COURSES OF PRODUCT DEVELOPMENT IDENTIFICATION – EFFECTS AND VISIONS

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ABSTRACT
It is a paradox that wide and intensive activities in the field of product development and design in the course of more than 30 years has produced situation that existing consensus about the lack of new products. The article joins efforts to discover the reasons for this situation and to establish methodology for prediction courses of product development based on TRIZ methodology. The first part of the article contains an analysis of product development and design efforts in the past time in connection with social and economic circumstances, discoveries and important inventions. The trends of actual product development and design methodology are also analyzed. The second part of this work attempts to identify main postulates, potentials and forces which cause product development expansion. In the past a few of those factors and their results have been identified. For the future, new power sources based on atomic fusion and the nanotechnologies are identified as the main "motors" for locomotion of evolutionary or revolutionary product development.

Keywords: Product development, Engineering design, TRIZ ,

1 INTRODUCTION
As well known, the new products drive market, economic, social and other activities. Lack of such products has for the consequence difficult social situations and economic crises. Since the beginning of industrial development, industry tries to create, organize and control product development process that is independent of the inspiration of exceptional persons – designers. This intention has encouraged more and more intensive development of methods and tools for product development and design. Historical overview [1-2] shows that the beginning this process has gradually increased and in the last period got with exponentially increase. However, despite these efforts it is obvious that the new products level and its number not correspond to the level of design and product development methodology. In order to improve it the actual attempt is based on different kinds of integration [2-3] of product development and design activities. These integrations produced multidisciplinary products and multidisciplinary approaches to product development [4]. This is actual attempt for improvement of product development and design results. However, those results are with improvement of existing products only, as well as innovations in the sense of intelligent control, harmonization with human and natural environment etc. Additionally, various specific aspects are integrated, as well as biomimetrics [5], ethnography [6] or emotion [7]. Sustainable solutions [8] are one more objective of the actual approaches in product development and design.
Regardless of all efforts, challenges and actions, lack of the fully new products which can improve economic situation, is obvious. It is possible to notice that exist saturation with something which was the base of previous industrial, economic and social development. The basic elements that challenged product development in the past are not efficient any more. As a first step it is necessary to identify those basic elements and then try to predict possible trends and expectations. This will be the base for prediction of products which have to be fully the new.
Inadequate effects comparing to the efforts and results in the area of product development and design methodology and tools are according to TRIZ administrative contradiction which has to be solved, but how? Altshuller's [1] analysis of patents and inventions (1960s), shows that the results aren't in relation to efforts and quantity of patents. Enormous quantity of patents is variation of existing solutions. Intensive development of the methodology and tools didn't change the situation. The TRIZ teach us that in the first step it is necessary to identify the main postulates which have to be fulfilled for much higher success in invention. Those postulates are probably independent of human efforts and intentions and are a result of circumstances produced by some other scientific or social events.

2 STATE OF TRADITIONAL AND ACTUAL PRODUCT DEVELOPMENT EFFORTS

Human interest for technical solutions is as old as a human and as such presents the main component of society development. Use of tools started the evolution of human which continued with permanent attempt of human mind to place under control all processes connected with human being evolution, technical systems development and with natural environment. Homo Faber Technologies understood the use of technical tools without scientific methodologies, but Homo Sapiens Technologies opened scientific approaches in human and technical systems relation. Antic philosophizers as well as Pythagoras, Socrates, Archimedes and the others, created theories of inventions which present the beginning of scientific approach to product development. Later on, Cicerones had to speak that "we have to live in harmony with Nature" in order to stop nature disturbing. The middle age period stopped this activity and society development all together. This very long period was interrupted by numerous inventions in the renaissance period, followed by craftsmen's production and later on by industrial production. Industrial Revolution sparked the beginning of systematic product development. The end of ninetieth century and the beginning of twentieth is the period of serious discoveries and inventions which accelerated product development. The twentieth century provided scientific and technological knowledge that is incomparable to all history. In industrial sense in the early 20th century, two important concepts were introduced. One was the scientific management of production (Taylor system) and the other was mass production (Ford system). It was powerful industrialization that needed efficient product development. Later on automatization and then computer technologies intensified it. In the last three decades of the twentieth century products got more and more variant, more complex and with higher quality level. A good example for higher product complexity is mechatronic products that also represent multidisciplinary products. Computer based design support tools were critical to develop such complex products with higher quality. This further meant integration of data and information for product development, and later, knowledge engineering and knowledge management. The market system played a crucial role in distributing production resources, production globalization and worldwide competition, and except for knowledge, everything else is now obtainable through the market.

