and costs. A professional diagnostic self-learning could be ensuring both by means of computerized expert system, and/or electronic-books.

THE EXAMPLE OF SYNDROMIC ALGORITHMIC DIFFERENTIAL DIAGNOSTICS USING CHEST X-RAY

Small fragment of L. Naumov's algorithm for X-ray diagnostics of diseases manifested by round shadow syndrome

Attention ! Here only ONE BRANCH of the algorithm is considered

0. Initial stage of NOSOLOGICAL clinical thinking

An indefined opacity on the chest X-ray

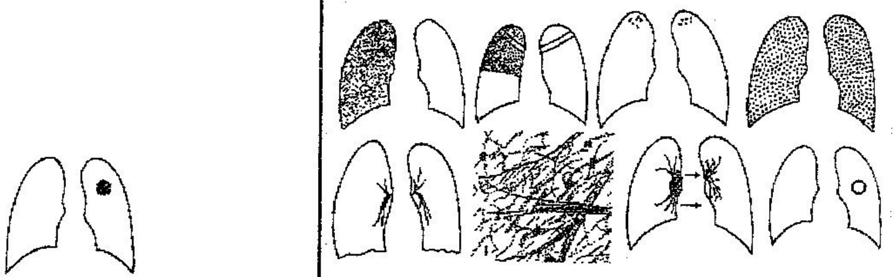
It is probable for more than 400 pulmonary and extrapulmonary diseases

START OF SYNDROMIC ALGORITHMIC CLINICAL THINKING

1. What leading X-ray syndrome is defined on the chest X-ray of this patient?

1. **total/subtotal opacity (about 20 diseases)**
2. **local opacity (about 50 diseases)**
3. **nodular lesions and local dissemination (about 20 diseases)**
4. **wide-spread dissemination (about 150 diseases)**
5. **ring-shaped shadow (about 40 diseases,)**
6. **total/subtotal/local hyperlucency (about 20 diseases)**
7. **pathology of lung marking (about 30 diseases)**
8. **pathology of the hilum and tracheobronchial lymph nodes (about 40 diseases)**
9. **round shadow (about 60 diseases)**

1. What is the leading X-ray syndrome ?



round shadow syndrome | **all other X-ray syndromes**

suggestive of "only" about 60 diseases

about 350 diseases which demonstrate other X-ray syndromes are excluded

2. What is the shadow shape ?

Fig.1a

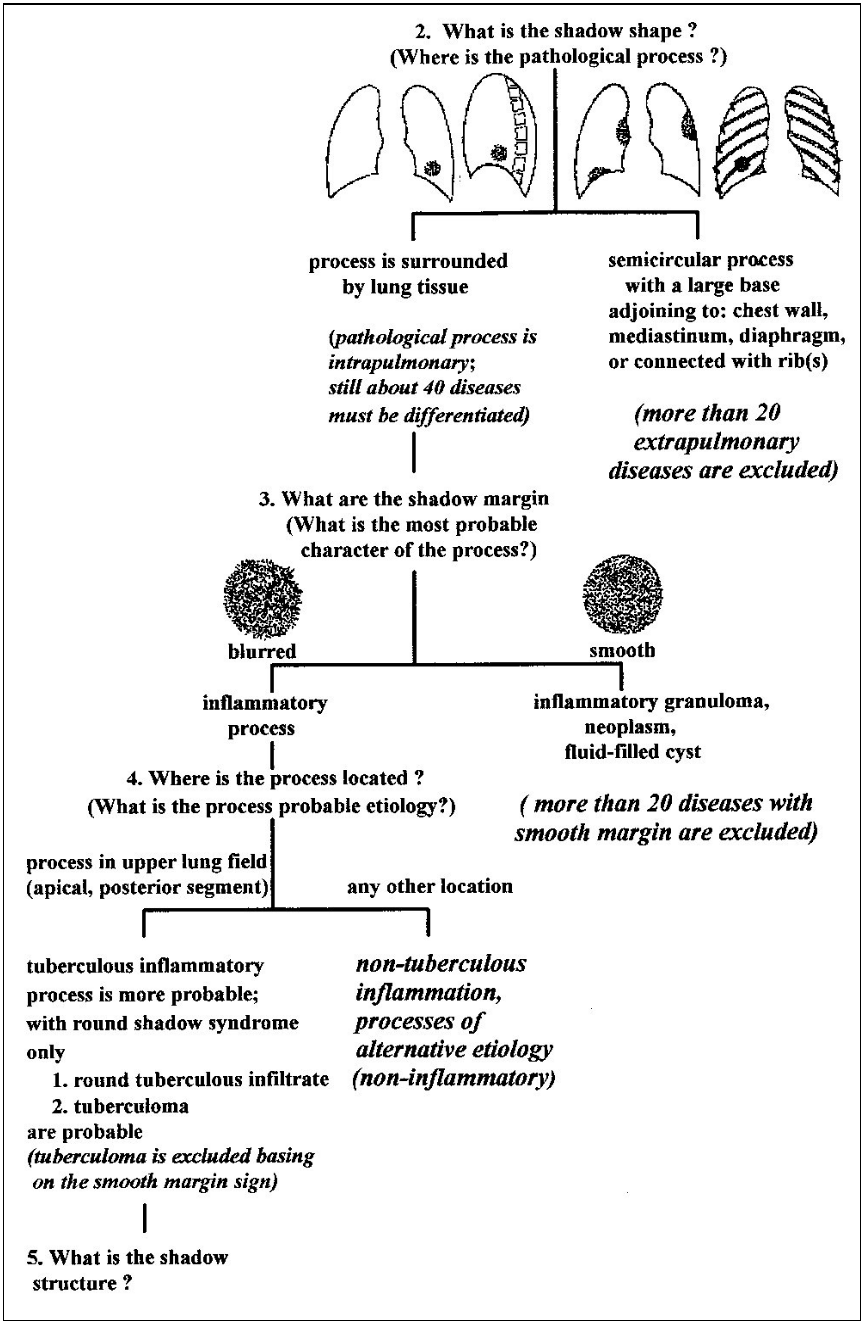

2. What is the shadow shape ?
(Where is the pathological process ?)
process is surrounded by lung tissue
(pathological process is intrapulmonary; still about 40 diseases must be differentiated)
semicircular process with a large base adjoining to: chest wall, mediastinum, diaphragm, or connected with rib(s)
(more than 20 extrapulmonary diseases are excluded)
3. What are the shadow margin
(What is the most probable character of the process?)
blurred
smooth
inflammatory process
inflammatory granuloma, neoplasm, fluid-filled cyst
(more than 20 diseases with smooth margin are excluded)
4. Where is the process located ?
(What is the process probable etiology?)
process in upper lung field (apical, posterior segment)
any other location
tuberculous inflammatory process is more probable; with round shadow syndrome only
1. round tuberculous infiltrate
2. tuberculoma
are probable
(tuberculoma is excluded basing on the smooth margin sign)
non-tuberculous inflammation, processes of alternative etiology (non-inflammatory)
5. What is the shadow structure ?

Fig. 1b

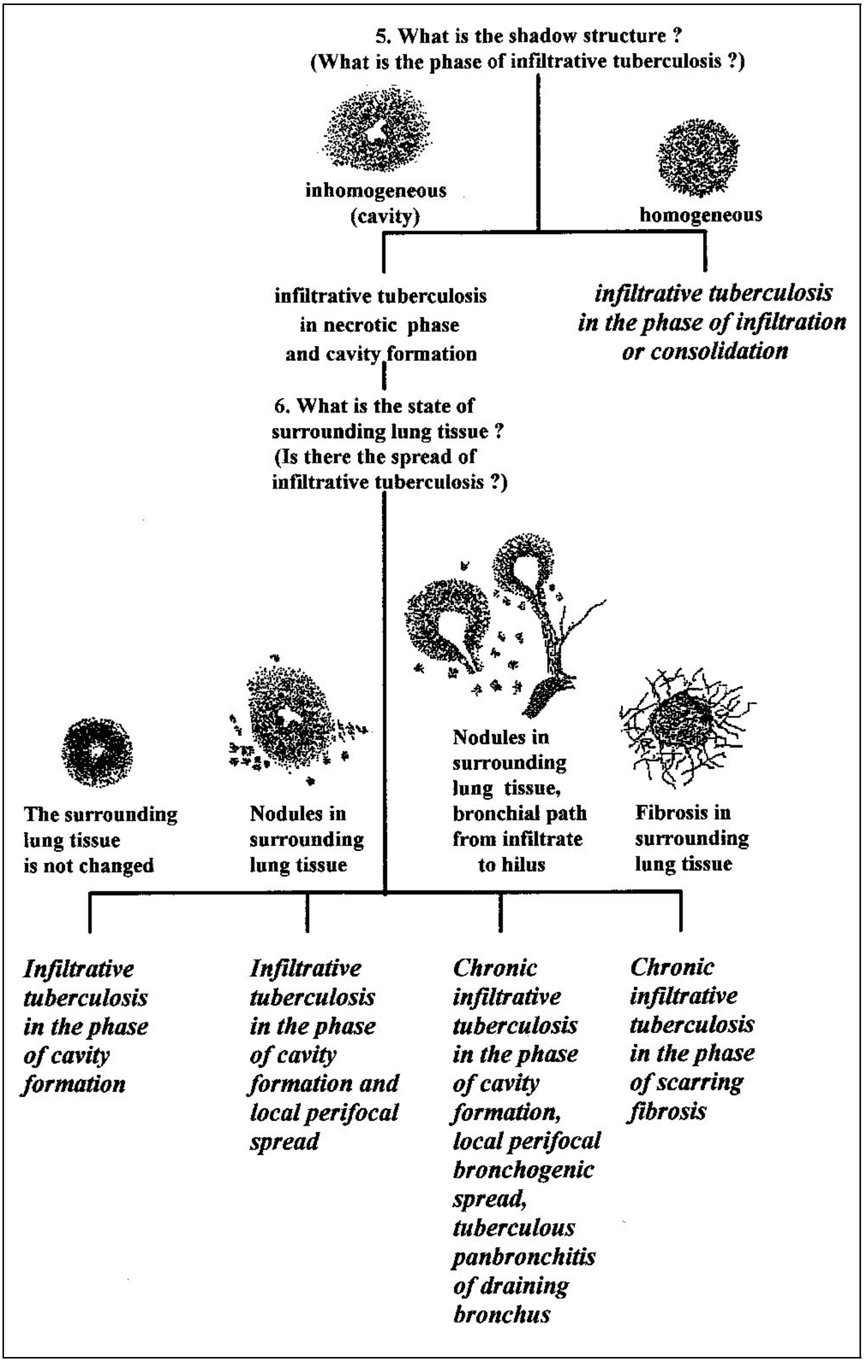

5. What is the shadow structure ?
(What is the phase of infiltrative tuberculosis ?)
inhomogeneous
(cavity)
homogeneous
infiltrative tuberculosis
in necrotic phase
and cavity formation
infiltrative tuberculosis
in the phase of infiltration
or consolidation
6. What is the state of
surrounding lung tissue ?
(Is there the spread of
infiltrative tuberculosis ?)
The surrounding
lung tissue
is not changed
Nodules in
surrounding
lung tissue
Nodules in
surrounding
lung tissue,
bronchial path
from infiltrate
to hilus
Fibrosis in
surrounding
lung tissue
Infiltrative
tuberculosis
in the phase
of cavity
formation
Infiltrative
tuberculosis
in the phase
of cavity
formation and
local perifocal
spread
Chronic
infiltrative
tuberculosis
in the phase
of cavity
formation,
local perifocal
bronchogenic
spread,
tuberculous
panbronchitis
of draining
bronchus
Chronic
infiltrative
tuberculosis
in the phase
of scarring
fibrosis

Fig. 1c

8. Conclusion

A diagnostic professional skill of the students and experts does not depend from geographical, financial, political and social settings. It depends only on efficiency of professional thinking. Therefore, initial and continuing training based on the III level of training, syndromic algorithmic principles of thinking, and eighth didactic system can guarantee repeated improvement of disease diagnostics and treatment of the patients. The algorithmic solution of professional problems is expedient, besides medicine, in other fields of vocational education and activity.

Enormous achievements obtained by development of newest ***medical diagnostic technology (engineering, equipment, etc.)*** are almost exhausted. Very undesirable consequence of this direction is a multiple rise of a cost of a diagnostics, and decreasing of the accessibility of a medical aid for a population. It is necessary to define the ways where the most successful break-through can be achieved now.

The optimization of an intellectual diagnostic process by mentioned new pioneering methods presents the most effective and promising new ways.

The optimization of clinical diagnostics allows solving of diagnostic and training problems relatively fast and cheaply. Working out and using of mentioned methods of intellectual activity optimization has a paramount importance and should be applied widely. Therefore, the true optimization of initial and continuing professional training should be considered as a serious acquirement for modern society.

International significance of the project, including financial one is defined by the following. ***24*** member countries of OECD have ***~885,000,000*** *population*, ***~2,000,000*** *physicians*, ***~7,000,000*** *hospital beds,* ***1642*** *higher medical schools worldwide****, more, than 1 billion PCs***. [12,31]

In the author's opinion, ***the optimization of a professional education is a transformation of an education system to such level, which one can ensure to each learner stable maximal outcomes of vocational training and activity that are close to their theoretical limits, with the most efficient way, minimal costs, time, efforts, and means of learners and teachers.***

Each! Maximum! With minimum … An improving of training quality of a doctor and other professionals is possible. It is necessary! How? As well as it is briefly recited here.

How many acts were considered impossible,
until they were carried out.
Plinius Senior

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BENCHMARKING TRIZ IN THE FIELD OF PRODUCT SERVICE SYSTEMS "PSS"

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Abstract

There is no dispute about the applicability of TRIZ in the technical fields, product development and problem solving. In this regard the uniqueness of the knowledge-based methods of TRIZ could generate new concepts and spur for continuous innovations, its remarkable successes have promoted TRIZ to be the engine for the vehicle of systematic innovations. This lead professionals and researchers to look into ways to apply the TRIZ methodology into other fields e.g. business fields [7].

This paper will look into the applicability of TRIZ in the field of Product Service Systems (PSS). The implementation of TRIZ will be undertaken through the introduction of a new PSS. In the process, TRIZ will be benchmarked against the previously identified "methods and tools benchmarking algorithm" [2] in order to assess TRIZ in its capability of providing systematic innovation and to check its applicability when extended to other fields.

The assessment is directed to measure: the TRIZ capability of identifying and assimilate new problems; its ability to build knowledge or identify the required knowledge; its degree of being scientifically based is to be tested by applying the different TRIZ tools; its comprehensivity feature will be automatically evaluated based on the results of this work and the degree of its success/failure to achieve answers, fulfill requirements and generate new ideas and concepts.

This work will also look into the applicability of TRIZ in revealing risks according to the benchmarking algorithm features or by providing the mechanism of overcoming previously identified risks.

Keywords: implementing TRIZ, problem identification, knowledge building, PSS, mapping characteristics, TRIZ assessment, Smart Little People (SLP), Creativity.

1. Introduction

This work is emanating from the INNOPSE project (INNOvation studio and exemplary Product Service Engineering, an EU funded project under the fifth framework 'Competitive and Sustainable Growth' programme). In brief, the project is split into three interdependent strands: the first strand conducted research and a survey to identify the general obstacles that hinder innovation, especially for SMEs. Based on the analysis of these obstacles, some key success factors and characteristics have been identified [1]. These characteristics are seen to be the features of successful methods and tools that SMEs, and others, intended to implement to produce innovation. The second strand, the innovation studio, houses infrastructure in terms of hardware and software designed to provide innovation management (IM) with the state of the art methods and tools for idea generation and problem solving. The methods and tools in the innovation studio (with TRIZ being at the core) are implemented in order to facilitate the production of the third strand (the exemplary development of four Product Service Systems "PSS"). The innovation studio provides answers and recommendations to the IM obstacles by identifying what is needed to overcome these obstacles.

In this paper, the success factors identified in the benchmarking algorithm [2] will be implemented to benchmark the performance of TRIZ in delivering solutions, guidance and consultancy for the design and development of a new PSS namely "simulation services for: load portfolio management and optimisation" (benchmarking in the sense of assessing its applicability to produce valid and reliable results). Since the benchmarking is directed towards methods and tools in the form of products i.e. methods and tools in software form, the process is carried out using two products which will remain for the rest of the paper anonymous because this work is not meant to be a marketing venue for any of them. The choice to implement the algorithm using two products is to avoid any pitfall, if any, of either one and to stress the point that the task is to assess the TRIZ methodology and not the product per se.

