Profiling Technological Competencies of Companies: A Case Study Based on the Theory of Inventive Problem Solving

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The Theory of Inventive Problem Solving (Russian acronym: TRIZ) provides several new ways for finding creative problem solutions. In addition to TRIZ as it is used for generating inventions, some of its instruments can be applied for strategic management support. In combination with patent databases, TRIZ can be used for profiling technological competencies of inventors and companies to support strategic decisions. This article demonstrates profiling of technological competencies, using a complex case study of a leading German company. In this case study a five-step process, developed by the main author, has been applied. After having analysed patents and patent applications of three major companies in the field of floor-cleaning aids, three characteristic profiles have been identified. This led to important activities in the area of R&D of the company doing the analysis, as well as to decisions of strategic relevance.

Introduction

The analysis of competitors is a major issue of strategic management. The management of a company should be well-informed about the products, the strategies, the resources and the leading employees of competing firms in national and international markets, because, as Merrifield (2000) points out, in these times of the Internet competitive advantages are changing between nations and over time. This analysis of competitors can have quite offensive goals; for instance Carayannis and Alexander (2004) show how such competitor information can be used for forming pre-competitive R&D consortia.

One important task of the analysis of competitors is to get insight into the technical problem solving competencies of a competing company, especially in industries where technological competition is the norm (Friar, 1995). For this purpose the analysis of patents may help, as patents are a publicly available important source for technology information (for alternatives to patents see Lange, 1994, pp. 141–43). Three approaches will be mentioned, as follows.

- Ernst and Soll (2003) suggest patent portfolios, from which a company may get insight into the structure of competition. In this context Ernst (2003, p. 235) introduces some patenting indicators for competitor monitoring like patent activity of a firm in a specific technological field, co-operation intensity or international scope.
- Teichert and Mittermayer (2002) show how to use text-mining tools for getting competitor information out of patents.
- Moehrle and Geritz (2004) introduce computer-based semantic analysis of patent texts in combination with multidimensional scaling for patent mapping. From the patent maps, structures of technological competition can be identified easily.

In the following paper, a new way of analysing patents and getting profiles of the technological problem solving competencies of companies will be presented. This way is based upon inventive principles as part of the Theory of Inventive Problem Solving (abbreviation derived from the Russian title: TRIZ). A process for such a TRIZ-based analysis will be defined, and a case study in a major German

Table 1. Forty Inventive Principles

1. Segmentation	21. Rushing through
2. Extraction	22. Convert harm into benefit
3. Local conditions	23. Feedback
4. Asymmetry	24. Mediator
5. Consolidation	25. Self-service
6. Universality	26. Copying
7. Nesting	27. Disposable object
8. Anti-weight	28. Replacement of a mechanical system
9. Prior counteraction	29. Pneumatic or hydraulic construction
10. Prior action	30. Flexible 'shells' or thin films
11. Cushion in advance	31. Porous material
12. Equipotentiality	32. Change the color
13. Inversion	33. Homogeneity
14. Spheroidality	34. Rejecting or regenerating parts
15. Dynamicity	35. Transforming the physical/chemical state
16. Partial or excessive action	36. Phase transition
17. Shift to a new dimension	37. Thermal expansion
18. Mechanical vibration	38. Strengthen oxidation
19. Periodic action	39. Inert environment
20. Continuity of useful action	40. Composite materials

Source: Ideation International, 1999, p. 83.

company will show the benefits of profiling technological competencies of companies.

Inventive Principles as Part of the Theory of Inventive Problem Solving

Based on a comprehensive analysis of patents, the Russian researcher Altshuller developed TRIZ, the Theory of Inventive Problem Solving (see Mann 2001, Phan 1995, Stratton & Mann 2003 for brief descriptions of TRIZ). One of his major insights was that a large number of superior inventions are based on a small number of inventive principles (Altshuller, 1984, 1996). In other words: the same principles have been applied in thousands and thousands of different inventions. Altshuller identified 40 inventive principles (see Table 1; for a discussion of these inventive principles and examples of their application see Moehrle & Pannenbaecker 1997). These inventive principles will be discussed in three aspects: (i) their structure, (ii) possibilities to cluster them, and (iii) their theoretical background.

