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TRIZ industrial case studies: a critical survey

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Abstract

TRIZ is one of the most powerful and accepted methods to make systematic innovation. Despite TRIZ official development ended in 1985, researchers have continued its development by proposing new approaches (e.g. OTSM, TRIZ+, SPARK) or by extending existing ones. After all these efforts, the spread of TRIZ has never reached the level of capillarity expected. For this reason, in the last years, TRIZ community has interrogated more than once about the motivations for this slow growth. In order to accelerate the spread of TRIZ, many attempts were made to simplify the method, sometimes by integrating it with other methods (such as FMEA, QFD, Lean) that were already present in production plants and increasing TRIZ notoriety by publishing successful case studies.
This work is an updated picture of the current situation of TRIZ case studies publications. More than 200 case studies from TRIZ journal and ETRIA TRIZ Future Conference have been collected, analysed and processed to understand Why companies needs TRIZ, which tools are the most used, how TRIZ has been integrated with other methods, and how industries and academies communicate their success.
Differently to other surveys, this study also focuses on the ways in which solutions are presented, so as to identify best practices or new ideas and trends from a communication perspective.
This paper contains the results of this analysis and the related comments.

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Keywords: TRIZ, Survey, Standard solutions, Inventive Principles

1. Introduction

Since its introduction, TRIZ has been used in various field of industry. Starting from Russia, where it was developed, it has spread through the whole world and its implementation is especially documented in Europe and North America [1], [2] and [3]. However, after an initial exponential growing, the spread of TRIZ has never reached the level of capillarity expected.

The spread of a methodology is, by itself, a positive index of its effectiveness in real application. But, are there other ways measure the effectiveness of TRIZ in industry?

Solutions coming from a problem solving activity, whether they comes from brainstorming, TRIZ or other methodologies, go through many obstacles before their implementation; not always they become a commercial product and sometimes they can be considered not feasible.
Problem Solvers around the world are nowadays involved in consultancy activities that can lead to a commercialized product, to a patent, to a consolidated procedure or other outcomes. Several factors, such as the kind of problem, the industrial areas, the involved people and others environmental parameters can affect both positively or negatively the outcome of a consultant activity based on TRIZ.

Several authors [4] have analysed the major shortcomings in application, others have high-lightened peculiarities of TRIZ applications in restricted area, showing what approaches are more popular, but ever considering a complete analysis for an entire project.

In this paper we classify past TRIZ-based consultant activity in industry that have been documented in literature by

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considering an entire consultancy project. More than 200 papers from TRIZ journal, ETRIA TRIZ Future Conference and other major journal of engineering design (Research in Engineering Design, International Journal of Product Design) have been analyzed. The following graphs summarize the time distribution of the considered case studies.

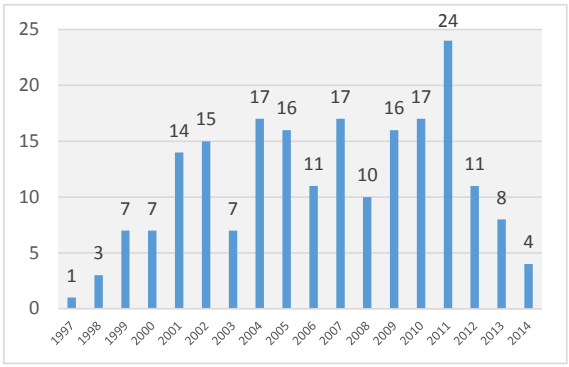

Fig. 1: Time distribution of the considered papers

Even if the coverage is only partial, the sample has to be considered highly representative. In fact, from a first analysis of the technical areas covered by the survey, as shown in Figure 2, there is a substantial alignment with the results of similar surveys previously made. (i.e. [4], [5]).

