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TRIZ on Rapid Prototyping
-a case study for technology foresight

Abstract
Although TRIZ is a problem solving tool, the application of TRIZ instruments supports the strategic task such as Technology Foresight. These methods provide the ability to visualize future trends and helps to generate ideas to reach them. In this case study on the technology of Rapid Prototyping, the capability of TRIZ to support Technology Foresight was explored. Different tools were tested and their applicability for this objective were assessed.

Abstrakt

TRIZ, ursprünglich als Instrument zur Problemlösung erarbeitet, kann auch die strategische Aufgabe der Technologiefrüherkennung unterstützen. Unter Nutzung von TRIZ-Werkzeugen können mögliche Trends veranschaulicht und die Ideengenerierung unterstützt werden. In dieser Fallstudie wird TRIZ zur Unterstützung von Technologiefrüherkennung anhand der Technologie Rapid Prototyping getestet und bewertet, sowie die Anwendbarkeit verschiedener TRIZ-Werkzeuge für diese Aufgabenfelder beurteilt.

1. Introduction

The major aims for Technology Foresight are to improve the competitiveness in the future as well as differentiating a company. New technology areas can be identified in order not to miss out on new trends in the future. Global changes and technology discontinuities must be anticipated to prevent companies from being run over by new technologies or competitors.

As part of the Master of Science program in Technology and Innovation Management at the University of Applied Sciences of Brandenburg in Germany, an approach to Technology Foresight was made by using TRIZ. At the first stage the method was studied, particularly on its ability to support Technology Foresight. The second part of the project was the application of the method on a technology. First intensive knowledge on Rapid Prototyping as the selected technology was acquired and the TRIZ tools to be applied were chosen. Then experimental data was collected and by discussing and applying TRIZ the problem to be solved was defined. The sources were expert interviews and consultations, a visit to the international trade-fair ”Euro Mold 2002“, patent survey, rating, literature and internet research.

2. Rapid Prototyping

For companies focused on the strategy to reach competitive advantages by innovative products, the product development process is the main business activity. The crucial factor here is the time-to-market, consequently reducing the product development time cycle. The key factors are intensifying the data exchange on basis of shared databases in order to achieve an integrated product development process.

Accordingly, models and prototypes need to be fully integrated. The requirements on the prototyping process are holding up the closed data structure and maintaining the data applicable at every stage of the development process.

Rapid Prototyping is a generative production process. By producing different layers and joining them to each other, a physical three-dimensional prototype will be generated (fig.1).
The process is entirely based on digital data. Different methods are available and work with different materials like resin, metal or ceramics. Depending on the application field, the appropriate method between concept modelling and functional prototyping, Rapid Tooling, Rapid Manufacturing and Rapid Repair will be selected.
The benefits of Rapid Prototyping in order to support the fast product development are the constantly available data base, continuous up to date data and direct processing from three-dimensional data. Rapid Prototyping is an integral function of the computer integrated manufacturing process (CIM).

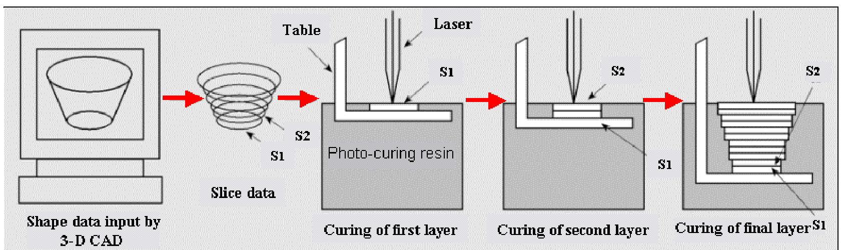

Fig. 1: *Applied engineering of Rapid Prototyping*
source: Oki Electric Industry Co. Ltd., (1997)

3. TRIZ

3.1. Procedure and Selected Tools

As a procedure for TRIZ on Technology Foresight, a methodology with six steps, developed by Ellen Domb was chosen. This method uses different tools, taken from four basic groups of tools including Analogous, Vision, Systematic and Knowledge (fig. 2)

The steps include the application of tactical and strategic TRIZ. In this case the steps for strategic TRIZ were used. Tactical TRIZ should be part of problem solving, in this case developing the next technology generation.