Aside from this short introduction, the paper is composed of three parts:

1. A short introduction about PSSs and their development strategy using TRIZ: a brief review of the general aspects of PSS and a background description about the proposed PSS is presented. This part also introduces the strategy followed in the innovation studio in using TRIZ to develop PSS examples.
2. The development part: where TRIZ is used in the design and development of a new PSS according to the development strategy introduced in part one.
3. The assessment part: The performance of the TRIZ methodology is assessed according to the factors identified in the benchmarking algorithm found in [2]. The assessment is based on the implementation of two of TRIZ software products and a scan of the TRIZ tools in literature in an attempt to cover all aspects of the TRIZ methodology and to overcome any TRIZ product pitfall, if any. This part is ended with a conclusion.

2. What is PSS?

State of the art research and studies about PSS (manifested in the research activities and dissemination conferences done by currently running EU projects (as of August 2004) i.e. INNOPSE, SusProNet, Prosecco, Brainfridge, ASP-NET, PROTEX, IPSCOM as well as literature studies [12], [9] show that the main characteristics of a PSS are:

1. Reduction and optimization of use of resources

2. Adding value for customers (quality, comfort, reduced costs, time) through the delivery of the product's function in a form of service
3. Sustainable, economic and environmental friendly

In general, the drive for the introduction of PSS are the need for sustainability development that optimise and minimize the use of resources and shift from product oriented to service oriented consumers and, due to the emergence of what is known as the knowledge economy, there is a trend towards the use of other peoples knowledge i.e. in the form of joint activities, collaboration, outsourcing and abandoning the "not manufactured here" syndrome. In other words the trend is to use the knowledge of others in order to achieve certain functions, which is in fact to have their service. A comprehensive and detailed literature research about the different aspects of PSS is presented in a review report in [12]. In summary, there are three basic venues for introducing PSS, these are:

1. Product oriented eco-efficient services (a product is sold to the customer but extended by a service, e.g. repair, upgrading, recycling)
2. Use oriented eco-efficient services (a product is owned by the service provider and used by the customer for an agreed time)
3. Result oriented eco-efficient services (customer only buys a result and does not care how the result is produced by service provider and which products are involved).

In PSSs, there is a consensus between both customers and those who deliver the service on top quality issues. That is easily understood from the customers' point of view because they demand a top quality service; from the providers' point of view the competition is not any more centred around quantity of sold products but rather on manufacturing top quality durable and environmentally friendly products that can be used many times with a long life cycle time and this in turn leads to reduce cost for the providence of the service to the customer.

A given PSS is usually meant to target a wide range of customers. A successful PSS is the one that meets the requirements of all (product, use and result oriented). This issue requires the presence of various degrees of resources according to the type of PSS (result oriented requires more resources than the others and in this sense it is better to base the development of the PSS on the result oriented model).

3. Development strategy

3.1 PSS and TRIZ

The TRIZ methodology has been centered around technical engineering systems and products; recent efforts have looked into the applicability of TRIZ into the business and social fields [8], [3].

Realising that PSS is a mix of products with business activities, and TRIZ has a knowledge base that is adept in the technical fields. Then TRIZ, in its originality, can be still a valid method for the design and development of existing and new PSSs. On the one hand, PSS needs the technical knowledge base from TRIZ to have products that are durable and utilize fewer resources (producers will be more concerned with manufacturing for using instead of manufacturing for selling) and on the other hand, PSS needs innovation in the existing business models to provide innovative services with added value (i.e. with added functions to a products).

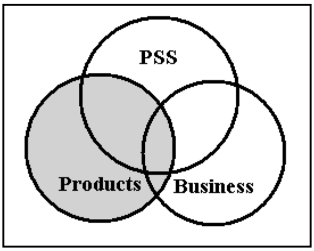

Figure 1. The shaded area represent TRIZ competency

In general, the strategy that has been followed in designing and developing the PSS examples, as shown in Figure 2, is manifested in the following points:

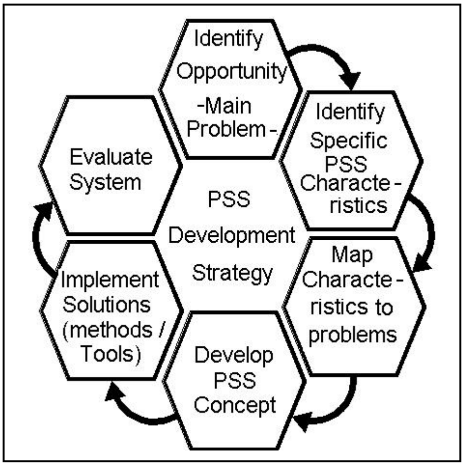

Figure 2. PSS development strategy

1. Identify the opportunity: either by identifying an existing problem or need across a certain sector in the society, or industry and or businesses, or by picking up a product and brainstorming additional functions. The outcome of this stage, similar to the problem definition stage in the TRIZ methodology, is a clear definition of the problem/s to be tackled. Usually this problem will be repeating itself across the industry/business fields.
2. Map the specific features and characteristics of the proposed PSS to that of the general characteristics of PSSs in general (resource optimization; value added; sustainable, economic and environmental). These mapped characteristics are to be checked for contradictions and they are to be mapped to the previously identified problems to provide directions for solutions.
3. Develop the PSS concept: at this stage the developer must have a clear idea to what the PSS shall provide and what problems to solve.
4. Implement TRIZ: based on the nature of the problem, choose between the different TRIZ tools to look for solution concepts. Use the ARIZ methodology of tackling

problems to solve the previously identified problem/s and conduct a scan for the TRIZ tools looking for new ideas and directions for solutions.

5. Evaluate the results especially by checking the solution against the patterns of evolution and especially the law of increased ideality. This requires the identification of the new system and comparing it to the previous system thus identifying the advantages.

4. Developing an example

4.1 The opportunity: Situation background

The liberalization of power market in the EU led to the inception of a number of new players in the energy market which contributed in the change of the market dynamics and produced fierce competition [4]. In the new energy market, the demand side has the opportunity to freely choose their electricity supplier while at the same time the new entrant energy suppliers are sharing markets with the already existing electricity producers who still have the opportunity to supply customers [5]. Thus, shifting the energy market from a highly protectionist and quasi-monopolistic platform to a market-driven economic system. A major factor of determining the success and expansion of a given provider is its ability to optimise its cost and/or revenue structure. In this type of market the margins from selling energy are very low [9] thus innovative companies have to look for innovative ideas in order to increase their revenue and reduce costs.

The role of EEX in the new energy market

Currently in Germany, the EEX (European Energy Exchange. See http://www.eex.de/) is providing a trading system “Eurex®” for its members (suppliers and distributors) to trade energy. The EEX system for trading and clearing energy Futures is based on its electronic system. On average, Eurex processes 1.5 million trades per day. The members use the Eurex software by filling a form and submitting it back to the EEX through a data transmission line. The pitfall of the current system from the point of view of the customers “suppliers who will be referred to, from now on, as traders” is that they are tide up to use certain types of contracts thus not enabling them to fully optimize their future loads. That is caused by the nature of the energy loads where the values of the available contracts do not fit exactly to the peaks and valleys of the traders’ load curves. The spot market gives the traders the opportunity to overcome this difficulty buy giving the opportunity to sell the excess from their previously bought contracts or buy from others to fulfill their current needs. The volatility of the Spot Market trading prices makes it risky to trade contracts resulting in either buying at high prices or selling at lower prices. This process makes it hard for traders to optimize their traded contracts according to their needs, which in turn incurs extra costs.

There are seven types of contracts: two yearly contracts (yearly peak and yearly base); two quarterly contracts (peak and base); two monthly contracts (peak and base) and spot market contracts (these contracts are available only on the spot market “meaning that they can’t be traded in advance”)

Each contract has the following attributes: Name; Fixed volume; Starting date; Last trading day; Date of minimum price (expected); Date of maximum price (expected); Minimum price (expected); Maximum price (expected).

The proposed PSS

The idea behind the proposed PSS is to give the traders the service of knowledge in a form of decision support that helps them to decide on when to trade (buy/sell) electric energy based on the time of the year, their market size and the availability of stocks in the market. This service is directed towards a business-to-business interaction where the traders (who are responsible for the delivery of the energy to consumers) can have the opportunity of maximizing their profits by buying future contracts of energy at lower prices to be delivered to their consumers or resold to other traders in the market at higher prices.

This is the concept behind the proposed PSS; to provide traders (and large customers “industrial companies”) enough trusted information to help them decide on their energy stocks to maximize their profits by avoiding to be caught in the spot market with unplanned extra or insufficient contracts thus increasing their load portfolio optimisation and managing their risks.

Defining the problems

To achieve this step both TRIZ products and the ARIZ methodology of problem definition have been implemented.

Despite the use of some different names and terminologies in the various TRIZ products, they all mean the same thing “define the problem”. All have their roots in the versions of the original ARIZ process of analysing the problem, and they use similar techniques of asking structured questions at and around the problem space, building graphical models, identifying resources leading to an exhaustive process of identifying all possible factors affecting the situation.

This process lead to the following problem definition:

Traders at EEX are not able to have optimised load profiles due to the following reasons:

1. Traders lack the knowledge and experience to forecast their future markets and prices.
2. The dynamic nature of the energy market after its liberalization (new entrants and the possibility of customers to switch between distributors).
3. The unavailability of trusted standard tools that provide systematic help (they, or their consultancy, are using different existing tools i.e. Microsoft applications)
4. The nature of the traded contracts (fixed volumes and dates)
5. The volatile nature of the Spot Market is causing the main risk.
6. Traders incur financial losses either by not optimizing their loads or by turning to external consultancies and/or employing more people to take care of the situation.

Problem number 4 is to be living with the new PSS because the nature of the contracts can’t be changed.

4.2 Mapping characteristics

The purpose of mapping the specific characteristics of the given PSS from the general characteristic of PSSs is to have a consistent and coherent process where the final result will be supporting the general characteristics of PSS. The second point from this process is to identify the relevant problems from the previously identified problems that will be addressed or challenged and resolved by achieving the mapped characteristics. In other words, the mapping process identifies the offerings of the new PSS and solves the problems within the PSS characteristics.

Table 3 shows the mapping results.

PSS general Characteristics	Load portfolio management/optimization				Problem/s to overcome
Reduction and optimization of use of resources	Automated process (**less labor**)	Faster process (**less time**)	Better optimization (Use of historical data, **reduced risk**)	Use of Internet (**utilizing existing resource**)	1, 3, 5, 6
Adding value for customers (traders)	**Save time** and **money**	**Meet** their **customers' demands**	**Increase profit** through trading future contracts	Be **competitive**	2, 5, 6,
Sustainable, economic and environmental friendly	More networking and communication with **Less travel**	Software automated (**less paper**)	Increase efficiency (**less Energy**)		1, 6

Table 3. Mapping the proposed PSS characteristics to the general PSS characteristics

This helps developers to deal with the previously identified problems in terms of the characteristics of the PSS. Meaning, for example, that to overcome problem number 1, which says: "Traders lack the knowledge and experience to forecast their future markets and prices", can be overcome if the PSS provide (optimisation "through the use of historical data", use of existing resources, more networking and communication).

4.3 PSS concept

Based on the mapping of the characteristics, a concept of the proposed PSS can be presented. It is very much related to the problems that the sector faces and the functions that the proposed PSS will provide.

Figure3 translates this understanding of the concept into a graphical representation.

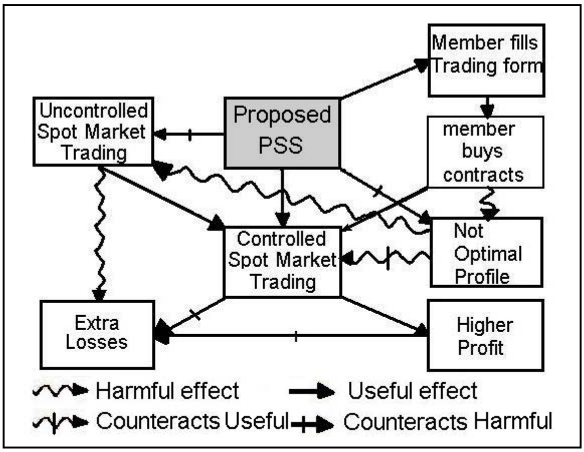

Figure 3. PSS concept

It says that the proposed PSS will:
1. Help members fill their trading forms
2. Counteract the harmful effect of getting not optimal profiles
3. Produce more of the controlled spot market trading and
4. Counteract the harmful effect of suffering uncontrolled spot market trading.

4.4 Implementing TRIZ

Using the TRIZ products, and based on the scenario of traders at the EEX with the problems identified earlier, the following ideas were generated:
1. Provide a prior action before the member fills a template form for trading (i.e. consultancy or a new service)
2. Provide a copy of the software for those who are inexperienced (to train).
3. Get the EEX to provide a simulation first then a confirmation of purchase.
4. Each trader owns his own simulation software similar to that of EEX.
5. Device an automatic process where human intervention is not needed (increased ideality) that eliminates the cause resulting in not optimal loads profiles. By introducing a mediating component in the process before the trader fills the EEX form (a prior action).

After the ideas generation phase, the solution development, there is quite some difference between the products of TRIZ and the TRIZ methodology in the literature. Both of the products are introducing their own methodology of evaluating the generated ideas based on the identification of other factors in the system and or related to the application of the idea. While in TRIZ tools (i.e. ARIZ 85) the solution ideas are generated by identifying the Ideal Final Result (IFR) and finding the factors that are preventing its achievement and implementing other TRIZ tools to solve the problems. In case of failure TRIZ says to step back from the IFR and do the same trials until a solution is reached [6], [10]. The evaluation of solution ideas in TRIZ is conducted by seeing whether the new solution gets the system closer towards ideality. This same TRIZ methodology is still fit towards PSS models as the one under development.

Thus, following both criteria of the two products and the TRIZ law of ideality lead to the choosing of idea number five as a solution concept for the PSS, namely:

Device an automatic process where human intervention is not needed (increased ideality) that eliminates the cause resulting in not optimal loads profiles. By introducing a mediating component in the process before the trader fills the EEX form (a prior action).

To continue and implement this solution idea, both products offer their own methodology. Both are centered on a different choice of TRIZ tools. At this point, this work shifted to scanning the TRIZ tools to further develop the solution concept.

The TRIZ tools scan is based on the general characteristics of the PSSs mentioned earlier.

It is evident that the new PSS will be utilizing IT to perform the job. Thus it is logical from now on to think of the new PSS in terms of software.

The following table summarizes the results from TRIZ tools scan looking for further solutions ideas for the development of the PSS:

Requirements (PSS characteristic)	Relevant TRIZ Tool	PSS context
Faster process compared to current system	Inventive principle 1: segmentation.	Break the service into tasks and: Employ people to do the tasks Use of infinite number of electrons to do the job. Use of infinite bits of zeros and ones to do the job. Use Object Oriented Programming Use Agents systems Use Neural networks Use Fuzzy controllers
	Principle 6 "Universality": have an object carry out different functions	Use a combination of the above to perform the different functions
	Principle 25: self service	The PSS package does all the required activities by itself i.e. software checks for data (contracts, dates, volumes) and takes decisions alone. Thus shortening time for consultation or waiting on human actions.
Less labor (increase automation)	Principle 25: Self-service. Patterns of evolution: increased automation (decreased human involvement); Law of ideality	Use of artificial intelligence to take decisions. Enable auto access of databases for information (i.e. previous loads)
Does not require extra resources (optimization)	Principle 26: copying: use a simple and inexpensive copy instead of an object which is complex, expensive, …	Use of software algorithms to replace humans Use fuzzy logic or Neural Networks to copy human reasoning. Use historical data to forecast the future.
Does not cause extra cost (Competitive)	Principle 16: Partial or excessive Action (slightly less or slightly more)	The rules to be followed (i.e. by the software algorithm) shall allow, **with price and date control conditions**, the software to trade little more or little less than what the member future load portfolio leaving a room for controlled Spot market trading.
Produce more profit	Principle 22: covert harm into benefit	Use the spot market trading for controlled trading for the extra/less contracts
Reduce risk (optimize controlled Spot Market Trading)	Principle 16: Partial or excessive Action (slightly less or slightly more)	Place rules for operations (base lines based on the history's lowest/highest prices "i.e. a human chooses parameters that control the operation of the PSS") One agent is responsible for the spot market contracts that buys/sells little above or little below (depending on the prices, market size and stocks) than needed (if achieving the exact amount is not

		viable)
Reduce risk	Principle 1: segmentation	Each object/agent is responsible for only one task in order to produce reliable results
Increase information	Principle 10: Prior action: Introduce a useful action into an object or system (either fully or partially) before it is needed	Have databases that save previous loads and prices to strengthen the predictability of future loads Have databases that keep record of the market size. Document the climate conditions and tie it with energy consumption
Requires less travel	Patterns of evolution: increased ideality	Use existing resources i.e. Internet and virtual networks and meetings
Requires less paper work	Principle 20: Continuity of Useful Action	The software is used again and again with the gained knowledge documented electronically and accessed by the system through the designed databases.
Consumes less energy	Patterns of evolution: increased ideality	The use of software on the internet is reducing energy consumptions compared to the previous system of having humans or consultancy agents to do the job.