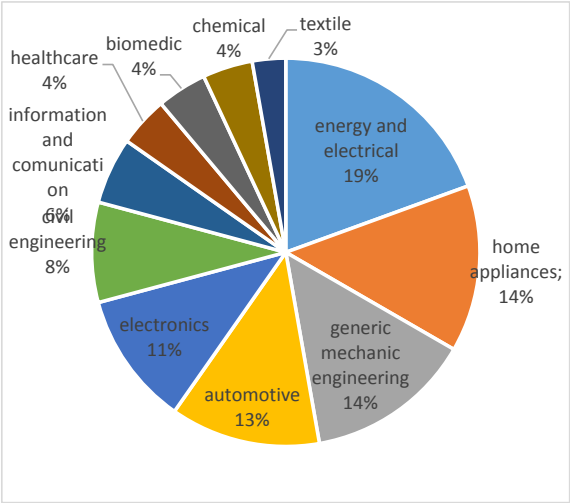

Fig. 2: Distribution of industrial sectors (in %)

The goal of this analysis is to provide data to better understand what can influence the reputation of TRIZ. Specifically, the following questions are considered:

- What are the most important external factors and pre-requirements that influences the outcome of a TRIZ-based consultancy activity?
- How the application of TRIZ changes when applied into different fields?
- What are the most popular approaches to present the results obtained by TRIZ?

To do this, we have tried to analyze data after breaking down by type of purpose and problem solving activity.

2. Why companies needs TRIZ

Needs and goals in a TRIZ-based consultancy activity are intended as the reasons or motivation for the activity that has been planned. According to [6], TRIZ is accepted in western companies thanks the capability to innovate a product more rapidly, increasing the competitiveness of the companies in an increasingly competitive market.

Other applications can be found in situations where new laws constrain product to meet specific requirements [7]. For instance, the European Directive on Energy-related Products (ErP) have stimulated the application of TRIZ in eco-design and in energetically efficient buildings [8].

To achieve their needs, industrial planning can act at different levels (strategic, tactical, operative, etc.) and in many cases they implemented TRIZ in this activity. This survey shows that TRIZ was adopted in:

- Quality improvement: for ameliorating planned functionalities and requirements, especially for products [9], systems [10] and services. TRIZ works in addition to the general quality improvement process [11].
- Reduction of product pollution.
- Lunch of new product: supporting the launch of new product (such as [9]) or service during or before the conceptual design stages.
- Productivity improvement: for ameliorating the aspects related to manufacturing and management of processes (e.g. [12]).
- Product/process innovation: improvements of existing products or processes by introducing new functions.
- Energy reduction (i.e. [13]).
- Safety improvement.
- Cost reduction.

Figure 3 shows for what purpose TRIZ was mostly used by users.

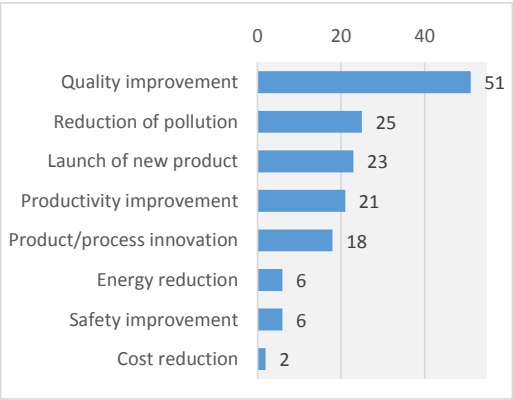

Fig. 3: Why companies needs TRIZ

The categories identified above are very general and not very indicative. For this reason a deeper analysis was conducted on the documents with the aim of understanding what are the specific activities in which TRIZ was used.

- Early design: TRIZ is used for conceptual design, in order to identify alternative physical effects or define the behavior of a potential solution. Several examples show TRIZ integrated with Pahl and Beitz approach and FBS Function Behaviour Structure theory.
- Optimization and Robust design: TRIZ is used to support optimization stage during design, FEM analysis, and robust design.
- Decision making and Forecasting: TRIZ can lead a different prospective highlighting new business opportunities [14] and forecasting, such as [15] or [9].
- Eco-design: TRIZ is used in an eco-design approach, especially to solve contradictions that emerged from the application of a partial solution.
- Design for X: TRIZ is used for improving product manufacturing, assembly and maintenance or for improving risk management models (i.e. [16], [17]).

Figure 4 shows the absolute frequency of utilization of TRIZ in the different problem solving activities.

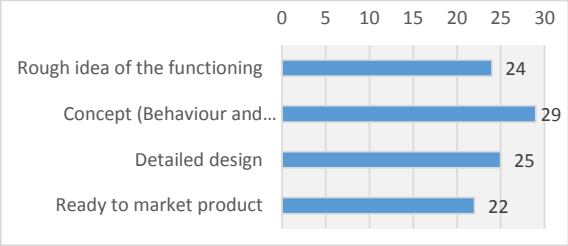

Fig. 4: Number of TRIZ case studies according to the design activities

A further analysis has been conducted in order to analyze the relation between goals and problem solving activities. This data allow us to identify the precise areas of real use of TRIZ in industrial problems.