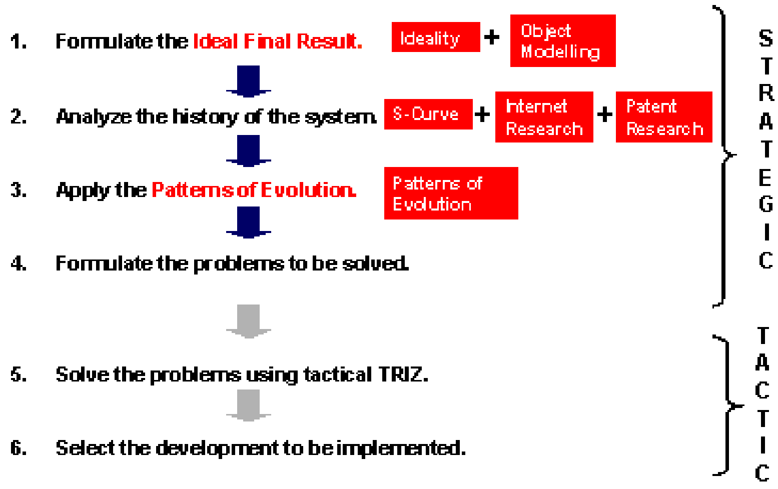

Fig. 2: *Procedure to apply TRIZ on Rapid Prototyping*
source: acc. to Domb, E., (2000)

4. The case

4.1. Formulate the Ideal Final Result (IFR)

Altshuller defined the IFR as "…a fantasy, a dream. It can not be reached, but it will allow us to build a path to the solution…"[1]. At the beginning of the case study the equation of Ideality has been used as a preview analysis to get an overview of the elements of the system and their functions. Then an object model helped to find out the Ideal Final Result.
Ideality is equal to all useful functions over all harmful functions plus costs. Useful functions for RP are the use of multiple materials, time reduction, automatisation and the construction of complex geometries. The harmful functions are the long preparation time, limited resolution, the need for model support structure, stairstepping, post-process, accuracy problems, poor physical properties, poor finish, data lost and material contraction. Cost factors are the high material prices and the expensive machines.

4.1.1. Object Modelling

An object model of the technology, containing the basic elements, their function and the possible harm was made including the steps identification and elimination of help functions, so that the determination of synergy between elements and the elimination of side effects and a good abstraction of the system was accomplished (fig. 3).

[1] Altshuller G. (1984)