2.1 The Approaches of the Mid 20th Century

Rise of industrial production and market competition caused necessity for efficient product development and design. In the middle of twentieth century several methods for this purpose have been developed. These are Method of Focal Objects, Brainstorming, Synectics, Morphological Analysis, Lateral thinking, Neuro-linguistc programming, etc. Method of Focal Objects - MFO is based on observation of the chosen object that needs to be improved. This object in "focus" is by observation compared to other objects in books or nature surroundings with the goal to improve or lead to a new idea or solution. Brainstorming method - BS has many different versions. The essential feature of these methods is generation of ideas and critiques of them. They stimulate creative thinking, provide new views on the problem, and search for the new ideas. Brainstorming method stimulates associative thinking and comparative analysis. Method of Synectics - SYN is based on the Method of focal objects but with precise orientation. The stages of the method are: problem "as is", elimination of obvious solutions, problem "as is understood", and suggestive questions. The method is suitable for universal use, for iterative application in order to approach the area with solutions, for team use, but also applicable for individual work. The method is applicable for complicated problems, difficult to learn but suitable for development of individual creativity. Method of Morphological Analysis - MMA is based on search field with systems organization, which is useful for search for solutions, for intuitive thinking, etc. The method is logical and simple, and provides a possibility for the area of solution recognition. Lateral thinking – LT method is a detail strategy for the comprehensive development of the creative capabilities of individuals. The method provides tactical analysis of variants which present possibilities of problem solving. Neuro – linguistic programming - NLP is the method which psychologically and physiologically stimulates personal creative abilities.

Presented methods are predominantly oriented to the search for ideas for a new product. Design process was classical and manual. Design procedure was empiric but with use of knowledge which corresponded to the time and level of the science. Knowledge based design (Knowledge engineering and Knowledge management) which is established much later including the great value of classical knowledge which was used in classical approaches in design.

2.2 The Approaches at the end of 20th Century

The last three decades of the twentieth century was a period with the expansion of the tools and methods in engineering design. This period started with standardization of design procedure (VDI-recommendations) and with the start of serious computer application in design (appearance of CAD systems). Standardization established systematic approach in design which was at first sequential in relation with production, exploitation, recycling (product life cycle), and then concurrent (simultaneous) engineering, vertical integrated design, virtual design and other approaches that spent efforts to make product development and design more efficient. For the same task in the late 1970s and 1980s the automation of the CAD application was in trend together with CAD/CAM product modeling including CAE, etc. The goal was to at least to "automate drafting tasks" for better productivity, although "automation of design tasks" was one of the aims. However, the improvement of product quality has become very complicated during this period which benefited the trend to reduce costs through automation. Also, during the 1980s, knowledge engineering approaches have established expert systems for product development. These systems were also a type of design automation but they quickly disappeared. Later on, in the late 1980s and 1990s, concurrent engineering spreaded in all aspects of product design and production technologies as DfX (Design for X) and collaborative teamwork environment. As the products as well as product development processes became more and more complex, it was essential to have better collaboration among different product development participants. This not only shortened the product development lead time (i.e., reduced costs as well as competitiveness) by having greater overlaps between processes that were formerly performed sequentially, but also helped identifing design defects before production. Thus, the primary focus was on competitiveness, rather than productivity, through improved costs and quality [2].

2.3 Current state of the art

At the beginning of the 21st century in the focus was product development process and research in the fields connected with it, instead of engineering design. This process has began at the end of the 20th century with research in the area of knowledge and in different kinds of collaborative product development and integration, then through a few specific methods of design (Axiomatic and Robust design), designers creativity development, etc. Product cost, product quality, lead time, product variety, organization and similar aspects supporting these objectives are in the focus of research at the moment.