		PS activities				
		Early design	Optimisation and robust design	Decision making and forecasting	Eco-design	Design for X
Goals	Quality improvement	18	21	2	1	14
	Reduction of product/process costs	0	1	0	0	1
	Reduction of consumption	3	0	0	3	0
	Reduction of pollution	10	3	2	13	1
	Product/process improvement	2	11	3	0	2
	Safety improvement	0	2	0	0	5
	Productivity improvement	6	7	0	1	13
	Launch of new product	13	8	4	0	5

Fig. 5: Problem solving activities vs requested goals

As we can see, in Figure 5 TRIZ is mainly used for:

- "Quality improvement", both in the early phases of design (18) and in optimization (21 results).
- To reduce the pollution, where TRIZ is integrated not only to improve efficacy of eco-design guidelines (13 results) but also for generating brand new concepts (10 results).
- To improve the products or the processes features and functionalities, TRIZ is used in the optimization phase (11) and more rarely for strengthen traditional tools as design for X.
- To improve the productivity. Here TRIZ is generally linked to Design for Manufacturing, Assembly and Maintenance (10 results), but also in optimization (7) and conceptual design (6).
- For the launch of a new product TRIZ is used during conceptual design phases (13 results), more than optimization (8) or together with other specific tools (5).
- Triz forecasting is used for launching a new product (4) than for product improvement (3).

3. Tools and methods for problem solving activities

Applying TRIZ means to apply several different tools (i.e. multiscreen, contradictions, inventive principles, etc.). Moreover, we can also integrate TRIZ method with other theories and approaches (i.e. Quality Function Deployment, Functional Analysis, etc.). In the rest of the paragraph, we analyze the most popular TRIZ tools and integrations.

3.1 The most popular TRIZ tools

Among TRIZ tools, some are more popular than others, like contradictions and inventive principles. Several studies have presented a frequency ranking and they have highlighted how the preferences are affected also by external factors as the field of application (i.e. [9]).

However, despite of the multitude of applications in industrial areas, the alternate success in the practice of everyday have lead the authors and the consultants to work on the customization of the methodology, flanking other theories to TRIZ method.

The founded results confirm what founded in previously survey works (i.e. [5]) so the situation seems not changed during the years.

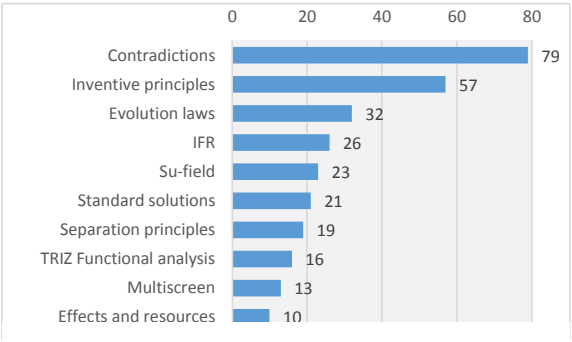

Fig. 6: TRIZ tools frequency of utilization

3.2 TRIZ combined with other methods

Several authors have commend the integration between TRIZ and other methods. [18] explain how for certain tasks, the use of only a restricted number of selected TRIZ tools integrated with other more suitable, precise or simply external instruments, may be preferable respect the forced use of the entire methodology. In general, integrations helps in the phases traditionally less developed by TRIZ method like the management of the requirements was improved in more rigorous manner, for example by [11] that integrates Quality Function Deployment.

The functional analysis was instead developed in cause and effect chain representation with the introduction of Rough Cause Analysis and in functional representation, like [19] with the formalism of the Energy Material Signal theory. While decision making was improved in two manner, providing more objective judgments, with the fuzzy logic, and making it easier the evaluation, like [20] that introduces the principles of the Value Engineering.