Structure

The inventive principles are differently abstract and some of them are divided into sub-principles. For example, one of the inventive principles is called 'local conditions', and it includes three sub-principles:

- Transition from a homogenous structure of an object or outside environment/action to a heterogeneous structure.
- Have different parts of an object carry out different functions.
- Place each part of the object under conditions most favourable for its operation (Ideation International 1999, p. 85).

One illustrative application of local conditions may be found looking at the keyboard of a computer. All keys seem to be identical, but the 'j' and 'f' keys have a raised mark. These bumps serve for those used to typewriters as an aid for identifying the right keys with their fingertips. Therefore a small transition from a homogenous to a heterogeneous structure has occurred.

Another inventive principle is called 'dynamicity' and it also includes three sub-principles:

- Make an object or its environment automatically adjust for optimal performance at each stage of operation.
- Divide an object into elements that can change position relative to each other.
- If an object is immovable, make it moveable or interchangeable (Ideation International 1999, p. 91).

Dynamicity has been applied for instance at advanced car radios. The objective volume is controlled by the speed: if the car is driven faster, volume is risen automatically, so the driver will always hear the same subjective volume of the car radio.

Possibilities for Clustering the Inventive Principles

It is not easy for a human to learn and remember 40 inventive principles. For easier application those principles should be clustered. There are two valuable, but still not finally convincing suggestions for clustering:

- A first contribution to the handy application of inventive principles has been made by Zobel (1991, pp. 108–116). He has formulated 13 universal inventive principles and related the rest of the inventive principles – which are much less universally valid – to these universal inventive principles. The resulting hierarchy provides a very reasonable structure.
- A second contribution has been made by Ruchti and Livotov (2001). They selected some 12 inventive principles and organized each of them together with the corresponding reverse principle. For instance, they selected the pair of combination (similar to inventive principle 6, see Table 1 above) and separation (similar to inventive principle 1, see Table 1 above) and suggested using both of them when searching for a solution.

Theoretical Background

Altshuller found the inventive principles with very intensive inductive research. The inventive principles are thinking variations, resulting from former inventors' intuition. The part of TRIZ that deals with the inventive principles is therefore empirical. This has three consequences. First, although at least the first 20 inventive principles sound very convincing, there is no theoretical reasoning why exactly those 40 principles have been found – was it just by accident? Second, there may be more inventive principles that have not been identified yet. Altshuller (1984) himself suggests expanding the list of inventive principles if new principles are found. Third, there is no scope for developing the inventive-principle list further by relying on the identified inventive principles. New inventive principles may only occur by advances in technical (or in the meantime also recognized) non-technical sciences.

Besides these theoretical considerations, Altshuller and his followers suggested using the inventive principles and other TRIZ instruments for making inventions. The inventive principles have been successfully applied in industry (for illustrative examples see Terninko, Zusman and Zlotin, 1998, pp. 10–11, detailing cases from Rockwell Automotive and Ford).

A Process Design for Profiling Technological Competencies of Companies with Inventive Principles

The inventive principles were originally identified by analysing patents. This is the key for profiling technological competencies of companies, which is founded on three ideas:

- If it was possible for Altshuller to extract the principles out of the patents between 1946 and 1970, it should be possible to do this extraction today as well.
- Each inventive principle represents a large group of inventions based on the same major idea. Therefore, the application of such a principle by a company shows a specific technical competence.
- The set of principles used by a company gives a profile of its technical problem-solving competencies.

The TRIZ-based competitor analysis can be implemented by a specific process (see Figure 1). This process has been developed by the main author and applied successfully not only in the presented case study, but also in other cases with the same company, as well as in the photovoltaic industry. It offers a unique alternative to other approaches of profiling technological competencies as mentioned in the introduction of this paper. With the aid of the inventive principles it is possible to get deeper inside, an X-ray view through technological competencies.

The process for profiling technological competencies comprises five steps:

1. There should be a definition of the technological field of interest. As an alternative to the technological field, a group of competing companies may be defined for analysis.
2. The patents and patent applications related to the technological field and/or the selected companies have to be selected within a database. At the moment there seems to be no better alternative to patents available, although patents have some disadvantages as data sources: they are published with a notable time lag after