Table 4. TRIZ tools scan for solutions

From the previous analysis, it is clear that the major conflict is stationed around the Spot Market and the lack of knowledge about future energy markets. If the trading in the Spot Market is controlled (i.e. if the prices of contracts were low "compared to historical data" and the member bought extra contracts with the full knowledge of the market supply and demand for the purpose of selling these extra contracts in the spot market at higher prices), then it is a favourable situation. If the Spot Market trading is uncontrolled (meaning that the member didn't previously buy enough contracts to cover his consumer demands or he mistakenly bought extra contracts) then he is forced to trade at the Spot Market and here is the greatest risk of either buying at higher prices or selling at lower prices.

The concept now is clearly indicating the need to develop software that is intelligent enough to optimise the load portfolio directed more towards achieving controlled spot market trading in order to mange and reduce risk with the least human intervention. To help achieve this, it is important to understand the nature of the load profile.

The nature of the members' load profiles and the Smart Little People (SLP) tool

Basically all energy loads are following a curve that is somehow predictable but, given the available contracts, is very hard to fill before hand.

Figure 4 shows the general picture of a one year load curve, the picture gets better, "applying principle 1: segmentation", when it is zoomed to represent only one week as shown in

Figure **5**. In this figure it is very evident why it is hard to fill beforehand the energy loads with the available contracts that are of fixed volumes and dates.

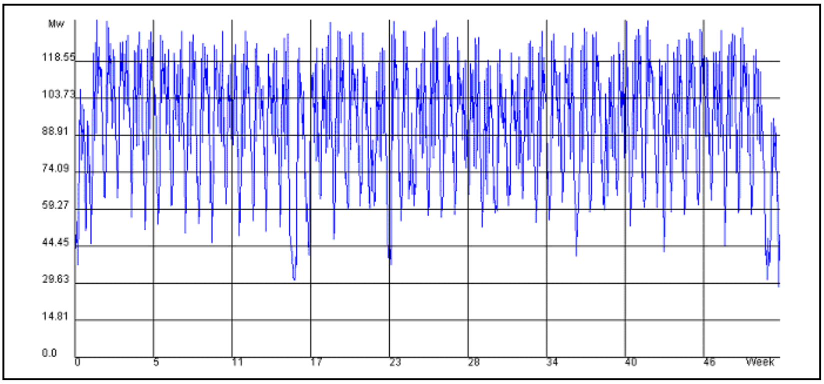

Figure 4. The general nature of the energy loads (one year energy load curve)

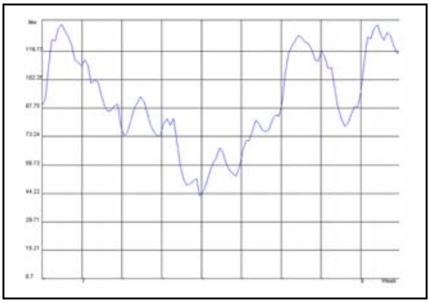

Figure 5. One-week energy load

To solve this problem, lets free ourselves from our psychological inertia as TRIZ suggests and get the help of Smart Little People (SLP) as shown in Figure 6:

TRIZ says that we have to sketch the zone of conflict placing SLP as much as possible. Then imagine that those SLP are able to act as the situation in the conflict zone requires them to do, or in the opposite direction i.e. they can move, help, oppose, resist, carry, push, pull…etc. Having in mind that the available contracts possess different attributes, then it is better to introduce different SLPs i.e. SLP for guarding the border, other for the names and values, third for the starting dates, fourth for the last trading date, fifth for the minimum and maximum prices' dates and sixth for the maximum and minimum prices.

The possible scenarios for these SLPs who are imagined to be filling the load curve and setting at the border are:

- First, a group of SLP sets at the border of the energy load and prevents the contracts from exceeding the curve limits.
- SLP fill the body of the load curve with as much possible future contracts to minimize the spot market trading. They are responsible for the different attributes of the different contracts.
- One group of SLP is to be policing the rest for valid dates and prices of the carried in contracts.

- The police group shall let in contracts that can lead to controlled spot market trading (noticeable cheap buying prices) and reject the ones that lead to uncontrolled trading. They verify the validity of the dates, prices and volumes of the contracts to allow purchase. They also verify with the border SLPs on how much contracts to allow in (buy)
- Border SLP can also work on pushing the load curve inside (at the peaks), those SLP are represented in black in Figure 6.
- Border SLP can pull the load curve extending it (at the valleys), those SLP are represented in red in Figure 6.
- These SLP are smart enough to operate independently.

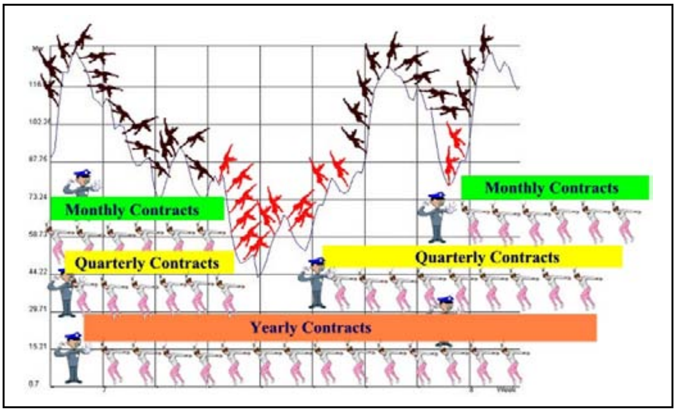

Figure 6. SLP at work in optimising the energy load portfolio

These SLPs can be substituted by intelligent systems, software objects or algorithms and the police SLP can be substituted by decision-making algorithms.

The SLP simulation has helped in identifying the knowledge level of the user and allows more understanding, uncovering new possibilities and solution options and empowering imagination and weakens psychological inertia.

Business meaning of the SLP activities

The role of the SLP has extended beyond the design and development stage and spurred the generation of new business ideas that the traders can achieve thus enhancing their profit and competitiveness.

SLP activity	Business idea
Red SLP: extending the curves at the valleys	Traders shall promote better marketing strategies looking for new markets and winning new customers, thus allowing them to buy more contracts.
Black SLP: pushing in the load curve	This can be translated into business activities like: • Not buying contracts that cross the load profile border. • Negotiating with customers to reduce their energy consumptions at the peak hours. • Negotiating with customers to reduce energy consumption in total by turning to energy efficient products and households appliances.

Table 5. Business ideas emerging from implementing the SLP tool

Resource options

Much of TRIZ focus on the use of resources and elimination of contradictions. One step beyond the identification of resources (and possible resources) is the identification of the best resource combination. The methodology of the morphological box has been applied in order to find the best option to choose from the available resources.

4.5 Evaluation of the system

Checking how far the system has progressed towards the ideality situation is one effective way of evaluating the system. Before looking at TRIZ law of ideality to evaluate the PSS, here is a brief discussion about PSSs and the law of ideality.

PSS and the law of ideality

The highest level of PSS is the result oriented services where the customers become more interested in having their needs fulfilled rather than in owning the product that fulfill those needs. In this PSS orientation, the provider is the owner of the product and responsible for its maintenance, repair, handling and delivery.

Ideality has many levels, the highest of which (the impossible one) is to have the function without having the system that produces that function and without incurring any harmful effects. The level of ideality degrades as the system that produces the function uses more resources. In the PSS world, and from the customer point of view, the customer wants the function achieved without any harmful effects (i.e. even without costs). In the highest level of PSS world (the result oriented), customers demand the closest to perfect ideal results.

In reality this is impossible, but this is the goal that innovators head for.

Ideality is defined as the quotient of the sum of the system's useful effects, Ui, divided by the sum of its harmful effects, Hj:

$$Ideality = \frac{\sum U_i}{\sum H_j} \qquad (1)$$

From the customers' point of view, in terms of PSS, ideality will be according to the following formula:

$$Ideality_{Customer} = \frac{service \quad (Useful \quad function)}{Costs \quad (harmful \quad functions)} \qquad (2)$$

In response, companies have to optimize the production and delivery of the function through implementing sustainable processes (i.e. the use and manufacture of top quality durable products, resource utilizations, remanufacturing, reuse, recycling…etc.) leading to cost reductions (i.e. reducing costs of consumables, labour, maintenance, delivery and manufacturing). Adhering to equation 1, from the provider viewpoint, the ideality equation will be as shown in equation 3.

$$Ideality_{Provider} = \frac{Costs \quad from \quad customers \quad (Useful \quad function)}{Expenses \quad spent \quad for \quad the \quad service \quad (Harmful \quad Functions)} \qquad (3)$$

It is evident that there is a conflict of interest between the providers and the customers. It is in the providers' interest to charge the customers higher costs while reducing the expenses (harmful effects) that they incur. This conflicting ideality is represented in the graph in Figure 7 where the customers tend to reduce the price while providers tend to increase the price for a given service. The optimal situation is that when the two lines merge to form a compromise line.

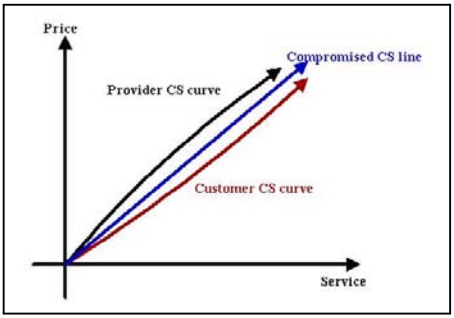

Figure 7. Cost Service (CS) Curves

Ideality contradiction

Realizing that the provider's expenses spent on providing the service to the customer include time, money, material, workforce, delivery, transportation, storage…etc. leads us to the point that in order to fulfill the customer's ideality it is required to lower the costs paid in return for the service, while from the provider's side it is required to reduce expenses in order to maximize his ideality and/or increase the useful functions (profit from customers).

The impact of this contradiction can be reduced if the provider can provide the service by reducing his expenses. Learning from TRIZ ideality that can be achieved by using existing resources i.e. the provider can make use of some existing customer resources. For example, if the provider requires the use of a ladder in order to deliver the service, it can cost less to the customer if the customer has a ladder at his premises that the provider can use in the course of the service delivery.

Ideality in the new PSS

Ideality, in the load portfolio management and optimization PSS, is achieved through the following (compared to the situation previous to the introduction of the PSS):

1. The usage of fewer resources: less time is allocated for the process, the number of employees required to perform the function is reduced dramatically. Companies can still utilize their existing IT infrastructure to do the function (no need for new resources)
2. Producing knowledge: knowledge is a never-ending resource, the more knowledge is used the more it is getting better, bigger and wiser. The system through its integrated subsystems is aware of this fact and utilizes the use of its previous knowledge that is tabulated in databases and accessed autonomously.
3. Reducing costs: The PSS eliminates the need for consultancies thus reducing costs and eliminating the need for travel, contracts, paper work and the like.
4. Standardization: All members will be talking the same language, learning from the same system thus leading to a better understanding and trust between the community of users.

S-Curve analysis

PSSs in general are at the beginning of their S-Curves. And particularly for the load portfolio management/optimization it is a new PSS where it is now at the beta development stage. There is no such valid standard system present that fulfills the functions proposed by the load portfolio management/optimization service system. Existing alternatives are company specific with the implementation of diverse tools (databases, spreadsheets, internet, consultancy agencies…etc.)

Being at the beginning of its S-Curve means that it has not entered the growth phase yet and thus it is expected that the proposed service will add up other functions. For example, as has been uncovered through the use of SLP, enabling distributors to engage into negotiations with their customers for more efficient energy usage and reduction of energy usage in peak hours. On the one hand, this service (together with the negotiations) can maximize the providers profit and enhance their energy market management by reducing their overall energy consumption especially in peak hours “the most expensive energy stocks especially in winter peak hours” allowing providers to trade available energy stocks with their competitors and resulting in a least cost maximum profit model for energy providers. The least cost will be achieved when the provider buys future stocks at reduced rates and maximum profit results when the provider resells his stocks at higher rates and/or negotiates with his consumers for efficient ways of consumptions. On the other hand, this causes the initiation of further research on efficient household appliances and electrical equipment; the need for more in house monitoring processes and equipment…etc.. Full utilization of this service results in This PSS concept is shown in Figure10.

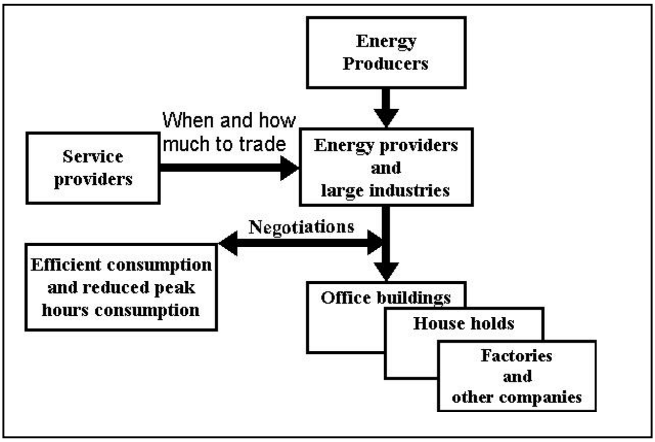

Figure 8. Energy providers PSS concept

The benchmarking algorithm factors

The previous sections have described some of the development aspects of the load portfolio management/optimisation PSS. In this section, the TRIZ performance is assessed using the factors identified in [2]. In fact the assessment process is based on the development of two PSSs, the other being the Energy and substance lab model demonstrator for simulation service, which will be published later.

The assessment factors are of two types, those that can be measured when the method/tool is in a product form (i.e. software products), which is skipped in this paper, and those that are performance oriented. Table 6 provides the assessment results of the performance of the TRIZ methodology based on the work done in the two developed PSSs.