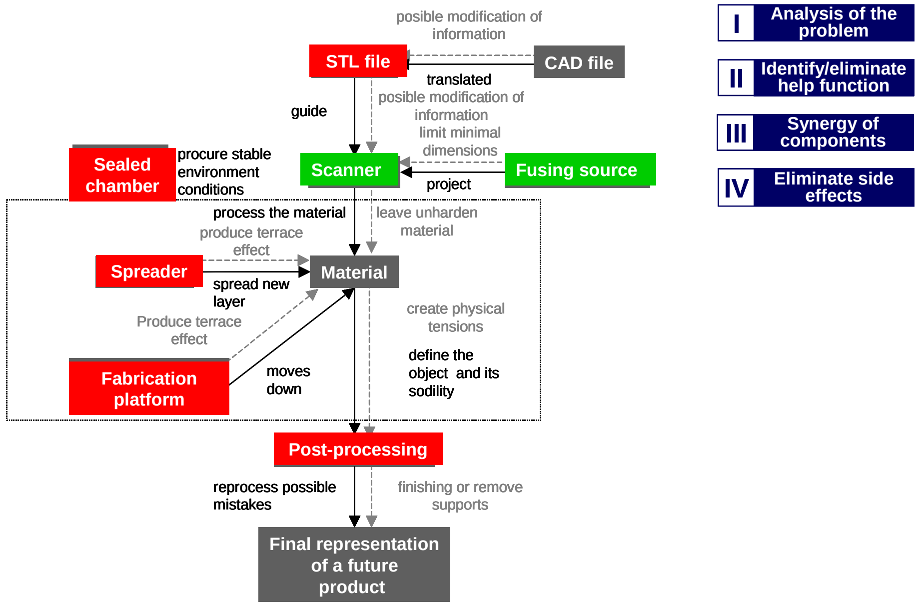

Fig. 3: *Object model of the Rapid Prototyping process*

With the next steps - replace the performance component and elimination of the need, three possible Ideal Final Results were defined (fig. 4). Replacing the element virtual representation leads to possible "aided sculpture", or the possibility of designing direct on the prototype. Replacing the machine it self leads to a combination of virtual reality and haptics instead of producing a prototype. Eliminating the need (generation of), leads to computer calculations instead of prototypes.

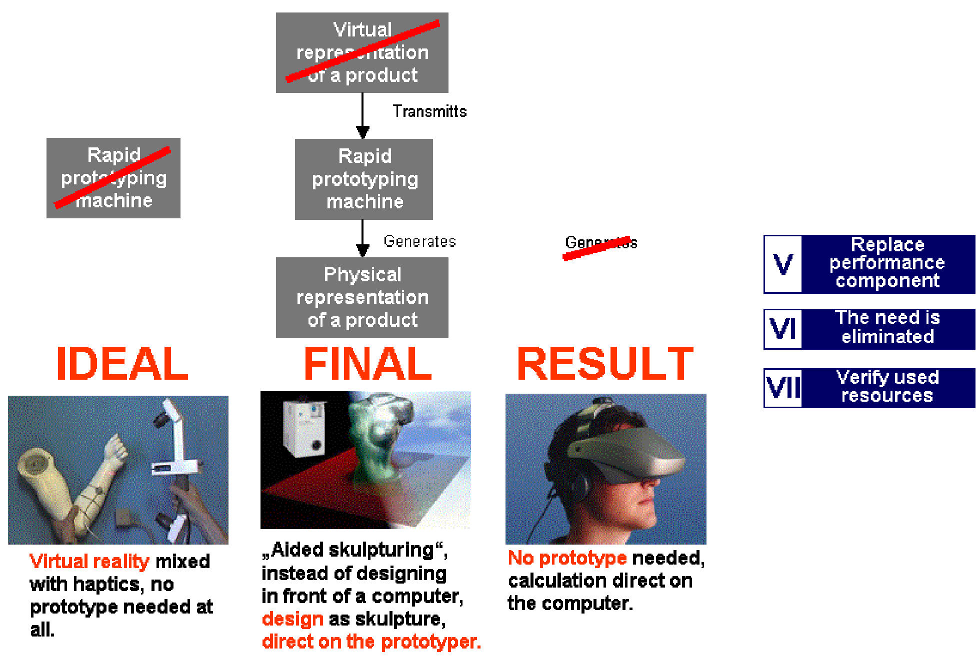

Fig. 4: *Ideal Final Result: Object modelling*

The Ideal Final Result helped to obtain an objective understanding of the technology, to formulate the key questions and to discuss many different evolving directions of the technology. Paradigms on the technology were broken.

4.2. Analyzing the history of the system

The S-curve is a powerful tool, to stay aware of the existence of the technology life cycle and helps to understand, at which maturity stage the technology is at present time. In difference to other S-curve- concepts, the TRIZ generated S-curve is related to base lines (fig. 5-8). Every base line has an unique pattern, and the combination of the base lines create the maturity S-curve. Building the S-curves requires literature, internet and patent research and further information from experts. The result graphs in the following steps were matched with the base lines, given by Altshuller.
Numbers of patents (fig. 5) are based on the patents submitted yearly. The data was acquired by using web based patent databases like www.depatisnet.de, using boolean logic terms. The first patents are from 1982 and the number of patents steadily rose until the peak in 1999 was reached. After that year a decrease is visible.