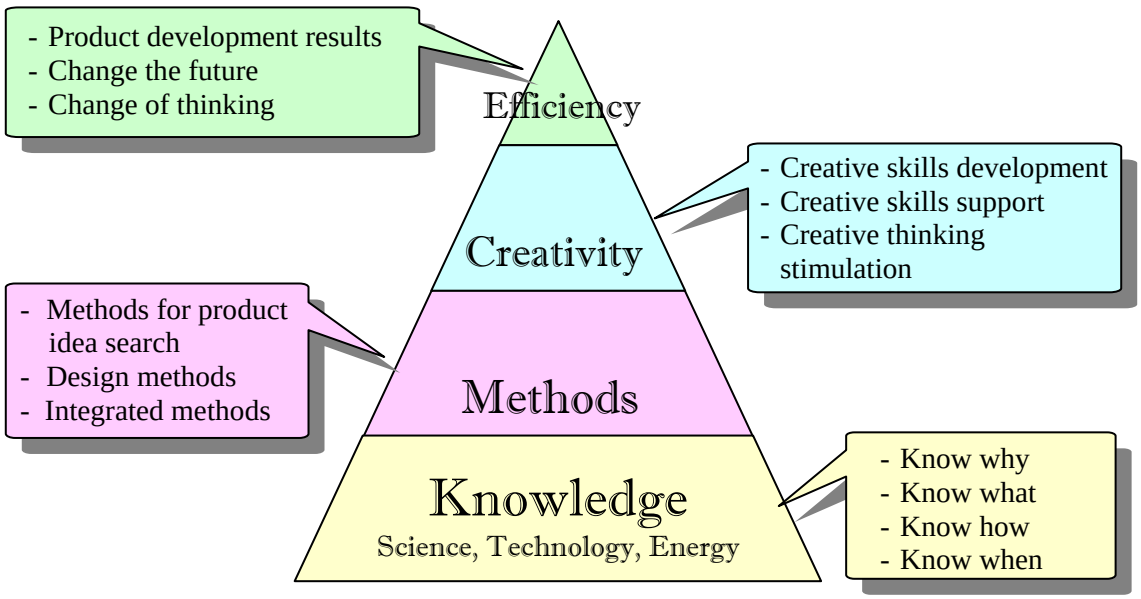

Figure 1. The areas of product development research

Knowledge which includes science, technology, energy, experience, and so on, was the basis for design and product development all the time (Fig.1). Knowledge organization, manipulation and use are some of the key elements for successful product development. As the increased number of design methods and tools in the previous period resulted in lack of new products, the answer and solution to the problem is locked out in the knowledge area. The knowledge engineering in the previous period was the first step. Then followed knowledge based product development, knowledge integration, knowledge management, and knowledge fusion. Different types of knowledge integration are connected with the trends in product development. Collaborative design, multidisciplinary products (mechatronic products for example) and similar needs caused necessity for the horizontal integration of knowledge. Abandoning design automation changed the approach in knowledge manipulation and use. Cognitive approaches have become dominant, and the field of creative expression beyond. TRIZ approach found an important role in various areas of product development and design.

During the last decade of 20th century and at the beginning of the 21st, product development and design are oriented to reduce product cost, to increase quality, to various types of integration, organization, design for X, etc. The methods (Fig.1) had to follow and support these needs and trends. Liu and Boyle [3] analyzed (review) results of design and product development research presented in Journal of Engineering Design in period 2007-2008. Presented advances predominantly contain area of design and product development methods and the main points of this analysis are as follow. Decision support is one of the methods which is not of strategic nature but of tactical and operational. Methods for decision making in design started developing in the last two decades of the 20th century. In the 21st the forms and the tasks are in relation with the new approaches in knowledge processing and in product development. Virtual reality – VR and other 3D technologies are present attractive methods in product development and design. VR in design applications provide visual analysis of the product characteristics and relation between the user and the product. Also functional behavior of the product, manufacturing (product assembly), usability test etc, can be carried out using VR tools. Robust design is the new method that can provide a product insensitive of service and other conditions variation, with a high quality of the product in the first try. The field of Robust design application is getting wider. Ergonomic design and Eco design are not really new methods (approaches) but in order to create higher level of harmony between product-user-environment, these are in stronger focus and application. Biomimetrics methodology [5] is also not really new, but of extremely high importance. This methodology provides possibility for transformation of principles and design solutions from biological systems.