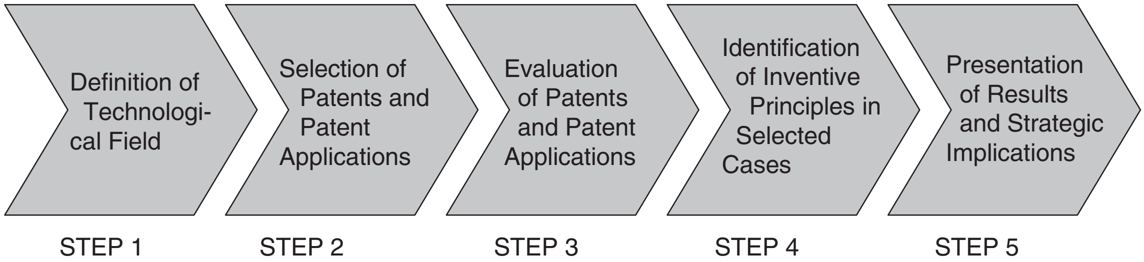

Figure 1. Five-Step Process for Profiling Technological Competencies of Companies

application and there are some industries where patenting is not used very often.

3. The patents and patent applications should be evaluated. Only patents and applications that represent a major invention are of interest. In some cases companies try to get patents for a large amount of minor inventions. It seems to be not very helpful to specify those as relevant for the technological competencies of that company.
4. In the evaluated patents, the inventive principles should be identified. This may take some time, because often the analyser has to go into detail to find the 'real' invention. Sometimes there will be even more than one invention within a patent or an application.
5. The results should be presented in graphics; a verbal classification then gives insight into the specific profile of technological problem-solving competencies. Strategic decisions such as changing the companyit'ss own profile of technical problem-solving competencies or spinning-in of other companies may be based on these results.

Case Study: Analysing the Field of Floor-cleaning Aids for the Home Market

The profiling of technological competencies of companies was evaluated with a case study in a leading German company. This company mainly produces chemical products but also cleaning aids and wanted to get insights into both its own technological problem-solving competencies and those of its competitors. The case study comprises the five steps specified in the preceding chapter.

Step 1: Definition of the Technological Field

The technological field to be investigated was defined as floor-cleaning aids (mops) for the home market. The company doing the analysis has been successfully in this business for many decades with different types of products, ranging from microfibre wipes to complete cleaning systems. The products connected to this field are typical consumer products. They are characterized as low price, but not necessarily low tech.

The technological field can be characterized as follows. In the home market, mainly flat floors, sometimes with some smaller unevenness, have to be cleaned. Types and degrees of dirt may vary in a broad range. For instance, dirt may be poorly water soluble, greasy or oily. The goal of cleaning is to get the floor clean and – as far as possible – dry. The floor-cleaning aid should be easy to handle and (as characterized above) low-priced.

Step 2: Selection of Patents and Patent Applications

The patents and patent applications of the defined technological field were identified in Derwent World Patent Index, which collects patent data from 40 leading countries in the world. Using 'mop' or 'mops' as keywords led to 1,300 patents and patent applications. Only the 300 most important patents and patent applications, identified through their belonging to the IPC Group A47L 13/00-62, were investigated further. Before going into detailed evaluation of those 300 patents and patent applications, two findings concerning the whole population will be discussed.

- Over the years there has been growth in patents and patent applications in the field of floor cleaning aids. Starting with 4–9 applications in the years 1963 to 1970 the number of applications has risen to 133 in the years 1995 and 1996 (annual growth rate: 12%). There may be different reasons to explain this growth rate. In general, patents are more often used in competition nowadays. Also, the level of invention for granting a patent has been lowered by the patent offices. In particular the technological field of floor-cleaning aids has been broadened by new products like flat wiping and wringing systems.

- There are very many inventors and applicants in the field of floor-cleaning systems. The major 19 applicants own 292 of the 1,300 patents and patent applications. The rest – more than 1,000 patents and patent applications – are owned by approximately 750 applicants. This may be explained both by the supplier structure, which is dominated by small and medium-sized companies, and by the high percentage of private inventors, who are inspired by the usage of those floor-cleaning systems in their own home.

Step 3: Evaluation of the Patents and Patent Applications

The next selection criteria was the type of invention. Only such patents and patent applications in which major inventions have been published were considered. This selection was made on the base of expert knowledge of the company and led to 65 patents and patent applications. Within this step the experts analysed the patents and patent applications with the help of a five level structure, which Altshuller (1984, pp. 16–25) suggested for invention classification:

- Level 1 – apparent or conventional solution; solution by methods well-known within specialty;
- Level 2 – small invention inside paradigm; improvement of an existing system, usually with some compromise;
- Level 3 – substantial invention inside technology; essential improvement of existing system;
- Level 4 – invention outside technology; new generation of design using science not technology;
- Level 5 – major discovery and new science.