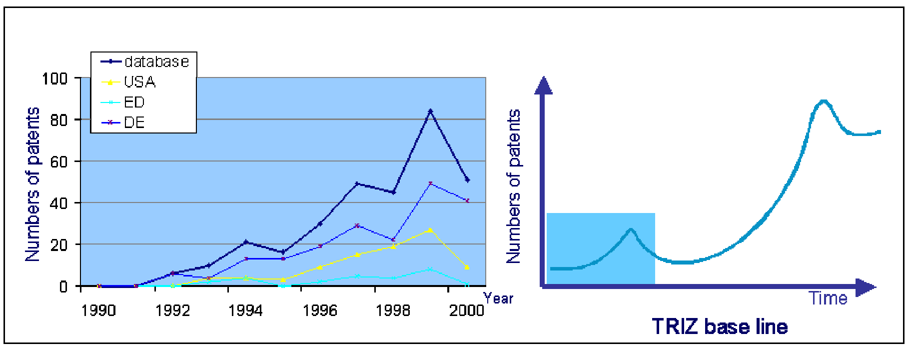

***Fig.5:** Numbers of patents: Case data and positioning on the base line*

The data to build the **profitability** line was not easy to gather. RP is a technology used world wide and the companies keep internal data secret. As an assumption, the

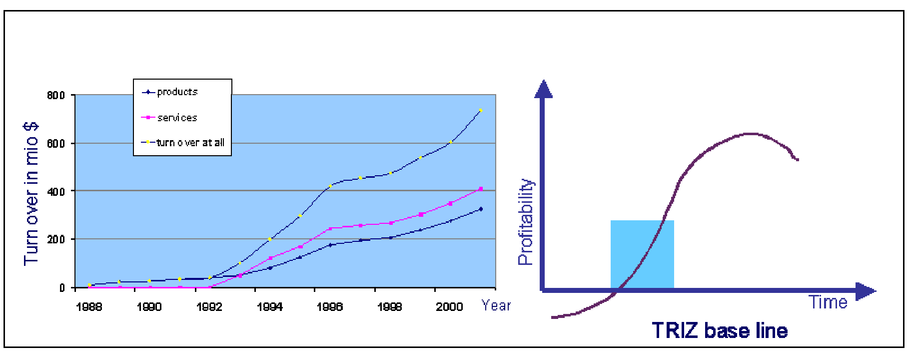

***Fig. 6**: Profitability: Case data and positioning on the base line*
source: data acc. to Wohler T. (ed), (2000) P.27-41 and Wohler T. (1993- 2002)

annual turnover was chosen to represent the profitability of the technology[2]. The data was taken from company's annual reports (1991-2002) and from Wohler associates international industry reports. The graph shows a clear boost in 1993. (fig 6)

[2] Acc. to Severine G. (1999). „Application of TRIZ to Technology Forecasting. Case Study: Yarn Spinning Technology“

For the **performance indicators**, speed, strength and accuracy were discussed as being the most representative factor. From expert interviews and ranking different indicators, accuracy (or layer thickness) was chosen. The data was acquired by using internet search engines, and entering the terms “thickness” or “accuracy”. The data which could be related to a year was selected and used to build the graph. More accuracy means less layer thickness. To make this data comparable with the TRIZ base line, inverted numbers were used (fig. 7).

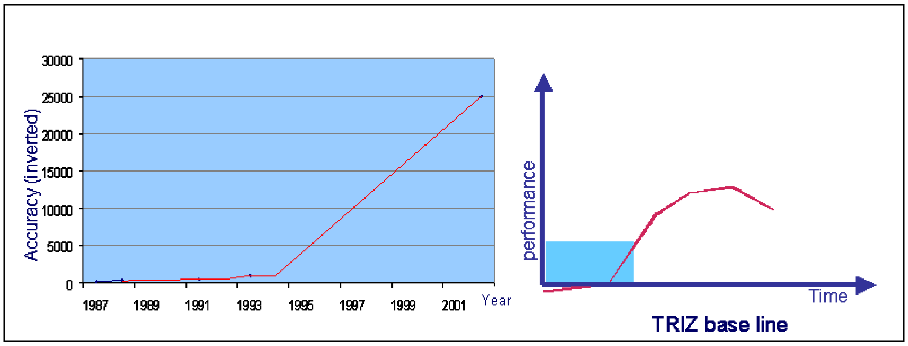

Fig.7:*Performance: Case data and positioning on the base line*

According to the applied knowledge and the impact of the invention to different fields, Altshuller divided inventions into 5 levels. In order to relate the **level of invention** according to the years, different possibilities like patent citation, or patent research with invention related keywords were considered. As most reasonable, the following steps were developed:

Analysing the history of the technology, searching and defining key inventions.