Creativity is an individual ability and skill of designer team members aided by available design methods, tools as well as economic and social environment. Individual creativity has to be gradually developed by personal education and systematic growth of circumstances in a given direction. Available product development and design methods are useless without creative approaches in their application. This is the reason why areas of creativity, methods and tools are mixed and in close relation, supporting each other and challenging farther development (Fig.1). Some of the methods and approaches contain both tasks, through stimulation and orientation of the way of thinking, to challenge the ideas and product development and design solutions. For this purpose the TRIZ approach, with the roots in the mid 20th century, is innovated in the form of modern TRIZ approach at the beginning of the 21st century. This approach try to teach have to thinking in order to make inventions and to change the future in general [1]. This is a qualitative theory, not a mathematical or quantitative one. Using available or newly transformed resources, procedures and analogies it is possible to remove the contradictions that prevent the achievement of ideal result. This approach is completely opposite to automation of design process, and based on cognitive resources. However, the results, i.e. effects are lacking. In Fig.1 pyramidal presentation shows that knowledge has to give very wide base for development of methods and tools together with creativity in order to provide strong penetration in the area of new products (new functions, new structures, new behavior of technical products). In order to provide deeper penetration of effects (higher pyramid) with the same base of knowledge, methods and tools, the solutions should be searched for in various kinds of integration and multidisciplinary approaches. Results are still not as expected. Something that can accelerate global industrial and economical processes, together with product development, is still missing.

Horizontally integrated approaches characterize product development trends in the first decade of 21st century. The main reason for this is the endeavor to increase product quality and reduce product development cost and development duration, especially for products of high level of complexity.

Tendency to achieve better design performance imposes necessity for a Holistic approach that also considers integration in product development. Recent research on integrated design includes system integration, requirements integration, knowledge integration, and method and process integration [3]. System integration has a motivation to support the concept of "whole system" design, as opposed to its separate components design. Requirements integration considers „vertical" and „horizontal" integration. Vertical integration considers development of product requirements through different design stages similar to simultaneous (concurrent) engineering principle. Actual trend of integration is horizontal one which considers different areas of product development because products are becoming more multi-disciplinary and their boundaries are expanding especially in the sense of the numerous new requirements. In Fig.2 some of the possible fields of product development are presented in the form of horizontal integration. Except from robustness, the product needs to satisfy aesthetic, ergonomic, eco and other requirements. Holistic approach can provide effective results. Also, separate design of multidisciplinary products is not acceptable, and therefore mechanical and electronic design has to be integrated. Biomimetric design has an important role in searching for new principles and solutions, in technical systems but integrated in a holistic design.

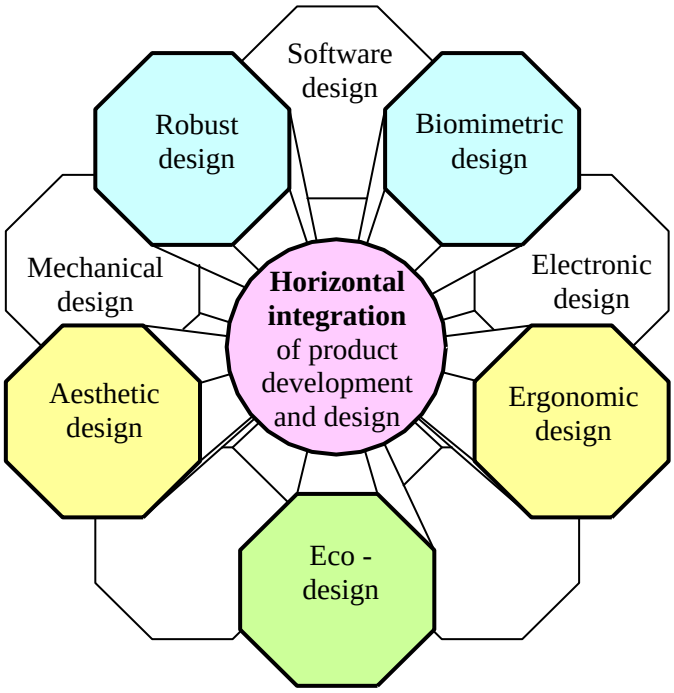

Figure 2. Horizontal integration of product development and design areas

3. PRODUCT DEVELOPMENT VISION - PDV

Prediction of product development processes in the future is a complex problem. Possible solutions are in close relation with historical and current trends, as well as with present and future circumstances. These trends and circumstances can be listed as follows.