Altshuller classified the inventions of 40,000 patents according to the five levels (Terninko, Zusman & Zlotin, 1998, p. 13). Thirty-two per cent of the inventions belong to Level 1, 45 per cent to Level 2, 18 per cent to Level 3, 4 per cent to Level 4, and only 1 per cent to Level 5. Although the borders between the levels may appear to be a bit fuzzy, the classification proved to be easily applicable to the engineers of the case-study company.

Step 4: Identification of the Inventive Principles in the Evaluated Patents

Each of the 65 patents and patent applications was studied intensively. The core ideas of each patent or patent application were formulated. The fundamental contradictions, which an invention overcomes, and the inventive principles used were identified and documented. Often there was more than one inventive principle used in an invention: in the 65 patents and patent applications, in total 104 inventive principles were applied.

The identification of inventive principles will be demonstrated using one patent. In European Patent 0097336, published in August 1984, a domestic floor mop is described:

> A domestic floor mop comprises an absorbent band mounted on a bracket carried at the end of a handle. A rotary torsion head is engaged with the band and is rotatably mounted in the bracket. A fastener is fixed to each end of the band, and the fasteners are mounted on the bracket for movement between a washing position, in which said fasteners are spaced apart and said band is deployed in a plane, and a wringing position in which said fasteners are closer together such that said band is gathered towards said rotary head to permit twisting of the band upon rotation of said rotary head. The fasteners are each slidably mounted in a respective guide carried by said bracket and extending in a plane parallel to the deployment plane of said band.

In the mentioned invention the main contradiction lies in the form of the band. On the one hand it should be deployed in a plane (for good washing results), on the other hand it should be close together (for good wringing results). The inventor, Roger Weiss, from Moulinex S.A. used inventive principle dynamicity (introduced above) to solve this contradiction. Sub-principle 1 of that inventive principle is: 'Make an object or its environment automatically adjust for optimal performance at each stage of operation', and that is exactly what has been applied in this invention.

In this state of research the identification of inventive principles is the most time consuming part of the analysis, as it has to be done by human experts (see also discussion). In the case study, it took two hours to analyse each patent.

Step 5: Presentation of Results

The case study led to three types of results, which will be presented here: (i) general findings about the application of technical problem-solving knowledge, (ii) the profiles of the three leading companies and (iii) strategic implications for the company doing the research.