1. Assessing these key inventions in a matrix by using Altshullers classification.
2. Transforming the data to the graph (fig.8).

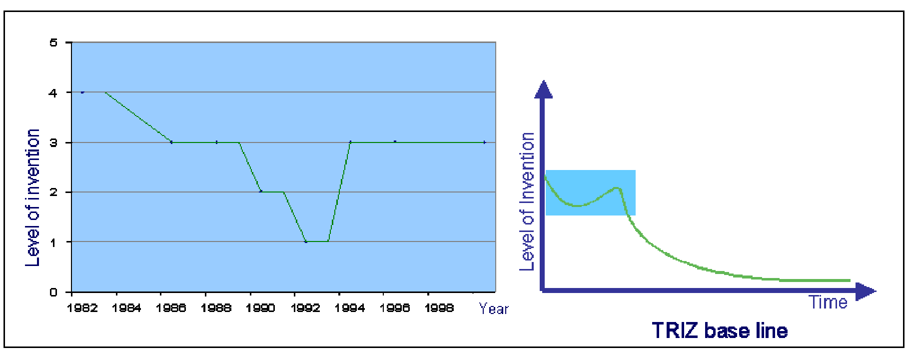

Fig.8: *Level of Invention: Case data and positioning on the base*

By compiling the four base lines, a mutual position was determined and matched to the S-curve (fig. 9). The most probable present position on the S-curve shows that RP is within the growth stage. Assumptions to be made here are that the technology has an high potential and it is worth investing in this technology.

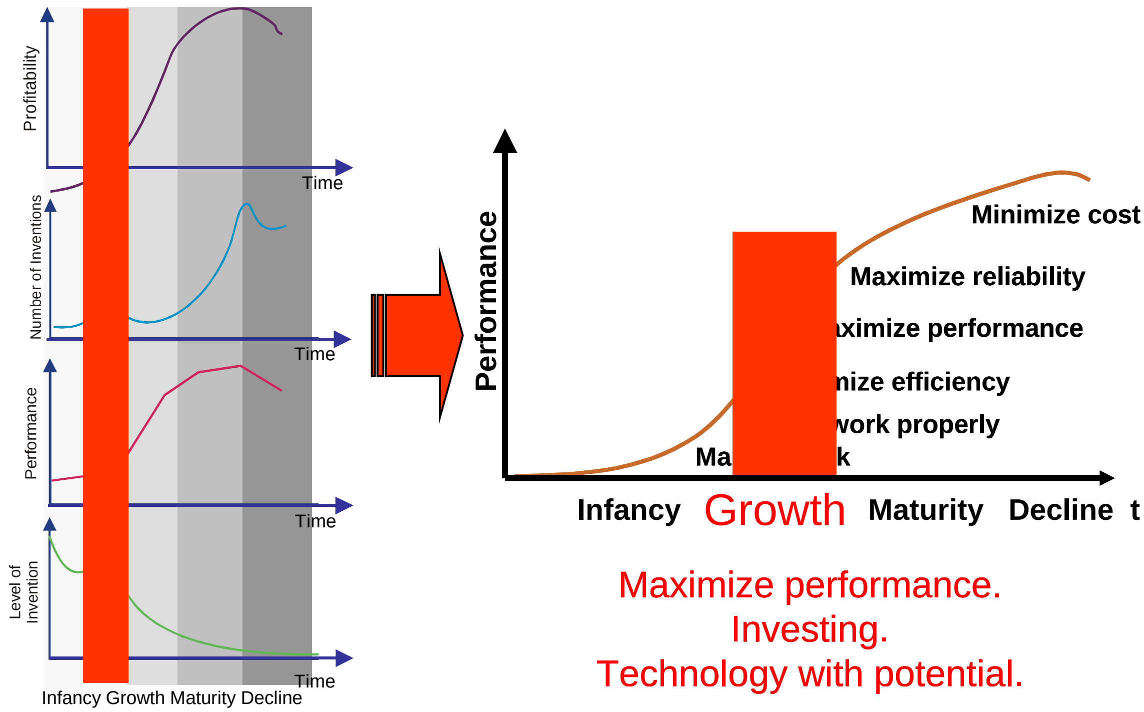

Fig. 9: *S-Curve*
source: acc. to Mann, D. (1999)