- Evolutionary trends in product development in the past and expected trends in the future.
- Revolutionary discontinuity in the product development in the past and expectation in the future.
- Social and economic circumstances in connection with the new product trends.
- Energetic, technological, scientific, and other resource tendencies.
- Other circumstances.

Considering these elements it is possible to establish some kind of model for prediction of further product development trends. The first step in this analysis is correlation between social conditions, economic potential and science and technology level. In the old age social conditions for new technical solutions development was favorable but science and technology level was low so technical solutions corresponded to this level. The middle age produced social circumstances that weren't suitable for any progressive activity. The Renaissance interrupted this situation and it can be considered as the first of revolutionary trend in inventive activities. The new age is the period with

gradual increase of efforts and results in product development. This increase can be interesting for analysis that could lead to further product development prediction. The 20th century is especially interesting for this purpose.
Social and economic relations are of special interest for this analysis. Invention of steam engine firstly produced bad social situation and subsequently prosperity in the form of industrial revolution. Before this historical event existed an era of animal power, and after the invention of steam engine the era of mechanical energy (mechanical power) began. Other inventions were also directed to production of mechanical energy. In the meantime increase of technological and scientific level, including product development, was directed to support energy transformation where mechanical one has the main place.

3.1 Available resources in the future

Relation between technology, products and user needs is known. New technologies need to be transformed into the products and then, using market rules and methods, user needs for these products, need to be developed. This is the path for the return of the investment in the new technology development and research. In "mechanical" era, the technologies are predominantly mechanical, at the macro, and later on at the micro level.
Nano-technologies are present by themselves a deep penetration inside material structure and investigation of processes into the "world" at this level. At the moment, numerous material features have no exact explanation. It is possible to expect revolutionary discoveries in the area of material behavior, in the area of biology systems functionality, in the area of new sources of energy etc. It can also be expected that research at the nano level will provide new sources of energy similar to universe sources based on atomic fusion. Gradually or revolutionary "mechanical" era will be replaced by "nano" era. For this purposes it is necessary to developed (expand) technical systems that can support these activities and provide application of the new knowledge for use by humanity i.e. for costumer necessity (Fig. 3).