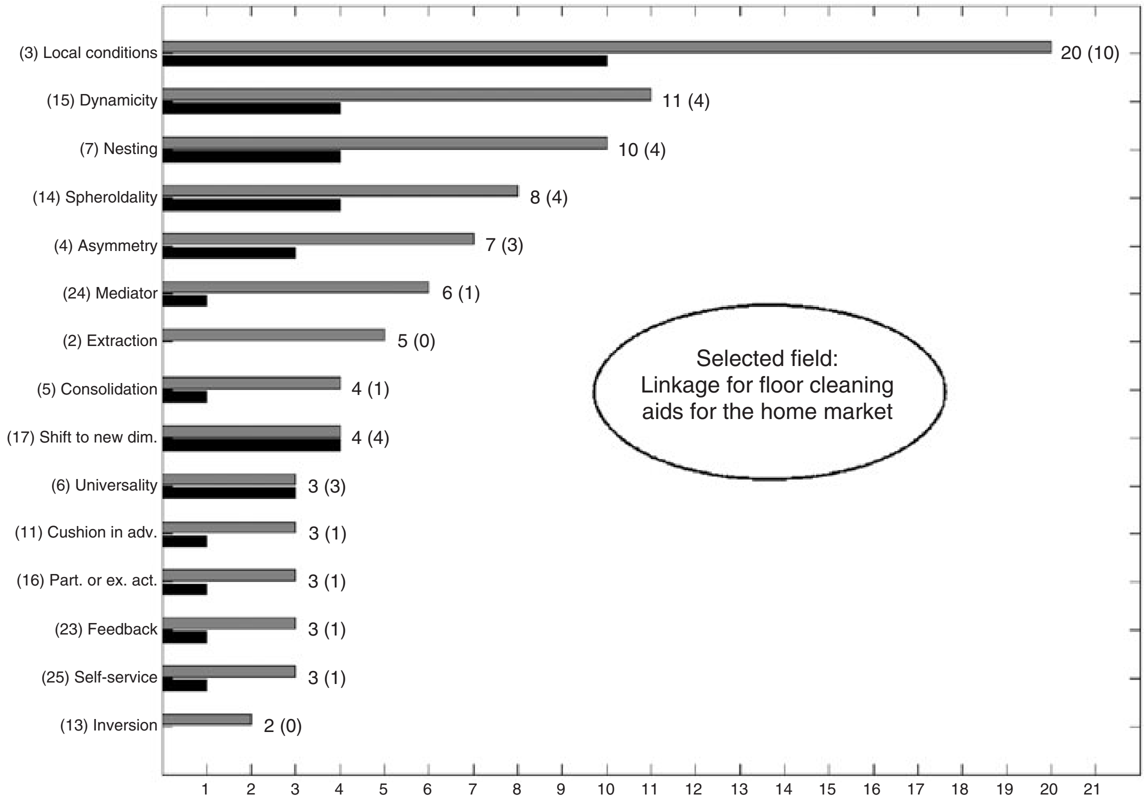

Figure 2. Application of Inventive Principles in Selected Patents and Patent Applications (See Table 1 for the description of the inventive principles)

General Findings

In general, in the field of floor-cleaning aids for the home market a broad spectrum of inventive principles has been used (see Figure 2). Most often, the inventive principles 3 (local conditions) and 15 (dynamicity) have been applied (see above for the description of these two principles), followed by principles 7 (nesting), 14 (spheroidality) and 4 (asymmetry). The inventive principles with low leading numbers seem to have been used the most: nearly half of the 104 identified inventive principles are located in the range between principles 1 and 7. That refers directly to the above-mentioned theory by Zobel (1991), which states that some universal inventive principles exist.

Profiles of Three Leading Companies

Three companies, one doing the case study and the two competitors with the highest number of patents and patent applications, were investigated further. The analysis shows clear and unique profiles of the technical problem-solving competencies of the three companies (see Figure 3). Company A is the 'local optimizer', company B is the 'dimension enhancer', and company C the 'dynamizer'. This verbal classification derives from the cluster of inventive principles a company has used most often. The principles 'local conditions' and 'dynamicity' have already been introduced above. The inventive principle 'dimension enhancement' represents inventions where the inventor has extended geometrical dimensions, for instance from plain to curved in one or even two dimensions.

There were also some overlaps in the technological competencies (see Figure 4). Principles 7 (nesting) and 14 (spheroidality) have been used by all three companies. Furthermore, there are some overlaps between two out of three companies. But all three of the companies have applied a significant number of inventive principles exclusively.

Strategic Implications

The insight into the profiles of technological problem-solving competencies had important strategic implications. In a first workshop with the heads of R&D the reasons for these profiles and whether there should be a change in the