Figure 7 shows how TRIZ is mainly integrated with QFD, FMEA and in patent strategies/tools

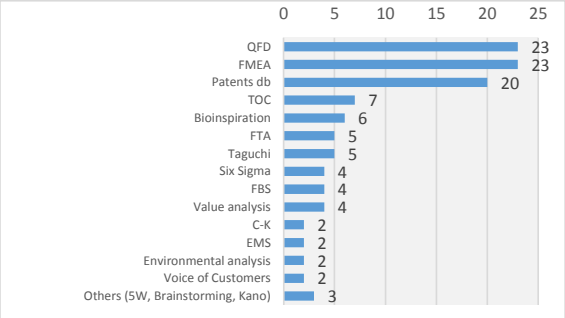

Fig. 7: TRIZ combination with other methods

4. How to present solutions with TRIZ inside

There are many ways to present a solution. It may be just an idea or can be accompanied by a feasibility study, as well as by a real prototype or finished product. Each of these modes may be accompanied by simple design sketches, as well as by complex analysis and detailed procedure description. This section analyses the most frequently used mode of presentation of the solutions made with TRIZ.

The level of detail with which a solution is presented has been divided as follows:

- Rough idea of the functioning (Only behaviour/physical effects): a consultancy activity that produce a solution at this level of abstraction aims at exploring possible new physical effects to achieve the product functionalities. In this case, the structural aspects are secondary and they are used to test the behaviour.
- Concept (Behaviour + Structure): when the solution have a structure quite similar to the final results but does not already satisfy the requirements of industrialization and marketability.
- Detailed design: if the product designed that can be produced and tested but is not yet ready for the market.
- Ready to market product: if the designed product is at its final level and can be introduced into the market.

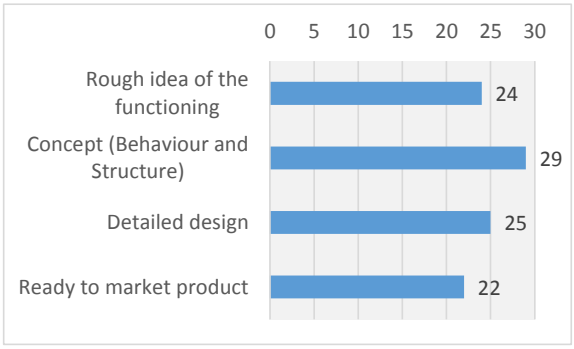

Fig. 8: Number of case studies describing ideas, concepts or final products designed by using TRIZ

Figure 8 shows that the distribution of TRIZ case studies is uniformly distributed on different levels of detail. It also means that less than 25% of cases studies deals with products already in the market today. There is a greater focus on the case studies in the planning stages.

Sometimes the goodness of the results is not sufficient to decree the success of the consultancy, because the presentation of the results plays more and more a crucial factor. In order to provide best chances of acceptation to the proposed results, we have firstly to choice the level of detail and then the smarter modality of presentation.

The choice of the correct level of detail can strongly affect the chances of acceptation of the idea and consequently the success of the consultancy. In this manner, more aspect of the idea can be better valorized (like the behaviour and the physical effect) without compromising it with a too precise and limited structural description, generally more attackable.

After that, we have to define in which manner the idea can be presented. In the following we have reassumed the most common approach founded in our survey:

- Sketches: thanks to their simplicity and the immediacy are among the most common tool. Some of the most famous TRIZ software are based on this approach.
- Infographic: are generally more elaborated respect sketches and contains more complex information. They are generally used to present the results in relations to evolutive trends and benchmarking analysis.
- Diagrams and tables: they can support the product when a large mole of information are required by normative or to evaluate the performances in a wide range.
- Virtual model and animation, numerical simulation and statistical analysis: regard all the integration between TRIZ and CAD/CAE tools.
- Behavioral and Structured tests: provide information about the behaviour of the product during simulations.
- Prototype: the presentation of a structural or functional prototype is always a possibility especially when we want

to valorize certain morphological or behavioural aspects especially for design artifacts.

- Algorithm and Procedure: can be the interface of presentation of a process improvement or of a software or of a new modality of usage of a certain product. Materials Requirements Planning (MRP), Enterprise Resources Planning (ERP), Total Quality Management (TQM), Electronic Data Interchange (EDI), etc. are only some of the possible ones.