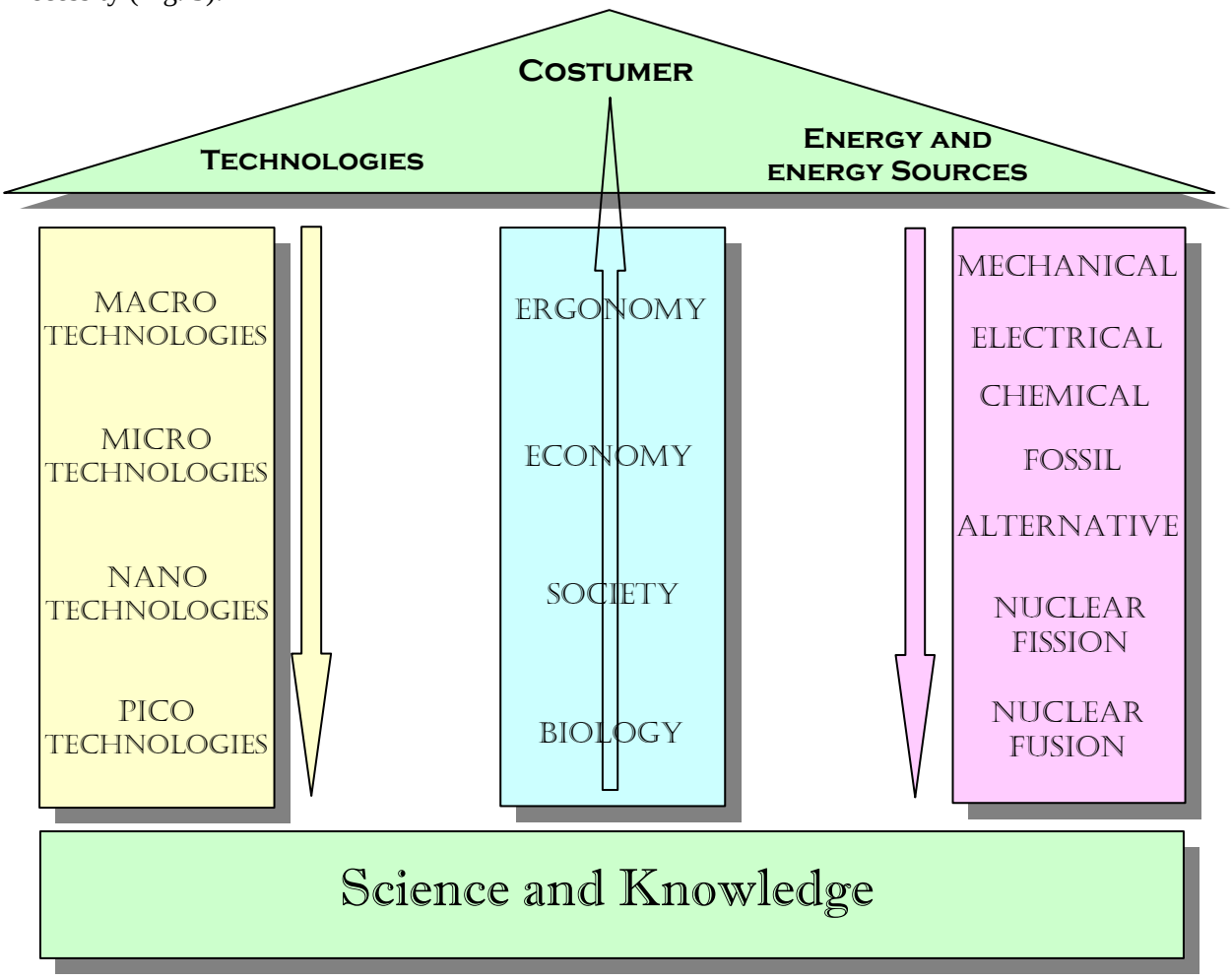

Figure 3. The three columns of development which lead towards the future

3.2 Product development prediction and visions

The TRIZ approach teaches us about the way of thinking in order to predict the future, and in order to design the future [1]. The main rule in the way of thinking about the future trends is analyses of past trends that can be evolutionary or revolutionary. Social, economic, scientific and other surroundings are extremely important for principle identification and its transformation for future prediction. Altshuller [1] also says that the study of the past methods and trends doesn't guarantee successful prediction. This is the reason why the following text contains presentation of the main resources that need to be increased and synchronized in order to change the future. Discussion about resources, possible product barriers and their burst through, and about possible expansion of product development (Fig.4) can be the orientation for personal vision of the future trends in this sense, according to TRIZ.