Algorithm factor	Measurement metrics	Assessment
Be simple and easy to implement	Simple vocabulary	TRIZ vocabulary is simple enough for people of engineering level. Nevertheless there are some terms and vocabulary that is not familiar to all and need some time to train i.e. Peltier effect or “Utilising associated phenomena”
	Time to train	To be TRIZ expert, it requires from six months to one year
Guide the user	Structured and systematic process	It has a clear structure (ARIZ)
Be developed	Proven results of previous implementations	In the technical fields it has been proven with many case studies (see TRIZ journal) In other fields i.e. business, PSS, social it is under study
	Its applicability to various situations and different fields of applications.	It is under study with promising signs [see the different TRIZ applications documented in TRIZ journal]
Identifies new problems	Setting up targets	Excellent (IFR)
	Match the product to the most sophisticated customers’ requirements	So far, TRIZ has no means of interacting with the customer through one of its tools. It is problem centred and solution oriented (the IFR can be an analogy equivalent to the most sophisticated customers’ requirement)
	Competency skills identification	This can be clarified based on the level of knowledge detected and the identification of the required knowledge through the substance-field analysis and graphical model representation
	Evolutionary growth status	Patterns of evolution and the S-Curve
	Benchmarking against competitors	NA*
Be comprehensive	Carry the idea into all phases	TRIZ seems to stop short after it suggests an idea for a solution.
	Includes different perspectives (org. fin. Cultural…etc)	NA

	Tackles products/processes and services	The work done in innopse suggests promising signs for the applicability of TRIZ in the PSS field
	Addressing external and internal issues	NA
Builds knowledge	Be a learning venue (from previous cases "successful and failed")	• TRIZ has a significant volume of previous technical cases. • TRIZ knowledge base is represented in its inventive principles and the 76 standard solutions • The use of SLP produced more understanding and opened new knowledge venues (business opportunities) • Documentation of failed cases would produce more learning from TRIZ.
	Translating tacit knowledge into explicit knowledge.	• In addition to the use of SLP, TRIZ identifies the current knowledge level through the drawing of the graphical models of the problem and the substance-field analysis • An improvement in TRIZ ability to represent knowledge in graphical models can be enhanced through the introduction and use of mathematical and logical operators (plus, minus, and, or)
Be scientifically based	Based on (and provide) empirical knowledge	Based on patents analysis
	Provide valid results with observed advantages	The PSS produced is faster, more accurate than the previous ways of doing business and saves resources.
	Clarify options and differentiate between them	This is done through: • The resource analysis, • The IFR and stepping back from the IFR
	Can be applied systematically	The structure and tools of TRIZ are applied and reapplied systematically
Pursue customer satisfaction	Unspoken requirements	NA
	Spoken requirements	NA
	Surprising requirements	NA
Reveals risks	Through requiring information	The problem definition phase conducts thorough analysis and requires the availability of information.
	Through requiring the presence of networks	NA

	Make use of empirical data	TRIZ knowledge base and case studies
	Learning from previous cases	Documented TRIZ case studies. There is no documentation for the failed TRIZ implementations!
	Identifying required resources	Substance-field-resource analysis
Improves creativity	Breaking the psychological inertia	SLP
	Diversified thinking (imagination)	Contradiction matrix: for example "thickness of an object" can be considered (length, strength, weight, waste of substance, durability)
	Creating pressure and relaxing	IFR and stepping back from the IFR
	Expanding thoughts	Resource analysis (i.e. void as a resource, environment as a resource)
	Broadening the persons creative domain	The TRIZ knowledge base opens more venues and stimulates more ideas

*NA: Not Available

Table 6. TRIZ performance assessment

5. Conclusion

The method followed in this paper for the design and development of "load portfolio management/optimization" simulation service provide a structured process that makes it easier to identify where to start, looking for the opportunity, and uncovers problems of the need and means (technology) to deliver the solutions.

In the process, the TRIZ methodology in analyzing problems and resources promotes better understanding of the situation and reveals options for producing an ideal result with least cost model for both the providers and the receivers through resource utilization and sharing.

The nature of PSSs being a mix of products and business activities makes TRIZ an optimal method to be implemented for the design and development of a given PSS. TRIZ, being focused on resource utilization and optimisation, futher strengthen the PSS concepts of sustainability and environmental protection.

In summary, the TRIZ methodology of tackling technical problems (documented in the TRIZ literature and manifested in the contradiction matrix, standard solutions…etc.) can be used in its originality when addressing the product side of PSS, when it comes to other aspects of the PSS, the following TRIZ tools have been found to provide invaluable hints and ideas for the development PSS examples (both examples are simulation software):

1. ARIZ structured problem analysis method including simulation with SLP.
2. 40 inventive principles: the most promising principles are found to be principles numbered: 1 "segmentation", 6 "universality", 10 "prior action", 16 "partial or excessive action", 20 "continuity of useful action", 22 "convert harm to benefit", 25 "self service", and 26 "Copy"

3. Patterns of evolution: especially the evolution towards automation (reduced human control) and law of increased ideality.

From the assessment table, we find TRIZ to be promising in certain factors while lacking other. This assessment is not final and there has to be further work done on TRIZ for the purpose of assessing its performance.

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INNOVATION MAPPING™
INTEGRATION OF PRINCIPLES AND TRENDS INTO INNOVATION DIRECTIONS, EVOLUTIONARY POTENTIAL AND A CONFLICT MAP

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Abstract
The multitude of tools in triz-sourced innovation methods brings overlap and doubt in the innovation process. This paper illustrates the effectiveness of an integrated structure, combining the strength of the evolution trends, the principles and conflict, the function database.
Innovation mapping allows creating a map of all evolution lines. The evolution lines and principles are integrated in a distinct set of three step directions that have their symmetrical direction. The evolution line setup is unique and hierarchical.
The approach allows the user to chart out a starting point of product, process or service and evolve along the directions whilst being fortified by the use of the functional database. Furthermore, by integrating the principles and trends in three step directions, the direction conflict matrix will show which direction to follow in need of solving a conflict. Similarly the tool is indicating what directions to evolve when faced with a physical contradiction.

1. Introduction $V = B - (H + I + C)$

Innovation is first about value creation. As a working definition, at CREAX, value was defined by the equation Value = Benefits – (Harm + Interface + Cost)

Products, processes or services gain value, firstly, by integrating new functionalities or performances. For example: Swiss army knives, integrated computer packages, fax-copy-printer, one-stop shops, multiple functional power tools, self-cleaning surfaces, mobile phone camera or package holidays.

A second focus of the value creation brings a reduction in harmful effects i.e. Sustainable innovation. For example a silent projector, less waste production, biodegradable materials, safety belt, low emission, UV shielding, circuit fuse, airbags, sunglasses, less heat production, copy protected software, popup blockers. Harmful effects can also be turned into benefits, being a blessing in disguise like: vaccinations, waste heat to generate power, use spare computing time for other purposes, corrosion protection, or the weak glue on post-it® notes.

As third major focus in value creation, CREAX examines user interface. Easier grip, lighter products, aesthetics, movie subtitles, easier component assembly, color coding, user profiles, see through packaging, transparent oven or wear indicators. The user interface is also greatly improved by adding the opposite component: pencil and gum, nail puller on hammer, stapler with staple remover, one way glass, ticket cancellation policy or insurance.

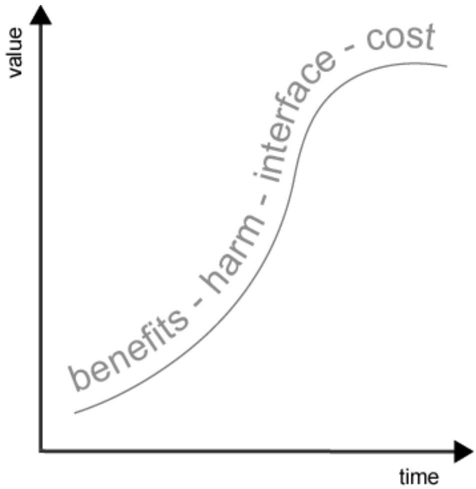

Figure 1. Value = Benefits – (Harm + Interface + Cost)

Finally value creation can be achieved by reducing cost i.e. like less material, less parts, integrating functions, free newspapers, free transportation, sponsored events, pay per use, leasing or refills. An important focus on the cost reduction is to eliminate components without eliminating functions.

This value definition is extremely effective to value new generated ideas and concepts and to compare them with each other and, eventually, the initial concept.

These results can be illustrated on a clear graph: the X-axis is the totality of harm, interface and cost. The Y-axis indicates whether there are more or less benefits. The crossing point is the initial product or concept:

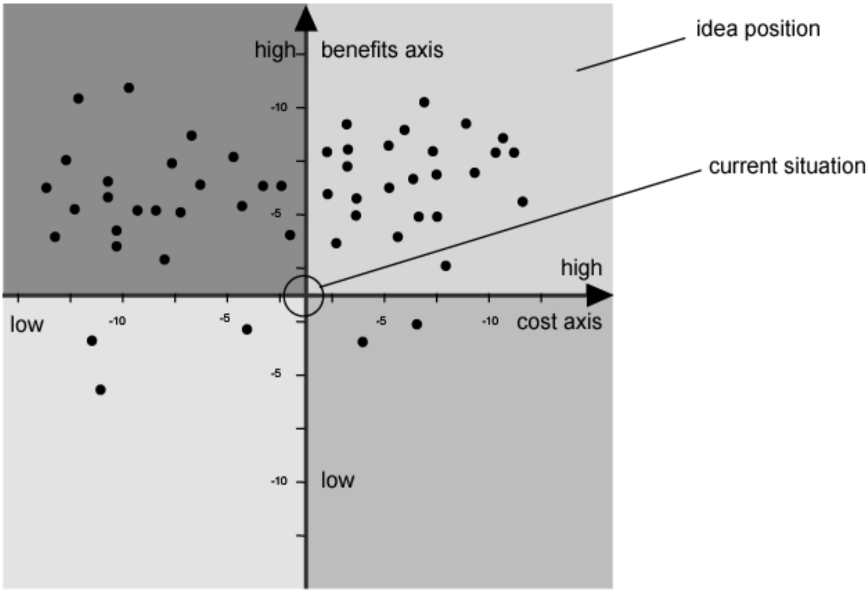

Figure 2. Graphing V = B – (H + I + C)

2. Innovation tools

In today's modernized society, tools and techniques have seldom replaced human ability to perform, innovate or achieve a goal. This is clearly illustrated by the slow evolution of artificial intelligence and its applications. The expected breakthrough hasn't actually taken place.

However, combining technology and mechanisms with personal creativity and entrepreneurship have greatly enhanced our capacity of value creation. Innovation tools are designed to strengthen and enhance the speed and effectiveness of innovation managers and engineers, by offering a systematic approach for the innovation process

3. Principles and trends into Innovation Directions

Within the variety of triz-sourced tools, the evolution trends and inventive principles are substantial. However, users often find it challenging to determine what tool to use during what case. Obviously there is also quite some overlap between the principles and the trends of evolution. Some examples:

Principle 1 'Segmentation' fits in the 'Object Segmentation' trend
Principle 18 'Mechanical Vibration' fits in the 'Rhythm Coordination' trend
Principle 25 'Self-Service' fits in the 'Decreasing Human Involvement' trend
Principle 31 'Porous Materials' fits in the 'Space Segmentation' trend

In figure 3 below are some examples of the three step innovation directions with their comparative principles. The complete set of direction includes all of the strength of the principles.

DIRECTION	STEP1	STEP2	STEP3	PRINCIPLES
segmenting	Solid	Segmented	Fragmented	1
adding holes	Monolithic structure	Hollow structure	Structure with multiple hollows	2
asymmetry	symmetric	asymmetric	matched asymmetry	4,35,37
combining	Mono-system	Bi-system	Poly-system	3,5,6,7,33,40
decreasing the weight	heavy	normal	light	8,37
coordination	action	Action + Prior (Counter) Action or Cushion	Fully Coordinated Action	*9, 10, 11, 34*
Surface	smooth surface	surface with rib protrusions or carve	3D roughened surface	14,17
dynamising	Immobile system	Jointed system	Fully flexible system	15,30,36
vibrating	Continuous action	Periodic Action	Use of Resonance	*18, 19*
Using harmful effects	Object with harmful factors	use of the harmful factors	Ellimination of Harmfull factor	22
Increasing feedback	Direct control action	Action Through Intermediary	Addition of Feedback	22, 23
customer	perfect	Now	free	27
Main	solid	Liquid/gas	field	26,28,29
Coloring	No use of color (Monochrome)	Binary use of colour	Use of visible spectrum	32

Figure 3. Excerpt of CREAX Directions for Innovation Mapping ™

4. Directional symmetry

Referring to the 'Tetrahedron of evolution' paper by CREAX at this conference; the directions shows an important symmetry. For example, the direction segmentation and adding holes are directly symmetric, and often solve the same problem;

- a strong but not a heavy table can be resolved by adding holes, or segmenting the table into portable units.
- a porous sugar cube dissolves as fast as a powder
- a sponge can filter as good as a powder

In search of alternative solutions, this symmetry has become a vital area of research for patent and innovation studies. Other examples of symmetry are protruding and carving, adding or being added, field within or in field.

5. Innovation Mapping™

Any product or process can be mapped along the set of directions as shown in figure in which we identify its level of evolution along every direction. The darker inner zone thereby defines the current system. All white space around the grey area, is untapped evolutionary or innovation potential. The user can then evaluate which step can be taken (R&D-wise) and which step can be sold (marketing wise). The search will be fortified by a set of '*benefits of evolution*', benefits that systems have acquired by moving along a direction. Example, adding holes brings benefits like less weight, less material, space for additions, space for filtering another material, or aeration.

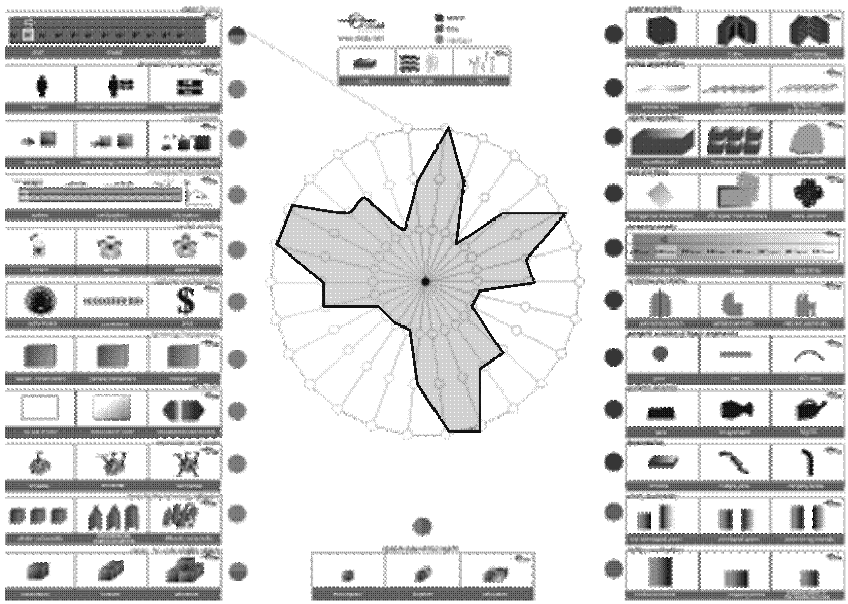

Figure 4. Innovation Mapping™

6. Conflict Map for Directions

Although the Innovation Mapping™ has allowed concentrating the innovators effort in a distinct set of innovation directions, time can still be optimise by connecting to a conflict. All systems contain conflicts. To refer to the example above, wanting strength though no weight is typical conflict. Knowing which direction to take, within the Innovation Map, can be guided by the conflict map for directions. Distilled out of patent research and recent CREAX publications, an integrated conflict map is proposed, of which an excerpt is depicted in figure 5. Both left and top columns contain parameters that describe the potential conflict. The crossing points are indicating which directions should be followed to solve the conflict, whilst gaining innovation potential. A similar sequence has been constructed for the solution of physical conflicts. The new tool integrated the formerly known principles and conflicts, and greatly enhance the user interface.

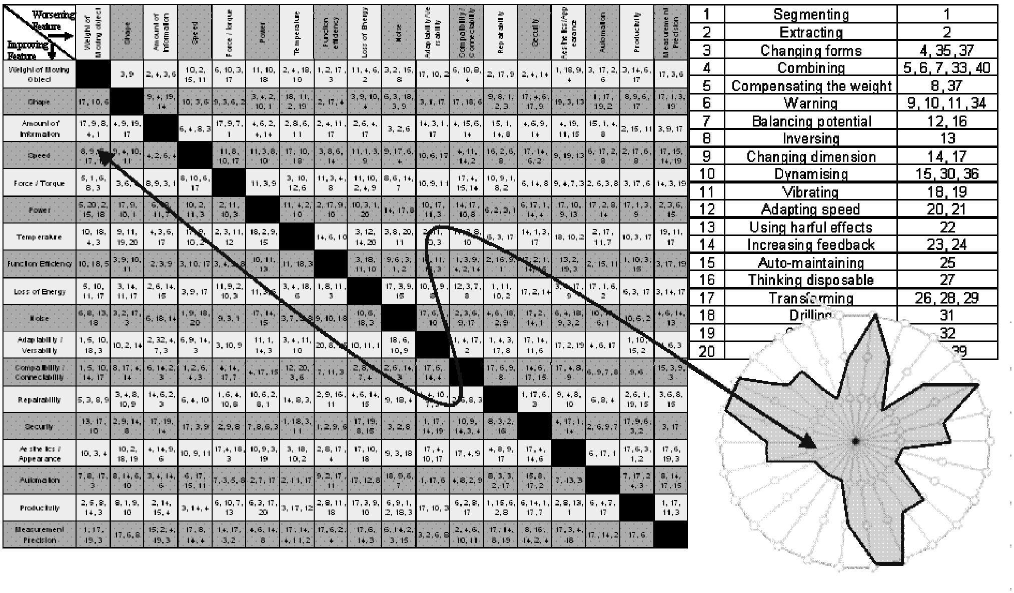

Figure 5. Excerpt of the conflict map for directions

7. Function Database Integration

Finally, as the innovator identifies the basis function, the system has to perform; the function database (http://function.creax.com) can depict all ways to achieve that function; shown in figure 6. It remains up to the user to evaluate, which functions in abstract fit untapped white zone, and can allow a gain in evolutionary potential on the innovation map.