4.3. Patterns of evolution, definition and selection

When the position of the technology is determined, its evolution has to be traced. The technology trends are defined with the aid of the 8 patterns of evolution purposed by Altshuller.

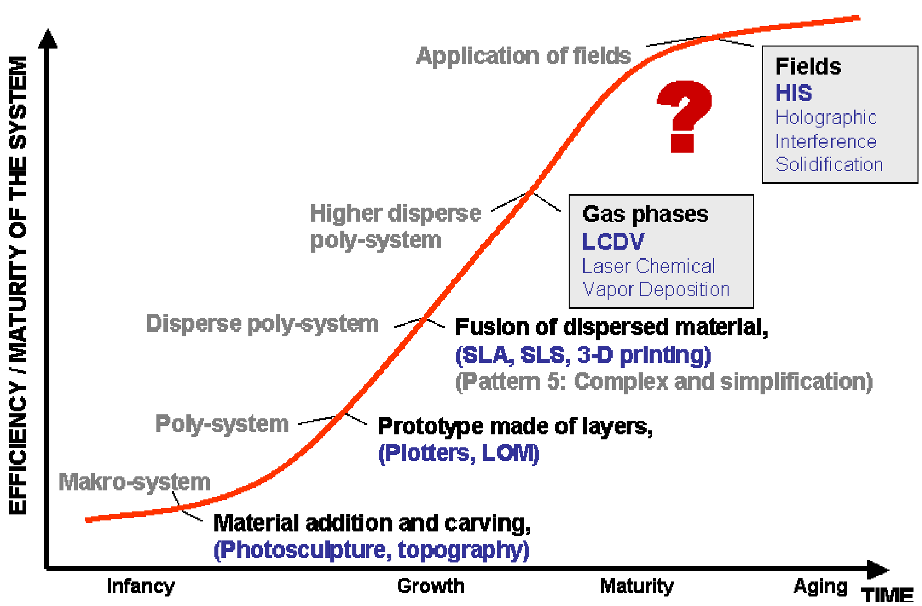

Fig.10:*Pattern 7: Evolution toward micro-level and increased use of fields*
source: acc. to Beaman, J.J. (1997) and Herb,R., Herb,Th., Kohnhauser,V. (2000), p.201

The pattern 7 (evolution toward micro-level and increased use of fields) was chosen as the most appropriate (fig. 10). The first stages of the pattern for RP were adapted from literature and the future evolution stages were deduced from the pattern. Suitable technologies at an early research level, like Laser Chemical Vapor Deposition (LCVD) or Holographic Interference Solidification (HIS) complete the pattern. They represent the maturity or aging of RP on the time axis.
Another important trend according to pattern 5 (increased complexity then simplification), was recognized. With the emergence of 3-D printing substituting the complex Laser Sintering machines, a trend toward more simple machines can be stated.

4.4. Formulate the problem to be solved

Following the definition of the pattern of evolution the major barrier that RP has to surmount, is generating the prototypes in layers. This task can be understood as developing a one-step synthesising 3-D process. This statement was formulated as a problem to be solved. The cause-effect diagram was used to decompose the main problem in sub-problems, for an easier analysis and future solution (fig. 11).