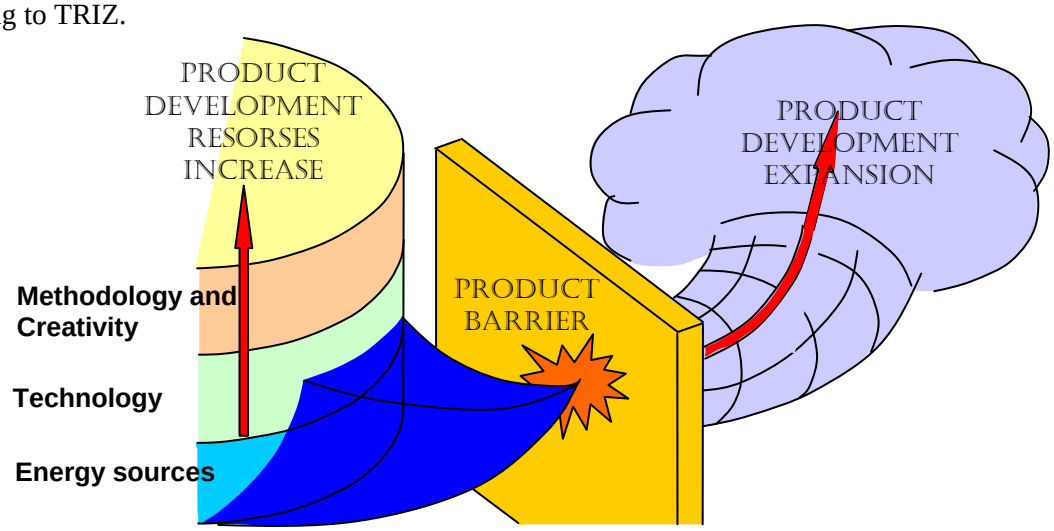

Figure 4. Expansion of product development when necessary potentials are reached

Resources that can produce expansion in product development are new energy sources, new areas of technology, and new and successful approaches in technological and scientific creativeness.

Fusion energy sources are one of the main potentials and challenges for expansion of new product development. Present energy sources based on mechanical power have numerous disadvantages (low quantity, ecological disturbances, high cost, etc). Expected new energy sources as well as sources based on fusion principles can change situation. Energy in unlimited quantity with necessary features can change existing principles of technical systems (principles of transportation, material processing, etc).

Nanotechnologies are in harmony with expected new energy sources and they support new technical systems development. Technical systems will be more and more similar to biological systems and nanotechnologies will provide identification of biological principles and their transformation into technical principles. Apart from development, nanotechnologies will support technical systems production and significantly increase the level of knowledge for this purpose.

Product development and design methodology is the third main potential which awaits the opportunity for aggressive action in the sense of changing existing principles, structures and behavior of technical systems. Existing and future procedures and methods for product development and design, with different kinds of integration, promise successful transformation of knowledge in technical systems that in harmony with the level of technology.

Expansion of product development in this sense can be expected when the level of above mentioned energy sources, nanotechnologies, and creative abilities and knowledge level increase enough (Fig.4). High level of these potentials will break the barrier that bounds the area of known principles, structures and technical systems behavior and will open the new world of technical solutions. Social and economic conditions need to be suitable for this fast evolutionary transformation. In the past, in similar situations, economic and social disturbances were very present, and created conditions that we today consider as industrial revolutions. New products, such as steam engine produced high level of mechanical power and left the many people without a job. Extremely bad social situation and hunger was overcome by fast increase of industrial production and new product development. Using the

principles of mechanical power production, numerous new products where developed that in the basic details are kept up to date. However, history shows examples where difficult social conditions spurred fast product development and accelerated technical, economic and social processes. An example of such conditions is wars. The TRIZ principles teach how to prepare conditions to avoid strong social and economic disturbances and instead of technical revolution, perform fast technical evolution. Every sudden change and replacement of technical systems disturbs economic and social and natural environment. This needs to be a special area of global human interest, i.e. it needs to be ready when the wave of the progressive potentials rises. Social progress without great disturbances will be provided by spurring of this wave and subsequently by skillful navigation in order to escape inconveniences.

4. CONCLUSIONS

Product development and design results are not a consequence of applied methodologies and creativity only. In order to prove this an analysis of historical and current trends and efforts is presented. The main constraints and challenges were connected with invention of power sources, technology and science level, and with social environment (crises, wars, etc.). Apart from the invention of steam engine, later on at the beginning of the 20th century, a few well known inventions (alternating electric power system, aircraft, helicopter, etc) and discoveries (Plank, Curie, Einstein, etc) were fundaments for technical progress through out the century. It seams that this base and potential is exhausted. The relatively small supplementary scientific and technological contributions are not enough for the great challenge which is required by actual global situation. According to TRIZ principle of future prediction and creation, necessary expansion of product development can be a result of coupled effects of expected discoveries in the field of nanotechnologies, expected power sources based on atomic fusion principle, and reached level of product development and design methodology, tools and creativity. These are the three postulates identified for product development expansion and for long term future prediction. Economic and social conditions will have very important consequences. Significant improvement is very desirable, but losing control at the social situation, which is very possible in these circumstances, could produce unwanted effects.

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