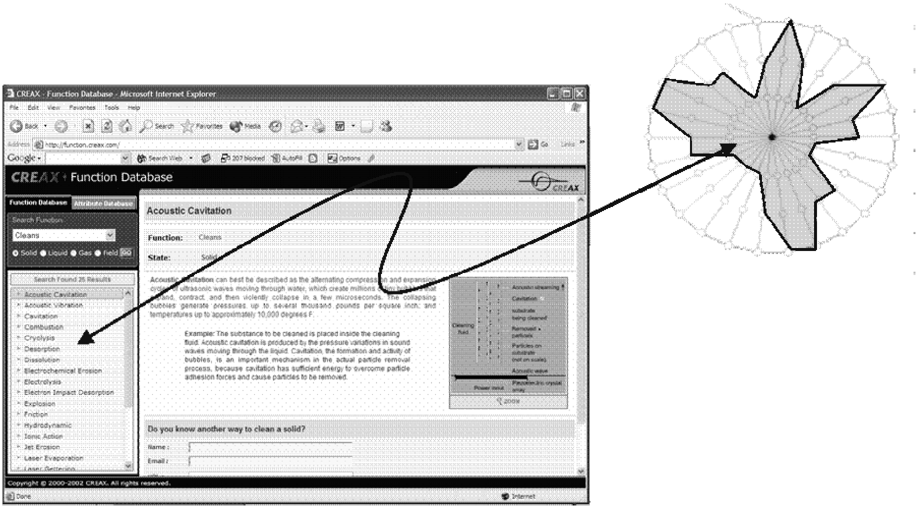

Figure 6. CREAX function database

8. Conclusion

This evolution to 'directions' has proven advantageous in its universality (principle 6, or rather direction 'combining'). The symmetry in direction has become a worthwhile area of research, opening a new performance in innovation studies and patent work. Innovation Mapping™ illustrates that parts of the method can be extracted without compromising on the innovation performance. Everything is evolution, and the attractiveness of a uniform sequence of clear and effective Innovation Mapping™ has already been justified by its recent success. R&D and marketing of numerous client companies have experienced a better working interface through Innovation Mapping™.

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http://function.creax.com

POSTERS AND EXTENDED ABSTRACTS

TRIZ EDUCATION WITH COMPUTER BASED TRAINING SYSTEM

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Abstract
After reviewing the State-of-the-art of TRIZ diffusion and education, the idea of TRIZ educational principles in computer based training system is proposed, and the optimal way to deliver the idea of TRIZ to mass people via computer based training system, CBT/NOVA™, is presented.
The computer based training system provides capability for people who wish to improve their innovation skills and to solve complex engineering problem by learning in deep TRIZ and its applications. Basic and Advanced TRIZ courses introduce the Laws of technical system evolutions, Algorithm to solve inventive tasks (ARIZ), Principles and Standards for resolving technical / physical contradictions in technical systems, and tools to activate creative thinking.
The computer based training system is built on client-server technology, and its scalable software architecture allows education professionals to create and manage different multimedia based education courses, control education process and communicate with each learner. Powerful features for test generation support teachers to create certifications programs of different level complexity.
The computer based training system supports daily education process in corporations, universities and colleges to support TRIZ diffusion on a large scale.
Keywords: TRIZ, Computer-based Training.

1. State-of-the-art of TRIZ diffusion and education

During last 10 years, TRIZ-based systematic innovation has penetrated all major industries. World leading companies use TRIZ to solve both long-term and short-term problems and generate new concepts of products and services. Based on 50 years of scientific studies, TRIZ helps to drastically accelerate innovation process by offering tools and techniques for systematic situation analysis, problem solving and new ideas development by combining system thinking and creativity.

But the difficulties to diffuse TRIZ on a large scale, such as within universities, enterprises, even nationwide, in Occident and Asia-Pacific are also appearing. Reviewing the

State-of-the-art of TRIZ diffusion and education, following three styles or paradigms of TRIZ diffusion and education are observed.

1.1 Seminar and/or training with TRIZ specialists

Typical case of this style is the success and hurdle of TRIZ in Boeing.

From 2000 to 2003, Mr. Royzen's 5-days TRIZ workshop provided more than 500 of Boeing's engineers with the ability to solve their real problem with TRIZ. Using TRIZ, substantial internal cost savings and new contract awards have been realized. [TRIZ Consulting Inc, 2003]

But according to [Masingale, 2003], due to the limited training that has taken place thus far in Boeing (500 out of approximately 100,000 technical persons in Boeing is not a high overall percentage) TRIZ has only marginal acceptance throughout the very large Boeing Enterprise. The optimal way to deliver the "initial introduction" of Basic TRIZ to tens of thousands of people is via web-based e-learning/training, followed up by at least a few hours, if not a few days, of coached practice working real problems. Its creation and implementation is paramount to having TRIZ widely accepted and fully implemented in major industrial institutions, as well as for the needed Global expansion of TRIZ.

Therefore, the short-term (3 or 5 days) TRIZ seminar/training make possible the introduction to TRIZ, but unfortunately, it is not enough to allow students or trainees to use TRIZ in practice.

1.2 Combination of TRIZ specialists and on-line training system

Typical case of this style is the success of TRIZ application in Samsung. [Shpakovsky, 2002]

The scheme of a three-stage TRIZ training was proposed at Samsung: (1) Teaching all employees by on-line training system "TRIZ-Trainer", (2) Teaching by seminars with teacher, and (3) Teaching by real consulting.

From 2000 to 2002, TRIZ training had done for more than 2000 employees at Samsung with the help of internal "TRIZ-trainer" developed by TRIZ experts from Belarus and Samsung engineers. The R&D cost savings is the equivalent of US$ 91.2m.

1.3 Distance TRIZ education via Internet

TRIZExperts [Sorkina] proposed distance TRIZ education via Internet, i.e., students can obtain the lectures of TRIZ specialists and individual tasks to be solved in time convenient for them.

This is an effective and efficient way to educate TRIZ for individuals. But as for TRIZ education in universities or enterprises, this style has difficulties to integrate with existing curriculum or training program.

1.4 TRIZ diffusion suggestions of Keynote speach [Cavallucci, 2003] in TRIZCON2003

Directions for successful diffusion & durable development of TRIZ:

- ✓ Robust & efficient industrial practices and reliable consulting actions is a must, but we need to understand that corporate cultural changes are necessary;
- ✓ Academic world must be involved to structure research effort around TRIZ integration & development;

- ✓ Worldwide recognition and aura of TRIZ must be cultivated by testimonies and success stories;
- ✓ Individual competences and skills must be disclosed and taught at all ages to guarantee industrial survival & uses.

Directions for successful nationwide diffusion:

- ✓ Convince the highest authorities in the nation (state) about the necessity to modify curriculums and skills definition;
- ✓ Teach the teacher's teachers (several per academia) with advanced trainings and disclose the pedagogical way they will be introduced into curriculum.

1.5 TRIZ educational methodology by Homenko and Altshuller

TRIZ objectives and theoretical issues of the TRIZ educational process were outlined in details [Homenko, 2002]. The theoretical and educational methodology is not only for engineers but also for young students. People who studied TRIZ through this approach can analyze various kinds of problems, not only engineering.

2. TRIZ education with computer based training system

After reviewing the State-of-the-art of TRIZ diffusion and education, a full range of training services, CBT/NOVA^{TM}, which helps engineers and students to learn a unified and structured approach to Systematic Innovation and master practical skills with its tools and methods, is presented. Our principal trainers have at least 15 years of experience with training Systematic Innovation worldwide. Both public and in-company training are supported.

2.1 Principles and objectives of CBT/NOVA^{TM}

Among various creative abilities at which TRIZ is aimed to develop and motivate system thinking. Overcoming of the intellectual and psychological inertia is one of the main objectives of the training. In this context, it's suggested to apply the system vision of the problem and to model the problem using the natural language without using domain-specific terms. The problem solver looks at the problem beyond the situation, where the problem occurs. This broadens the field of problem investigation thus looking for the solutions from other technical domains. The application of ARIZ is aimed at mastering of the following abilities: formulating of the technical contradictions, analysis of the resources and IFR, formulating of the physical contradictions at the Macro- and Microlevels, inventive rules based reasoning with TRIZ Principles and Standards.

ARIZ is a powerful tool that allows the problem solver to discover all the sides of the problem thus working out strong and effective solutions. To achive strong solutions, ARIZ supposes to use biological, physical, chemical knowledge, knowledgebase TRIZ Standards and the strong analogous solutions derived from the patents.

The main objective of TRIZ in CBT/NOVATM is to learn to handle the problem using the algorithmic approach. The learner is stimulated to develop and use creative thinking when analysing the problems and searching for the solutions.

2.2 Functions and structure of CBT/NOVA™

There are two TRIZ courses in CBT/NOVATM:

Basic TRIZ:

- ✓ Methods for Creative Imagination
- ✓ Laws of technical system evolution
- ✓ Technical and physical contradiction
- ✓ Conversion of technical contradiction into physical contradictions
- ✓ Principles for resolving of technical and physical contradictions.
- ✓ Principles of innovation knowledge base creation
- ✓ Concept evaluation principles

Advanced TRIZ:

- ✓ Introduction in Su-field analysis
- ✓ Standard Rules to Solve Inventive Tasks (TRIZ Standards)
- ✓ Algorithm for Inventive Problem Solving (ARIZ 85C)

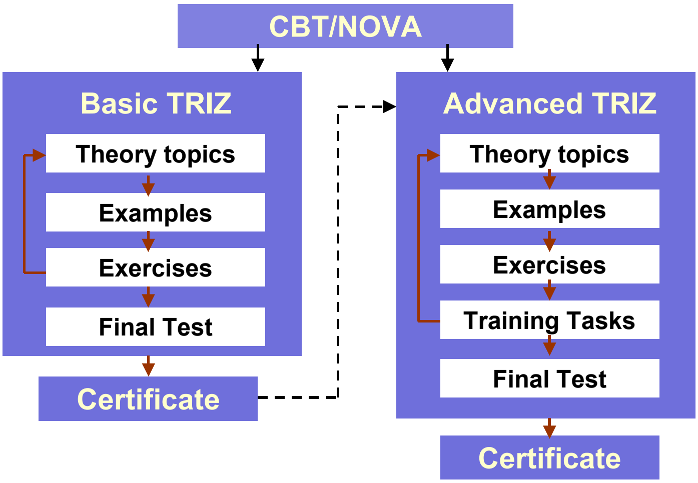

Figure 1. CBT/NOVA™ functional workflow for Learner

Theory topics introduce the fundamentals of the TRIZ theory.

Examples illustrate a practical embedding of the TRIZ methodology for problem solving according to the selected topic/subtopic.

Exercises allow nailing down acquired theoretical knowledge thus practicing problem sensitivity.

Training Tasks are special tasks needed interaction between Learner and Teacher. Training Tasks are aimed at mastering the skills for identifying the right problem solution according to the passed theoretical material. They are composed in the Advanced TRIZ course only.

Question Base contains the collection of training tasks and exercises. Teacher selects appropriate practical tasks, stored in the question base, and in such a way composes the final test (the question base is not shown on the figure1).

Final Test contains the practical tasks covering the material of the overall training course. This test is meant for final evaluation of learner's success.

Certificate is a document in electronic form, which states that learner successfully passed the training course.

CBT/NOVA^{TM} supports also the possibility to create additional courses and compose their contents.

There are no strict limitations on the quantity of exercises, final tests and training tasks to examine learner's knowledge. The concept is that practical tasks do not over-saturate the course and meet the requirements of the teaching-learning methods.

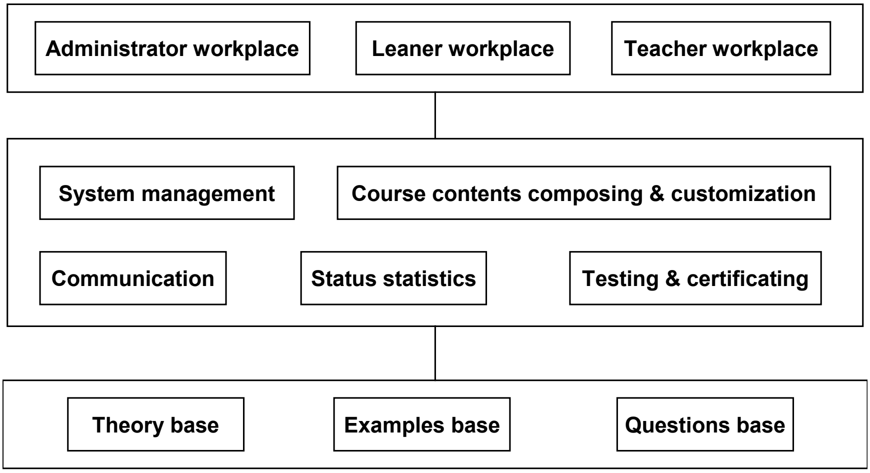

Figure 2. CBT/NOVA^{TM} structure and services

2.3 Benefits of CBT/NOVA^{TM}

Benefits of CBT/NOVA^{TM} are:

- ✓ Education management can easily organize and manage courses, teachers, students and students group.
- ✓ Knowledge composer provides publishing of texts and multimedia for Theory explanation articles, Examples of theory application, Tests and Training Tasks.
- ✓ Powerful features for test generation support teachers to create certifications programs of different level of complexity.
- ✓ Statistics tools allow teachers and students to trace education process (number of passed topics and tests)
- ✓ Teacher can state the creativity level of every student and communicate with person to help in resolving difficulties.
- ✓ Communication feature supports student in communication with teacher if the first completed Training Task or has questions to teacher.
- ✓ Basic and Advanced TRIZ courses introduce the Laws of technical system evolutions, Algorithm to solve inventive tasks, Principles and Standards to resolve technical / physical contradictions in technical systems and tools to activate creative thinking.
- ✓ All examples and exercises explaining TRIZ applications are original, based on real-life or industries-oriented cases, and have not been published in TRIZ literature.

- ✓ Custom Basic and Advanced courses can be supplemented domain oriented examples, tests and Training Tasks.

CBT/NOVA™ can be helpful in supporting innovation educational and training process for:

- ✓ Professors, teachers, students of engineering specialties
- ✓ Consultants in the field of innovation design and technology
- ✓ Organization of vocation qualifications
- ✓ Engineers of R&D department
- ✓ Engineers of Patent application department
- ✓ Quality engineers
- ✓ Chief Engineers of R&D department
- ✓ Senior Engineers of R&D department
- ✓ Production managers

3. Conclusion and future works

Goal of CBT/NOVA™ is to teach more and more young generations in order to build the foundation of TRIZ pyramid outside former Soviet Union. In the near future, following potential enhancements and perspectives of CBT/NOVA™ will be considered:

- ✓ New courses will be developed to support DFSS workflow:
  - ✧ Combination of technical systems.
  - ✧ Basic and Advanced QFD. QFD and TRIZ integration procedures.
  - ✧ FMEA. FMEA and TRIZ integration procedures.
- ✓ New courses will be developed to support TRIZ education for middle school students.
- ✓ New creativity assessment system based on TRIZ will be developed to support TRIZ diffusion on a large scale.

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DIFFERENT APPROACHES TO TRIZ INCULCATION IN DIFFERENT FIRMS

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Abstract
The experience of the authors and of their colleagues on TRIZ inculcation in different firms is generalized. The needs of each firm on TRIZ application are particular. The various approaches are debated. The 40 Altshuller's principals present one of the possibilities to facilitate this goal.
Keywords: TRIZ, inculcation, plantation, firm, Altshuller's principals.