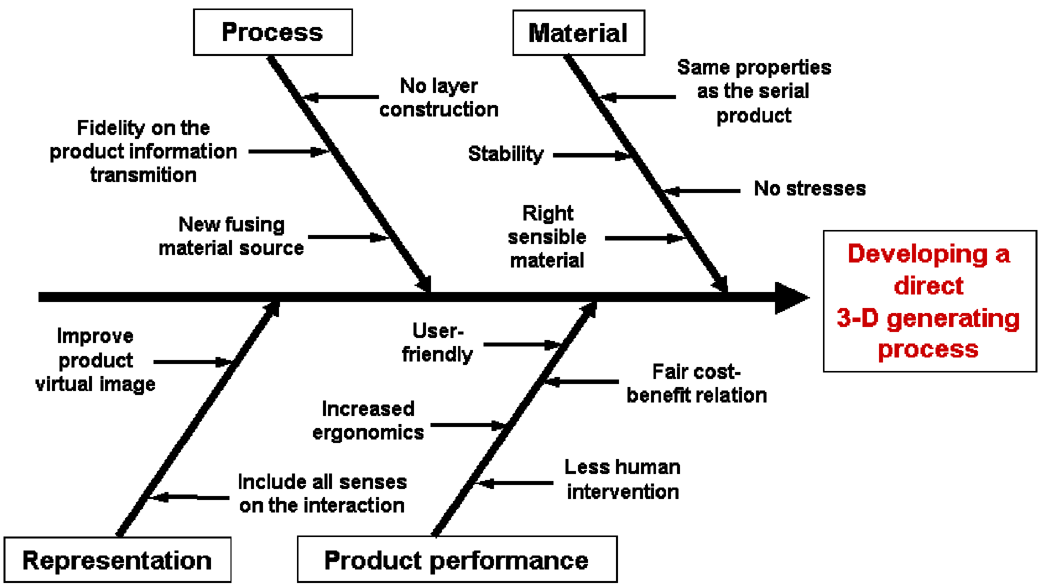

Fig.11: *Cause-effect diagram (fishbone or Ishikawa diagram)*
source: acc. to Herb,R. Herb, Th. Kohnhauser V. (2000), p.88

At this point strategic TRIZ was completed. The next steps belong to tactical TRIZ and intend to solve the problem and select a development to be implemented.

5. Conclusions

The conclusions can be divided in two parts, concerning Rapid Prototyping and a reflection on TRIZ as method a for technology foresight.

Although there is a final conclusion from the foresight process, each step can provide important ideas and benefits.

According to the Ideal Final Result, new ways of virtual reality including more interaction can be developed to support the product development process. A future without physical prototypes could be predicted. The position on the S-curve shows that RP is still in the growing stage and a high potential for investment can be assumed. Searching the next generation of RP, a non-layer-construction system and the use of serial-product materials was defined by the patterns of evolution. This conclusion can be materialized by considering the development of new methods like Laser Chemical Vapor Deposition (LCVD) or Holographic Interference Solidification (HIS).
TRIZ has an effective capacity as a problem solving tool, by defining global questions as a precise problem. Patent research is a key factor where professional assessment is needed. Finding out the profitability is not easy and needs the consideration of other indicators, for instance the turnover. Defining the level of invention is very subjective and the correlation to specific years is demanding. Another point is the difficult connection between the multiple TRIZ tools. Knowledge of this procedure is also decisive, so a TRIZ-experienced moderator is recommended.

But still the most important feature of TRIZ is that it opens the way of thinking and provide an alternative vision-thinking.

This case study was presented at the 3rd international TRIZ – congress in Zürich. Some comments about the case were added in order to improve future application of TRIZ for technology foresight.

1. *It is important in this type of technology foresight studies to consider point of view of the costumer 3.*

2. *The S-curve based on the number of patents was made with all the yearly submitted patents. This approach was critisized during other presentation at the congress. It was proposed not to use the numbers of patents related to the technology, but only to take into account just the patents that consider the specific parameter that was chosen to follow the evolution of the technology.4*

3. *In figure 9, the S-curve was determined by matching the curve of each parameter to the S-curve. The conclusion was, that the technology should be in the growth stage and that R&D effort directed to maximize performance and efficiency. But the curves can not been put together, because maybe each one have a different development speed.*[5]

[3] Coments given by Ellen Domb.
[4] Comments given by Sergei Ikovenko.
[5] Coment given by Darell Mann.

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