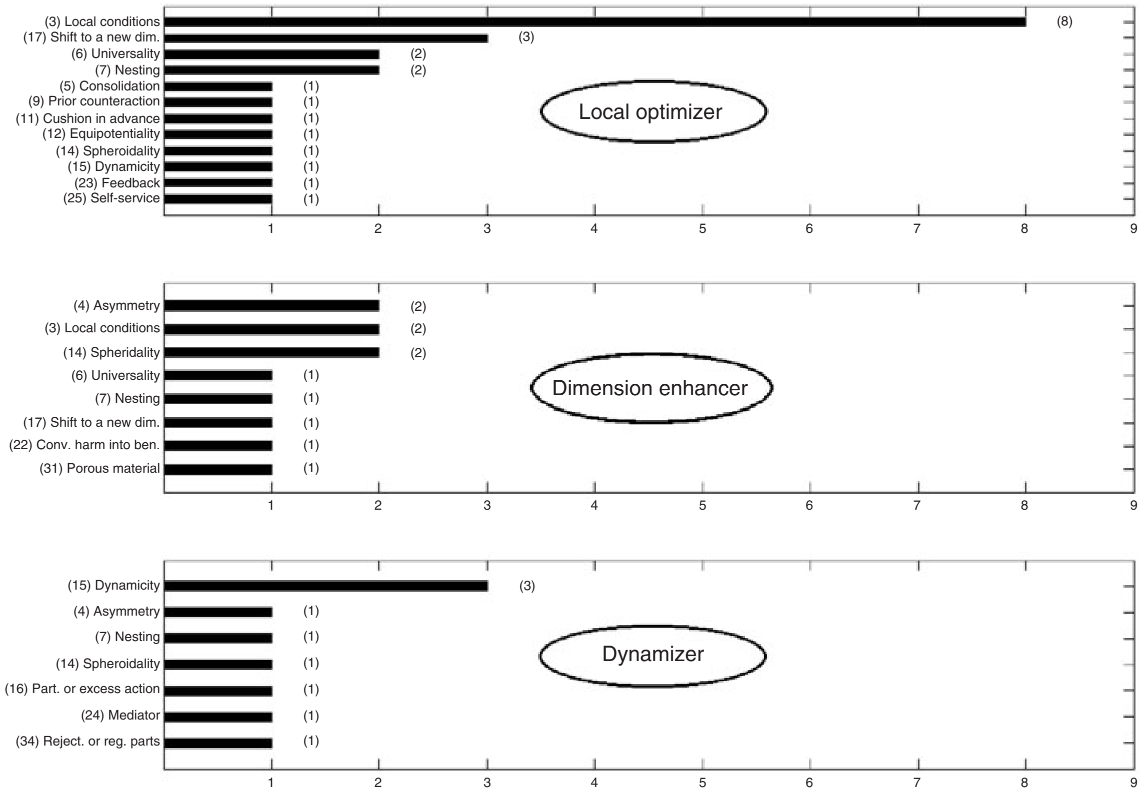

Figure 3. Application of Inventive Principles in Selected Patents and Patent Applications, Differentiated Among Three Companies (see Table 1 for the description of the inventive principles)

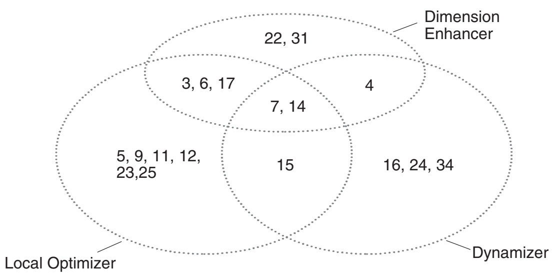

Figure 4. Overlap Diagram of Inventive Principles in Selected Patents and Patent Applications, Differentiated among Three Companies (see Table 1 for the description of the inventive principles)

fundamental directions of inventions were discussed. The question of spinning-in of company C arose and led to a technological co-operation with this company. A very successful follow-up workshop was organized. There, R&D employees discussed the profiles and applied those inventive principles that were normally used more often by the competitors. Based on that, it was possible to attack competitors in their field of competencies. All in all: the profiling of technological competencies of companies changed the way of technological competition in this field of application. Meanwhile, in this company other fields of interest are under investigation with the presented method.

Discussion and Conclusions

Profiling technological competencies with the aid of TRIZ is a new instrument for innovation and strategic management. Based on a patent analysis followed by the identification of inventive principles applied, it gives deep insights into the technological problem-solving competencies of a company and its competitors. It even may change the way of competition and/or co-operation in a specific market. But there are still a lot of questions to answer which could form part of future research:

- Can the described process be applied in every industry, where patenting is the common tool for defending the technological basis, or is it limited to some technological fields? First experiments show that it may be used in several engineering fields, but for instance is limited in chemical patents, where inventions often are described by new combinations of substances.

- How do the results of such an analysis change over time? In connection with this question the question arises, is the application of inventive principles more a particular feature of an individual (like a talented engineer) or more the feature of a group or department (like a specific engineering style)?
- How should the results of the profiling be connected to the economic value of patents? Until now there has been only weak empirical evidence that inventions on an higher level are economically more valuable than inventions on a lower level (see the classification scheme in process step 2). This should be investigated further for receiving better selection criteria.
- Are there any possibilities for enhancing the productivity of the analytical process? The experience value of two hours per patent limits the scope of possible applications. First tests have been made to use semantic patent analysis tools for this purpose, but it seems difficult to get the core of an invention by these tools.

As conclusions, three aspects shall be mentioned:

1. Profiling technological competencies of companies based on TRIZ enhances the theory of competition analysis by providing a new instrument giving deep insights (but see also the limitations discussed above).
2. The case study indicates the practical benefits a company can get from the instrument.
3. The presented instrument of profiling technological competencies shows that TRIZ has not only technical aspects, but can also be used as a powerful tool in strategic management.

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