It is obvious for everybody who deals with TRIZ that this subject (theory, method, discipline…) can be useful for each firm. But, if the firms are different, can the TRIZ inculcation to be the same?

The firms differentiate on their activity domain, on organisation srtucture, on "age", on greatness and on other caracteristics.

The wide practical experience shows that TRIZ inculcation can't be of the same kind for all the firm's type. Rather, it is to be individual.

But there are the common pattern that will be discussed in this work.

We shall consider the couples "Firm – TRIZ".

If we regard as IFR (Ideal Final Result): "All the employees of all the firms know TRIZ" – it is unattainable today. In that case, ARIZ recommends a "Step back from IFR" which can be formulated here as "All the firms use TRIZ ".

An intermediairy stage on this way: "In each firm somebody knows something about TRIZ".

An intermediary goal can be presented as a proposition: to "infect" the firms by TRIZ.

Here it is necessary to take in account the "structures" of both of the participants of the couple "Firm – TRIZ".

The structure of great firms differs notably from the structure of small firms.

In the large firms there are a lot of hierarchical levels (vertical ties). Each level has his domain of responsibility, his functions, his work methods. We consider it in form of System Operator ("9 screens presentation") and we take in account the horisontal ties also.

The small firms have the stuctures very simplified. On a limit, it can be 1 leader and several workmen.

The middle firms structure can be as one in the great but simplified.

We compare the *TRIZ structure* with the *firm's structure*.

TRIZ can be examined from 3 different points of view:

a) TRIZ as the theory (mainly, the theorie of technical and non-technical system developpement);
b) TRIZ as a method of problems solution in different domains;
c) TRIZ as a method of human creativity development.

Each aspect can be used by each firm, but on different manners.

There isn't two equal firms, each has its peculiarity. They can be classified on various basis. The simplest description of classification is their volume.

Firm's type	Firm's structure	Quantity of different technological operations
Small firm	Simple (spider-web)	Little
Large firm	Multilevel hierarchy	Much

Different firms need the different TRIZ application (the large firms – permanently, the small firms – occasionally).

Different hierarchical levels need different TRIZ "instruments" (parts).

There is no level to which TRIZ would be useless.

One of the ways to inculcate TRIZ – to apply the 40 Altshuller's principles.

Exemples:

Principle #1 – Segmentation.
To segregate TRIZ into different parts;
To segregate the firm into different parts and they attack on different manners.

Principle #2 – Extraction.
To extract the necessary part in TRIZ;
To extract the necessary subdivision in the firm.

Principle #3 – Local quality.
To use the different arguments in different conditions.

Principle #4 – Asymmetry.
To present the different TRIZ parts to different firm subdivisions.

Principe #5 – Consolidation.
To present TRIZ in a package with other methods, to show its strong singularities and advantages.

Principe #6 – Universality.
To demonstrate the universality of TRIZ, its capacity to different actions.

Principre #7 – Nesting.
To show that there are the different TRIZ levels.

Principe #8 – Counterweight.
To compensate the seeming TRIZ difficulties by demonstration of simple problems comprehensible to each audience.
.
.
.
etc.

One of the ways for the firms to make the first acquaintance of TRIZ is the acquiring of specific computer programs. It is necessary to understand that it is not enough, because

$$\frac{\textbf{TRIZ}}{\textbf{Computer program}} = \frac{\textbf{Mathematics}}{\textbf{Calculator}}$$

This “proportion“ means that a computer program application can’t be really useful without good attainments on TRIZ.

The methods “derivative” of TRIZ (SIT, ASIT, USIT…) can be useful for the initial familiarization, but the whole TRIZ is much richer.

TRIZ PROPAGATION STRATEGIES AND SYSTEM IN KOREA

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Abstract
KITECH(Korea Institute of Industrial Technology) is unique among all the national labs in Korea. KITECH puts its primary R&D focus on the technological support for SMEs. KITECH not only works hard to solve SME's current technological problems, it also leads SMEs into new technology development. KITECH's performance leads the nation: 71% of our research found industrial application or commercialization, 30,000 items of on-site technical support per year and 13% of projects conducted with international cooperation.
I would like to show you TRIZ propagation strategies and system in KITECH. We have TRIZ experts in KITECH, we will utilize domestic TRIZ experts and foreign TRIZ experts. KITECH and Samsung TRIZ group have concluded a MEMORANDUM OF UNDERSTANDING(MOU).
This paper will be a good reference to use and widespread TRIZ to reader's own country.

1. Introduction

According to my experience in TRIZ application to the R&D project, TRIZ is an excellent tool. However, since it takes a long time to learn and utilize TRIZ, the great concern has to be taken for developing and propagating TRIZ to widespread in Korea. In this paper, I would like to describe the TRIZ situation in Korea, to show the plan of KITECH how to propagate and to utilize TRIZ in Korea.

2. Korea TRIZ situation and KITECH

TRIZ Task force in KITECH has been set up in the early of 2004. I presume the TRIZ in KITECH is placed at the infant stage of S-Curve.

Before I proceed to show more about TRIZ plan in Korea Institute of Industrial Technology(KITECH), let me introduce KITECH.

Born in 1989, Korea Institute of Industrial Technology(KITECH) has tried to develop practical technologies and apply them to production line since it's foundation. With the technological support of KITECH, our small & medium enterprises(SMEs) are leaping toward the world stage.

KITECH is unique among all the national labs in Korea. KITECH puts its primary R&D focus on the technological support for SMEs. KITECH not only works hard to solve SME's current technological problems, it also leads SMEs into new technology development. KITECH's performance leads the nation: 71% of our research found industrial application or commercialization, 30,000 items of on-site technical support per year and 13% of projects conducted with international cooperation.

I would like to explain the Korea R&D situation.

There are 3million small and medium size enterprises(SMEs) in Korea currently in 2004.

Usually large enterprises have abilities to hire capable people and establish good R&D centers. But SMEs are not available(enough money, time, people). They know well the technical problem on their product.

I think SMEs' innovation bring another innovation to Korea industry. So my institute supports the SME's technical innovation. There are two associations in Korea, STA, KTA. But Samsung Triz Association can not propagate to my country. Since STA is under the enterprise situation. All of results by TRIZ are security in company. And KTA do not have a power yet. My purpose for the KITECH is problem solving of SMEs and public institute under prime minister office. If I can set up the TRIZ Task Force in KITECH, TRIZ can be widespread in Korea.

3. Work System

There are four main works in KITECH TRIZ Task Force. First is consulting, second is education, third is R&D and the last is operating TRIZ conference.

When a company wants to innovate their own company, the first thing is to decide who is in charge of the innovation. In case of methodology like TRIZ, which requires a long time to comprehend, it is hard to apply real problem.

If other company have some technical problems, they can request to KITECH to solve the problems. Then KITECH TRIZ task force decides between technical solving and education task process logic.

If TRIZ expert in KITECH supports its own costumer in request, Korea government supports 80% of the expense to innovate the company.

TRIZ education work operates the Management Of Technology academy in Ministry of Commerce, Industry and Energy(MOCIE). I emphasized to MOCIE the TRIZ is included on MOT curriculum. MOCIE accepted my opinion. So KITECH manages 'R&D problem solving methods' section. There are three kind of subjects. One is TRIZ, another is DFSS, the other one is QFD. Now, MOT academy is pre-operated until this year to open next year.

TRIZ R&D work will be development of software. There are not yet Korean TRIZ SW. A lot of TRIZ engineers in Korea want to use Korean TRIZ SW, and especially SMEs' engineers are good at engineering but poor at understanding foreign language.

The last one is make a TRIZ society in Korea. We will hold the international TRIZ conference in formal society. We will apply MOCIE to agree making TRIZ society until this year.

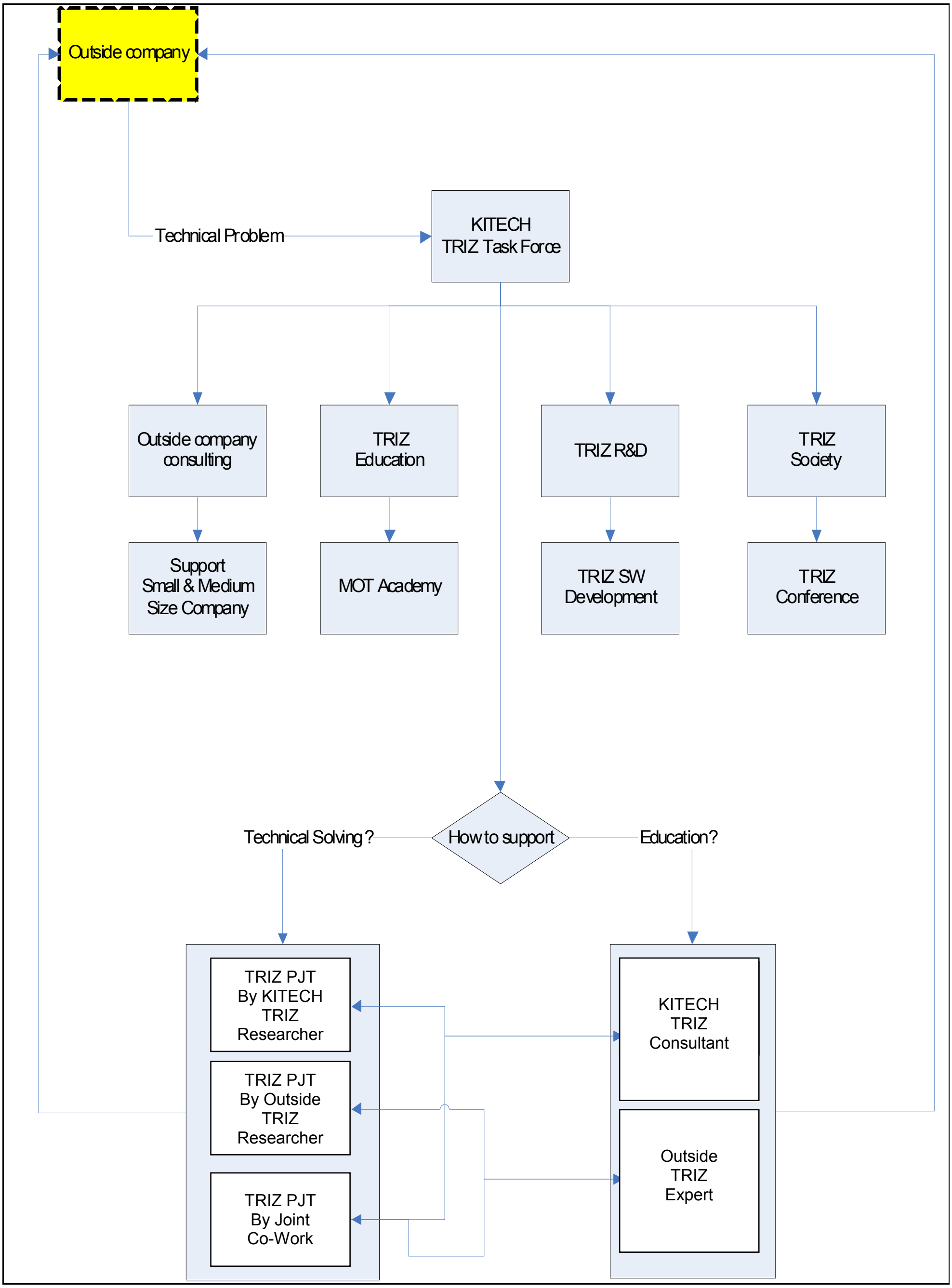

Figure 1. Work Flow for KITECH TRIZ task force

4. Patent and TLO

Usually TRIZ outputs are leaded to patent acquirement. The rest of Project required by outside companies are leaded to patent acquirement either. We will use these patent to sell outside company or person. There are Technology Licensing Organization(TLO) in KITECH. TLO is supported by Ministry of Science and Technology(MOST). MOST want to boost up the TLO in Korea. So KITECH TRIZ task force will use TLO.

5. Conclusion

KITECH made the first step toward TRIZ application to the Korea successfully and is trying to make another step. Experienced outside Korean TRIZ experts contributed to the successful first step by conducting TRIZ projects well and KITECH TRIZ expert. The processes for TRIZ project and education have been developed on the basis of my experience and my institute. In the second step, KITECH TRIZ experts will play an important role in Korea.

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NEW TRIZ-BASED TOOL — FUNCTION-ORIENTED SEARCH (FOS)

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Abstract
One of the major obstacles for a worldwide TRIZ implementation is a contradiction within TRIZ itself. On the one hand, based on Altshuller's five levels of Invention Classification, the best solutions belong to Levels 4–5, which require dramatic changes in the design of a Product or Process, or even the Action Principle. On the other hand, the TRIZ mini-problem approach requires minimal changes in the initial Product or Process, to make implementation of the solution easier. Usually, it takes years to actualize a new Action Principle.
As a part of the TRIZplus methodology, we developed a new paradigm shift — Function-Oriented Search (FOS) — to help solve this contradiction. The main idea of this approach is to find an existing Technology (Product or Process) and transfer it to the Initial Problem, as a Solution. Thus, we can offer a new and very effective Action Principle to solve the initial problem; we also do not need to spend a lot of time and effort proving the effectiveness of this new solution and putting it into practice, because the Technology already exists.
Keyword: Function-Oriented Search, TRIZplus, secondary problem, engineering system, action principle.

1. Introduction

Function-Oriented Search entails finding and effectively using appropriate existing Technologies. Three major issues should be addressed as part of that effort. First, a direct technology search is very ineffective — every subject matter specialist tries to find new developments in his or her scientific or engineering field. The probability of actually finding some new, effective solution via a direct search is very low.

Second, if you are trying to search for the right solution/technology in a remote engineering area, the search field becomes almost infinite.

Third, even if you find a potentially attractive technology in a peripheral area, you simply cannot effectively apply it to your initial engineering system, because you don't have enough knowledge about the new action principle.

FOS allows us to address these three issues.

We began to develop this new piece of TRIZ methodology in mid-1980s, in the former Soviet Union. The first practical implementation of FOS took place in 1988. Since then, we have seen hundreds of successful examples of FOS applied in various engineering areas, worldwide.

FOS further develops Genrich Altshuller's idea that the shortest path to an effective solution is to use an analogy; however, to find a non-trivial solution, that analogy should be not direct. Altshuller even suggested one of the possible bases for such remote analogies:

physical contradiction. He recommended using an analogous problem as a problem-solving tool in the latest versions of ARIZ. However, to effectively use this tool, the TRIZ community needed to create a significant database of the analogous based on physical contradictions. This was never done.

FOS represents another kind of analogous — based on the same or similar functions.

The simplified algorithm for FOS will be demonstrated with a practical case study.

2. Initial situation

The Client was producing plastic hygienic pads that had thousands of tiny holes. The Client produced these holes using multi-punch stamping equipment. There were two major problems with this product:

a) Low open area of holes (< 12%)

b) Uneven edges of holes after stamping

The Client also considered laser technology that could eliminate these problems, but that represented much lower productivity than stamping, and much higher cost.

3. FOS Algorithm

1. Identify the Key Problem that prevents the Product / Process from solving the Initial Problem. TRIZ*plus* has a fairly well developed methodology for identifying Key Problems.
   Example:
   One of the key problems related to hygienic pads:
   There should be a large number of holes to create a large total open area; however, there should be a very limited number of holes to prevent material strength deterioration.

2. Formulate necessary function(s) for Key Problem solving.
   Example: Function — to punch (perforate) the plastic sheet

3. Formulate required functional parameters.
   Example: Most important required parameters are:
   - Plastic sheet thickness — 0.5 mm
   - Diameter of holes — 5 μm
   - Open area (desired) — > 20%
   - Pad mechanical strength — not less than after stamping
   - Cost — not higher than stamping

4. Formulate a generalized function.
   Example: Generalized Function: create holes in a thin material

5. Identify a leading area(s) of industry where such types of functions are vitally important.
   Example: One of the leading areas found in the function-oriented database was the Space Industry

6. Find the best experts in the identified leading area.
   Example: Using our proprietary Global Knowledge Network, we found the best experts in the area of spaceship hull testing.

7. Using professional databases and experts' knowledge, identify candidate technologies.
   Example: We found a technology of micro-meteorites modeling for spaceship hull testing. The material for modeling was steel foil. Diameter of micro-meteorites was 5 – 10 μm. The technology for testing was based on a Powder Gun that shot thousands of equal-sized particles at the foil, making thousands of even holes in a fraction of a second, resulting in an open area of up to 30% without foil strength deterioration.

8. Select the Technology(ies) closest to required functional parameters.

9. Formulate a Secondary Problem(s) that would potentially prevent the selected technology from being immediately implemented to solve the Initial Problem.

10. Solve that Secondary Problem(s).
    Example: We formulated and solved a couple of problems for powder gun technology transfer / adaptation to the hygienic pad production.
    a) How to assure the largest total open area for a plastic sheet, not foil.
    b) How to set up a continuous process instead of the batch operation of the Powder Gun.

11. Describe a slightly modified existing technology as the solution to the Initial Problem.

12. Submit necessary data to substantiate the effectiveness of the identified technology, and suggest a practical plan for its implementation.
    Example: In the end, we presented to the Client an actual Powder Gun, with samples of perforated plastic sheet (25% open area).
    We also submitted all necessary data about a potential vendor of the equipment, cost calculations, and proof of patentability of the technology.

Key components for effective implementation of FOS methodology are:

- Function-based Technology Database
- Leading Area-based Global Knowledge Network (GEN3 has more than 7000 subject matter experts in almost all areas of science and technology).

4. Conclusion

We developed a new TRIZ-based tool for effective inventive problem solving — Function-Oriented Search.

Instead of direct problem solving (even with all powerful TRIZ tools), this method states that almost all solutions necessary to solve problems ***do*** exist in a form of some specific technology implemented in some engineering area.

We should find these best technologies and transfer them to the initial problem. There are two major creative steps in this process — how to:

- Find the best technology, and
- Effectively transfer it to the initial engineering system.

TETRAHEDRON OF EVOLUTION FOUR ELEMENTS, ONE PRINCIPLE FUNCTIONAL SYMMETRY

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Abstract

Early research has uncovered distinct patterns of evolution distilled out of patents. However the model has neither hierarchy nor super-system from which the patterns could be distilled. This paper proposes a structure that is build from basics, to distil the patterns by combination and propose new patterns to investigate. The model relies on the 4 elements, be it solid, liquid, gas and field, was it earth, water, air and fire. The common evolution of solid to liquid to gas to field already appears in evolution lines *object segmentation* or *dynamisation*.

Having identified the main pattern as solid to liquid to gas to field, the majority of evolution lines rely on the combination (principle 5) of these elements in space and time. For example, what was previously known as space segmentation, is redefined as a combination between the two elements solid and gas, be it full to hollow to porous to capillary. The opposite (yin-yang) of the combination is rather then gas in solid, solid in gas, solid to parts to powder to micro powder.

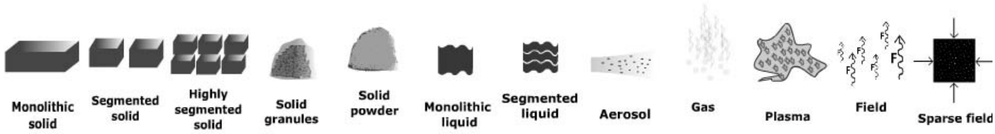
The importance of the *opposite* becomes apparent when the functionality shows equal, i.e. a sponge (segmented gas in solid matrix) or a powder (segmented solid in gas matrix) can perform the same function, and so can a spray (segmented liquid in gas matrix) or a foam (small gas in liquid matrix). Liquid with field is LCD or sputtering, solid with field is transparency or magnets, and so every technology has it's place in the tetrahedron and a direction of evolution; solid to liquid to gas to field or solid to liquid to field, or solid to gas to field, or solid to field. This paper demonstrates the structure of the tetrahedron, and some of the similarities of the findings with the ancient Indian four element theory VASTU.

1. Introduction

There is a large degree of predictability in value creation. Customers always want more for less or referring to our services more of the benefits, less of the cost, harm or interface. All of the trends describe either 'more function' or 'for less system, in line with the value equation. Ultimately one can assume that the target is more for less, towards everything for nothing. In other words perfect, now and free. "More with/or less" being the mother of evolution for products, processes and services, distinct patterns of evolution were identified across various industries.

2. Four Element Extraction

Whilst focussing in on two popular trends: *dynamisation* and *object segmentation* the four phases solid, liquid, gas and field can be identified, what early philosophy named as earth (solid), water (liquid), air (gas) and fire (field). Fields can be any waves like IR, heat or light. The figure 1 below highlights the four element extraction. The steps between the elements will be made up by combinations in space and time; the little roads between the big cities.



SOLID→segmented →powder→**LIQUID**→segmented liquid→aerosol→**GAS**→plasma→**FIELD** (1)

SOLID →single joint→multiple joint→flexible →**LIQUID** →**GAS**→**FIELD** (2)

Fig 1. Four element extraction; solid, liquid, gas and field

The paths (1) and (2) described by the trends above can be over-complete, as cases describe a direct jump from step 1 to step 4. Similarly, with the basic four element model, systems can evolve from left to right, along 4 routes:

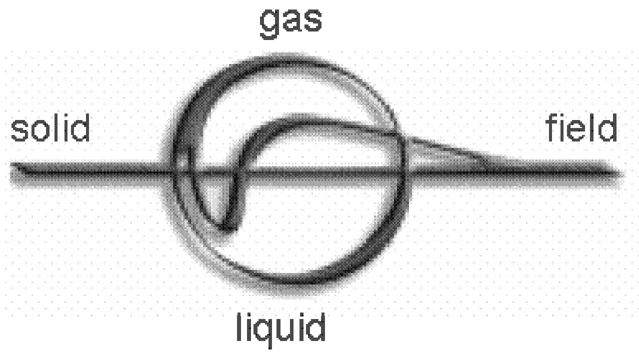


Fig 2. Four element scheme left to right.

First, systems are evolving directly from solid to field, example train rails to maglev train. Secondly, systems evolving from solid to liquid to field, example cutting with knifes, cutting with water rays, cutting with laser. Thirdly, systems go from solid to gas to field, example measuring with a ruler, acoustic measuring, laser measuring. Finally systems can take the full track, from solid to liquid to gas to field, example, extinguish a fire with sand, with water, with CO2 or with an explosion, like they do with burning oil sources.

3. VASTU Comparison

VASTU, an Indian philosophy, has build schemes of comparison with the analogous *earth, water, air* and *fire*. From the Fig 3 below one can infer that 'finer the element, lesser is the degree of expression, but higher is the degree of efficiency'. Using the elements as catalysts, *earth* (solids) has a limited effect on *water* (liquids), *water* has a limited effect on *wind*(gas), *wind* has a limited effect on *fire* (fields), but as far as power and energy are concerned, *fire* (fields) is more effective than *wind* (gas), *wind* is more effective than *water* (liquids), *water* is more effective than *earth* (solids). Fig 4 shows other patterns, taste and shape, derived evolutions from VASTU, currently under investigation

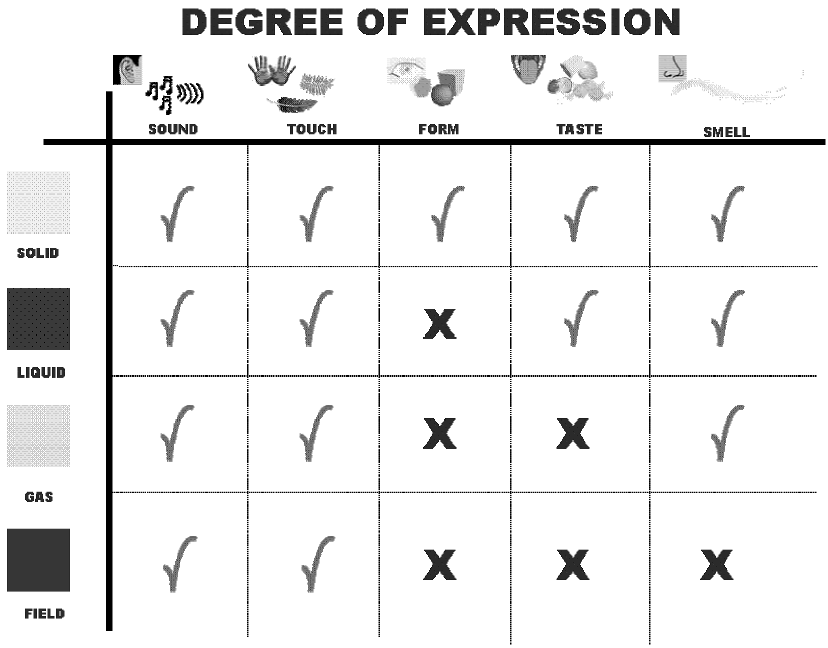


Fig. 3. Degrees of expression of the four elements

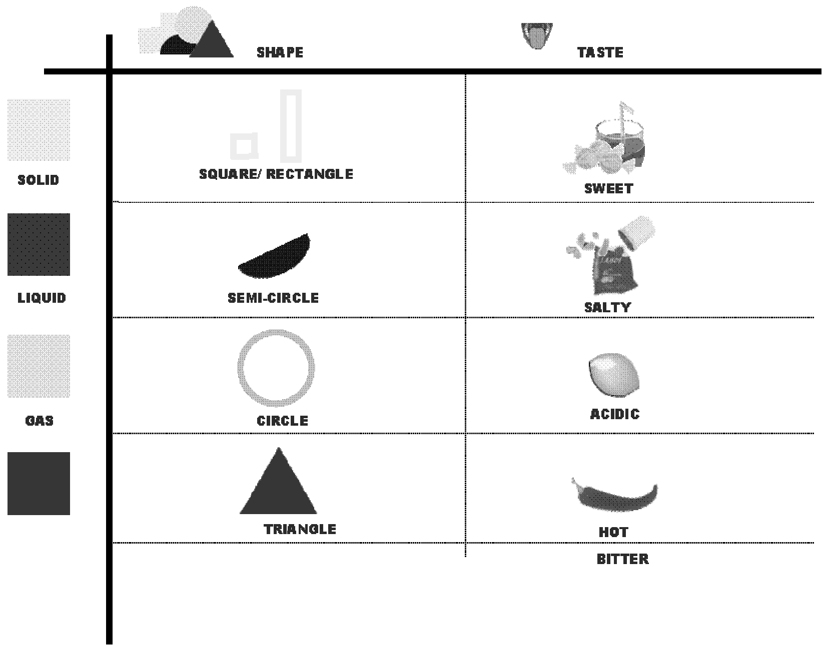


Fig. 4. Shape and taste analogy of the four elements

4. Four Element Combinations

Returning to the four basic categories, solid, liquid gas and field, the combinations need to be worked out. The remaining evolution directions are combinations of the four elements in space and time. Figure 5 below is working out the combination solid and gas in 1 dimension. Combination can be referred to as merge, or composite.

Considering 2 elements, solid and gas for merge:

solid→ gas in solid (*hollow*)→ segmented gas in solid (*sponge*) (3)

solid in gas→segmented solid in gas (*granules*)→fragmented solid in gas(*powder*) (4)

Fig. 5. Combinations of elements solid and gas in one dimension

Please appreciate the symmetry of the combinations; they are analogous to man-woman, day-night, and yin-yang. Most importantly, they express a *functional symmetry*; a sponge can filter as much as a powder. Or in the combination of elements liquid and gas, a spray (*segmented liquid in gas*) and foam (*segmented gas in liquid*) can perform similar functions. The symmetrical systems are considered 'different' in patent literature. This is where inversing the system can bring valuable alternatives.

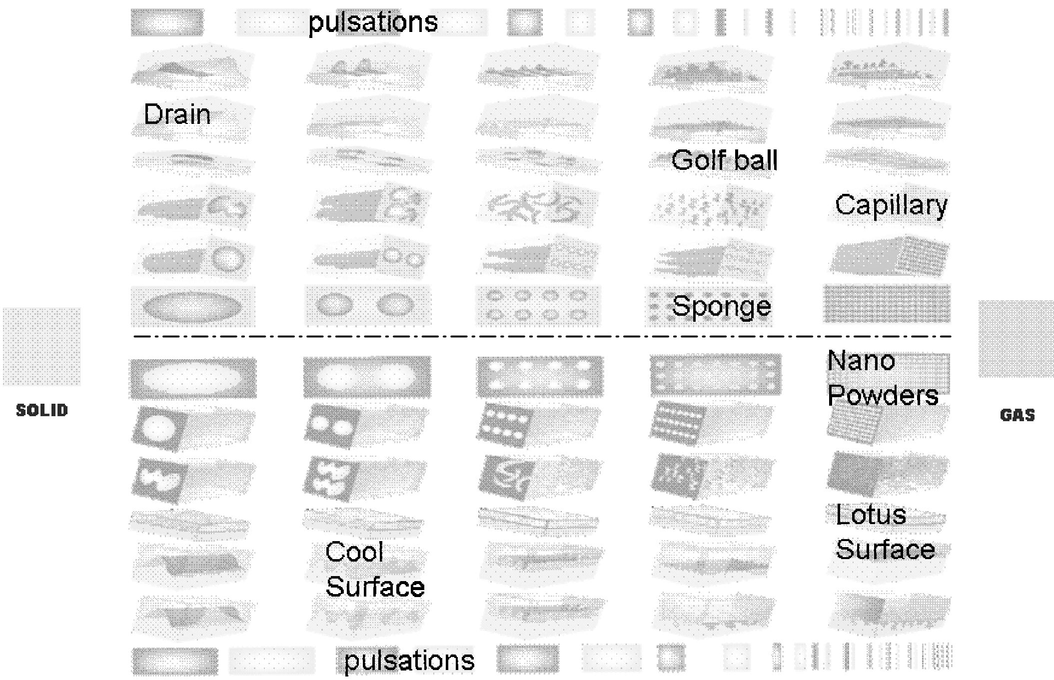


Fig. 6. Combinations in space and time of *solid* and *gas*

Combining in space and time the figure above is emerging; from left to right depict smaller mixes between the two elements, i.e. holes to pores, or beams to fibres to micro fibres. From centre horizon to upwards/ downwards, the figure shows an evolvement in space (inside and outside) and time.

In space, adding dimensions, makes (upwards) from a hole (1D) a tube(2D) a 3D tube. Opposite combination (downwards) makes a ball a beam, a 3D beam. Again, left to right beams become fibre, micro-fibres, and a tube becomes a filter, and capillary systems. Note the functional symmetry, for example a sugar cube, capillary or sponge, and its opposite; sugar powder perform the same function of rapid dissolution.

In space, at the interface, the bubble 2D is a protrusion, a hole 2D is a carve, again carving and protruding can perform the same function of more surface area, cooling capacity or grip. In time, gas can be pulsed in solid; solid can be pulsed in gas. Some examples are superimposed. Gas and field illustrates the patterns in light technology, solid and field gives transparency or magnets, liquid and field gives sputtering or LCD. Mixing all elements will provide a space for all existing technologies; with direction of evolution.

The theory furthermore allows to conduct ‘gap analysis in for example PVD or CVD, vapour deposition uses some of the element (a solid and a gas, or a field or a liquid) but not all. A gap analysis can evaluate which combination will create the most value.

Moreover, the more use finer elements, the more efficient, solid better liquid, better gas, even better field. Integrating all elements of in one diagram, a 2D diagram is suggested:

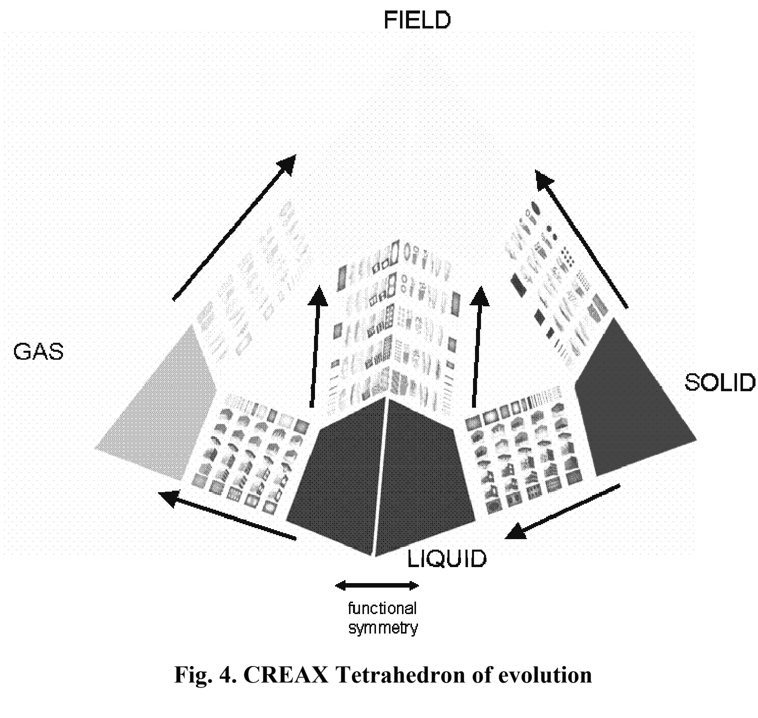


Fig. 4. CREAX Tetrahedron of evolution

5. Conclusion

Although much work of pasting all technologies within the tetrahedron is ahead, the structure has proven an efficient backbone for technologies and evolution. In the function database (http://function.creax.com) the four elements backbone (classification) has proven its relevance. VASTU has illustrated some of the uncovered patterns of evolution from a complete different source, which justifies an in depth study of their findings.

One of the most valuable additions of the tetrahedron is the functional symmetry; i.e. a field in a solid versus a solid in a field, a powder versus a sponge, a foam versus a spray.

Both the tetrahedron and the functional symmetry have considerably contributed to the innovation studies, the technology transfer, and patent work of CREAX.

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http://www.creax.com
http://function.creax.com

CREAX INNOVATOR®
CUSTOMIZATION OF
TRIZ-SOURCED INNOVATION TOOLS

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Abstract
The user friendliness of TRIZ-sourced innovation tools has its challenges. The vital notion of abstraction remains in cases a barrier for many beginning users. The CREAX INNOVATOR reduces barriers to new TRIZ-based solutions by providing exact textual examples a user can choose from.
The Innovator is based on:
1. 'Benefits of evolution' extracted from the lines of evolution
2. The abstract function database
The INNOVATOR has been constructed to generate a textual report on any subject it is submitted to.
The tool aims to minimize user input. For a basic 3 page report the user puts in a product, process or service of their choice. An in depth report is generated according to a subject check list. The first section of this report brings forward a series of descriptive paragraphs, each highlighting the benefits for evolution in a variety of directions. A summarizing 10-page report integrates the utility of the trend conflict matrix and function database
Keywords: TRIZ, checklist, benefits, evolution directions, beginner, textual.

1. Introduction

The most important reason SMEs and educational organizations have not yet fully embraced TRIZ is because of the complexity of its tools and the length of its process. The biggest challenge for beginning TRIZ practitioners is making the abstraction from their own field of expertise and adopting a bird's-eye view of existing knowledge and technology.

The Innovator's checklist format is both powerful and easy to use for beginners and experienced TRIZ practitioners. The Innovator generates a set of paragraphs which inspire the user to come up with ideas, to innovate on existing products, improve processes, and solve conflicts and contradictions.

2. Tools of TRIZ

Evolution Lines (Path)

Each successive step in the evolution line bring certain benefits for products, processes, and services. One example of a line of evolution is "adding holes". Obvious advantages of this trend are: reduction of material, less waste, less cost or place to put something in.

> When your product is solid, a hollow _________ will be lighter and you can add something in the hollow space. *Adding more hollows or pores in a _________ reduces use of material and you get space in the _________ to insert another material. You get a hole in the _________ to hang an object from or to hang the _________ itself. You can pass something through the _________ or improve heat transfer.* Examples are bricks, bars of chocolate, double glazing glass, radiators, soles of shoes, mattresses and tires.
>
> The smooth surface of your _________ can benefit from protrusions. These protrusions can provide grip on the _________, more surface area on the _________ or less noise. *These protrusions are also reducing aerodynamic drag of the _________, improving traction, improving drainage or improving heat transfer properties. They give the _________ a better aesthetic appearance, create deliberate weak-point to break into distinct parts or improve location when joining to another object.* Examples are golf balls, road markers, containers, self-washing surfaces, soles of shoes, handles, tires, helmets and beer glasses.

Figure 1. Blank textual report

> When your product is solid, a hollow **toothbrush** will be lighter and you can add something in the hollow space. *Adding more hollows or pores in a* **toothbrush** *reduces use of material or you get space in the* **toothbrush** *to insert another material. You get a hole in the* **toothbrush** *to hang an object from or to hang the* **toothbrush** *itself. You can pass something through the* **toothbrush** *or improve heat transfer.* Examples are bricks, bars of chocolate, double glazing glass, radiators, soles of shoes, mattresses and tires.
>
> The smooth surface of your **toothbrush** can benefit from protrusions. These protrusions can provide grip on the **toothbrush**, more surface area on the **toothbrush** or less noise. *These protrusions are also reducing aerodynamic drag of the* **toothbrush**, *improving traction, improving drainage or improving heat transfer properties. They give the* **toothbrush** *a better aesthetic appearance, create deliberate weak-point, to break in distinct parts or to improve location when joining to another object.* Examples are golf balls, road markers, containers, self-washing surfaces, soles of shoes, handles, tires, helmets and beer glasses.

Figure 2. Fill in the blanks

Function Database

For all products, processes, and services customers want certain functions achieved. For example; Customers want clean clothes, companies offer washing powder. Customers want communication, companies offer mobile phones. Customers want transportation, companies offer cars. There is a subtle difference between function and solution. Functions will remain the same, customers will always want to communicate, be clean or travel but not always with the same solution (phones, washing powder or cars).

By classifying knowledge by function one can bring companies 'all' possible ways to perform that function. If your function were to empty a glass of water without touching the glass, you could brainstorm and come up with solutions like: use a straw, let it evaporate, blow the water out or use a sponge. The abstract function to be achieved is "moving" a "liquid". The CREAX Function Database will immediately reveal 48 ways to move a liquid.

When filling in the 'main useful function' in the Innovator, it will present the user with a checklist of alternative ways to perform the same function. Many of these alternative ways will be further along its line of evolution and more effective methods of solving the problem.

3. Generating the checklist

The Innovator's functionality allows you to generate paragraphs on Benefits, Functions and Conflicts. Each time the software will ask you a minimum of information like the product name, main useful function or main conflict. It will then present you with a checklist to inspire innovative ideas and solutions.

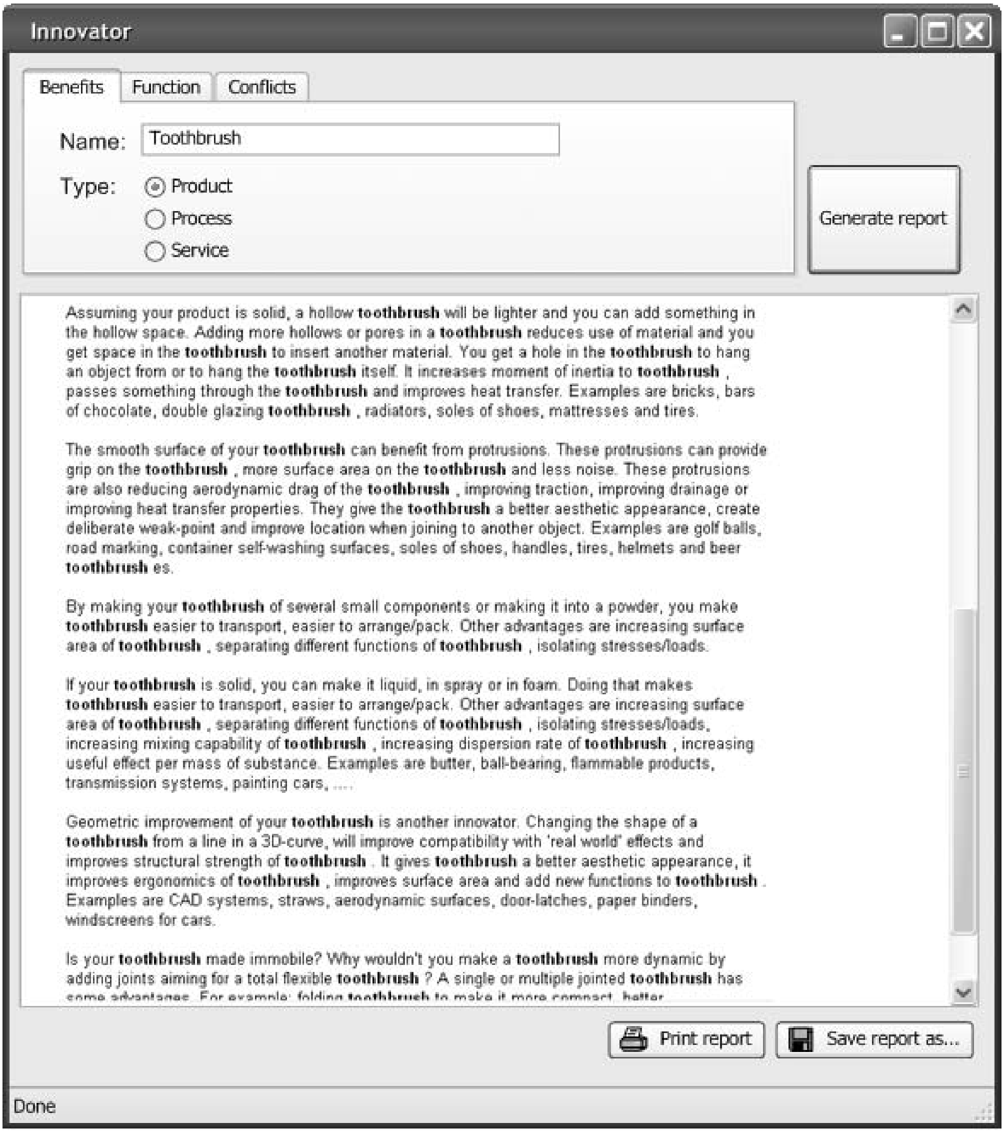

Figure 3. Innovator software

4. Conclusion

The Innovator is a user-friendly and easy to use tool for generating texts with innovation suggestions. The descriptive paragraphs will allow users to come up with product or process innovations. In several case studies, the tool has proven to be very powerful compared to the full TRIZ innovation process.

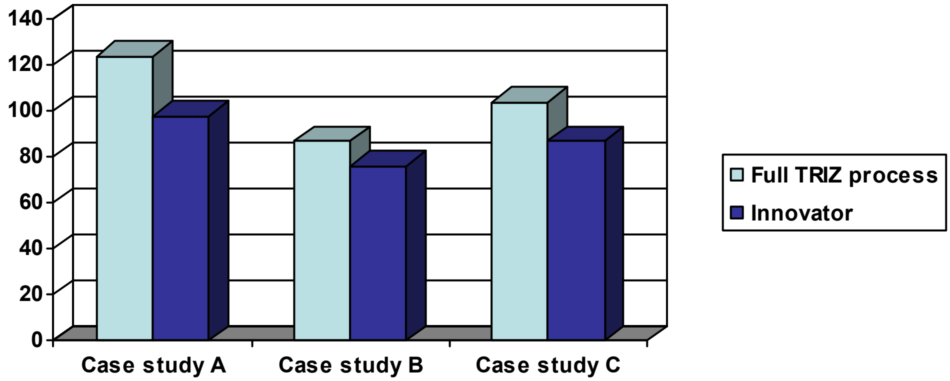

Figure 4. Amount of ideas generated during case studies

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http://www.creax.com
http://function.creax.com

A METHODOLOGY TO DEVISE DIGITAL ELECTRONIC APPLICATIONS

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Abstract
The development of abilities such as creativity and innovation is a challenge for higher education. For Digital Electronics major the challenge is to confront students to design new applications. This article presents a methodology that has been taught in a VHDL (VHSIC Hardware Description Language, VHSIC = Very High Speed Integrated Circuit) course to stimulate the development of creativity in designing electronic devices. VHDL is a powerful tool to describe, simulate and implement electronic circuits. As VHDL simplifies the implementation of an electronic device, the course has been oriented to make the students face the necessity to create problems instead of solving the ones designed by professors. Innovative devices have been the product of this endeavor.
Keywords: Electronic design, creativity, innovation, educational methodology, higher education.

1. Introduction

Nowadays the development of abilities such as creativity and innovation is a challenge for Tecnologico de Monterrey, a large university system located all over Mexico. In general, this is a challenge for higher education in Mexico.

The author considers that creative mentality is as important as scientific thinking in higher education.

For Digital Electronics Engineering, which is the field discussed in this document, an important educational challenge is confronting students to design new applications.

This article presents a methodology that has been incorporated in a VHDL (VHSIC Hardware Description Language, VHSIC = Very High Speed Integrated Circuit) course to stimulate the development of creativity, specifically in Digital Electronic design. VHDL is a powerful tool to describe, simulate and implement electronic circuits. As VHDL simplifies the implementation of an electronic device, the course has been oriented to make the students face the necessity to create instead of just practice. This change of orientation leads students to create problems instead of solving the ones proposed by professors.

The idea of developing creativity and innovation skills in students is based on the assumption that exposing them to problems related with devising specific circuits forces them to react by reinforcing or emerging their capacity to imagine new electronic applications.

On the other hand, another assumption on which the methodology is based is to consider that digital electronics has no limits. In today's market, it is possible to find transducers and sensors that convert almost every kind of signal into an electronic one. Also, there is a broad spectrum of actuators that allow circuits to interact with the world. Therefore, assuming that any kind of signal could be measured and produced makes any constraints on digital electronic processing disappear.

2. The Methodology

The methodology consists of a series of steps that empower the way in which the environment is observed. The idea behind the methodology is that a student that observes the world with the scientific method in mind allows clarity of detail that is not typically available to others. Furthermore, once the methodology of creativeness is assimilated, objects and events are seen under a different perspective.

The methodology consists of the following steps:

1. When observing the world, relate attributes to objects, events, facts, etc. (in order to generalize, the term object will be used). These attributes may be requirements, capabilities, characteristics, possible uses, etc. Objects could be concrete or abstract.

2. Establish relationships between different objects and between their attributes (this leads to observe the world as a relational database).

3. Make "queries" (as the ones made to obtain information from a relational database) to discover what objects may be added to relate two objects or attributes that were not directly related.

4. Analyze if the added objects exist or not. If not, imagine circuits (or appliances) that satisfy the characteristics of these objects (if possible).

In other words, the idea is to create a relational schema of a subset of the observed world (in the same manner as a relational database schema is created). The premise is that by establishing relationships, a non-existing electronic device will emerge to satisfy any given relationship.

Taking into account the General Systems Theory (Von Bertalanffy, 1976) in that "the whole is more that the sum of its parts", relating elements with ideas has the potential to emerge innovative devices.

Events observed on a daily basis should lead to the development of consumer electronic devices, while industrial events should trigger the inception of measurement instruments, electronic devices geared to enhance the quality of any given product, etc.

In the other hand, experience has taught us that when the world is observed under this perspective, this becomes the natural way of doing it. The opportunity for the arousal of creative ideas is related to the degree of interiorization of this type of observation.

3. Conclusion

The course in which the methodology is used takes place in the classroom and the lab. Theory related to circuits design using VHDL is taught in the classroom.

In the lab, students must complete several projects. The first ones consist in the design of circuits for commonly used devices, requiring the students to innovate functionality. In this way, students are required to develop their creativity by observing a determined universe. In the final project, students are imposed no restrictions and must create an electronic device from scratch. This maximizes and reinforces their creative potential.

In the last year the methodology was used with 103 students, 90% of the final projects worked properly, vs. 30% when the project was very specific. This fact has to do with the motivation of the students towards construct devices product of their own ideas. This semester it is being applied to other 48 expecting ambitious results.

With respect to education, assessment is the hardest part because it is hard to determine the degree of potential of use of a new device. Besides, the complexity of a circuit is not necessarily related with its creativeness.

Some innovative devices that have been developed are: a robot with a circuit that protected him against falling down from an elevated surface (with application in instruments for handicapped persons), a device for tuning musical instruments, videogames and so on.

These students will be followed up to observe if they continued creating in some other required projects of their academic curriculum. The expectation is to observe creative behavior in their careers.

Acknowledgments

Thanks to Ricardo Espinosa and David Said, laboratory instructors that made possible the implementation of this idea, also to the participant students.

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