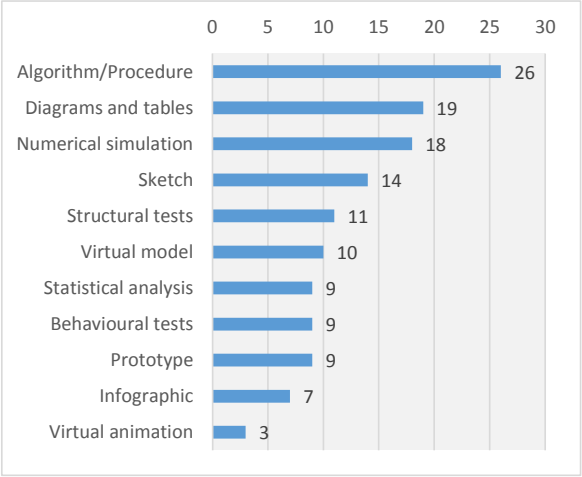

Fig. 9: Most popular interfaces of presentation used in combination with results

Despite the difficulties, we have tried to compare the modalities of presentation of the outputs with the obtained outputs and with the tools used together with TRIZ.

In the first case, we have compared the interface of presentation with the achieved results. Please note that the achieved results are independent from the followed problem solving approach in order to understand in what manner we can better valorize what has been obtained through a TRIZ activity.

		Interfaces of presentation										
		Sketch	Infographic	Diagrams and tables	Virtual model	Virtual animation	Statistical analysis	Numerical simulation	Behavioural tests	Structural tests	Prototype	Algorithm/Procedure
Outputs	Rough idea of the functioning	4	0	6	1	0	1	5	4	2	0	8
	Concept (Behaviour and Structure)	4	0	1	0	0	2	8	2	2	1	7
	Detailed design	1	1	1	1	0	1	0	0	2	1	4
	Ready to market product	0	0	1	1	0	0	1	0	1	3	3
	Not specified	5	6	10	7	3	5	4	3	4	4	4
	Total	**14**	**7**	**19**	**10**	**3**	**9**	**18**	**9**	**11**	**9**	**26**

Fig. 10: Results vs interfaces of presentation of the results

We can note that in certain cases, the specific achieved output is not specified but only the utilized interface of presentation. Anyway, algorithms, simulations and sketches seems to be most frequents. It is interesting that these interfaces are more exploited to explain how a conceptual solution (or first prototypes) have been reached rather than in paper that contain well-defined products. This because a real successful case study, that explicitly explains how many and in what manner TRIZ has contributed, is missing.

		Interfaces of presentation										
		Sketch	Infographic	Diagrams and tables	Virtual model	Virtual animation	Statistical analysis	Numerical simulation	Behavioural tests	Structural tests	Prototype	Algorithm/Procedure
PS activities	Early design	6	2	6	2	2	2	5	5	6	7	7
	Optimisation and robust design	4	0	2	5	1	3	9	3	3	1	9
	Decision making and forecasting	1	4	7	1	0	2	2	1	0	0	2
	Eco-design	1	0	2	1	0	0	1	0	1	0	1
	Design for X	2	1	2	1	0	2	1	0	1	1	7
	Total	**14**	**7**	**19**	**10**	**3**	**9**	**18**	**9**	**11**	**9**	**26**

Fig. 11: Problem solving approaches vs interfaces of presentation of the results

By analyzing the presented tables, we can state the following observation:

- Major part of the interfaces of presentation of the outputs are used to present the application of TRIZ in the early phases of product lifecycle (Early design and Optimization/Robust design).
- For decision making and forecasting, the most popular approaches are diagrams/tables and infographic.
- Eco-design and Design for X, there is no one single interface preferred to the others, except the algorithms that are used for explaining the methods rather than the solution.

Through the founded results we can understand for what interfaces of presentation of the results have been spent more efforts to better valorize the TRIZ consultancy/case study. In particular the presentation of a proper model and procedure seems the most popular approach; this means that the company seems to appreciate to convey the method.

5. Conclusions

In this paper, we have analyzed more than 200 papers about TRIZ applications in industry. We have analyzed and classified them according to the typical steps of a TRIZ-based consultancy activity with a particular focus on the way that Triz solutions are presented.

We have noted that TRIZ community has a trend of publications that is substantially constant (this analysis do not consider the new conferences in Asia) and that TRIZ continues to be an universal method used for many different applications. It is often used for strengthening other methods, not only in

early design phases but also in the embodiment phases and to concretize final solutions (e.g. to put a product on the market).

This lack of specificity in TRIZ literature might be one of the causes that makes it less appealing and inhibits its evolution. The lack of predominant modalities to present an idea shows how this argument is still immature and left to personal talent rather than systematic practices.

This paper have been preceded by previous analyses that obtained similar results with a very different approach. In that case, questionnaires instead of published case studies were used. Future development of this work regard the enlargement of the explored pool of papers by considering publications which are not from ETRIA, such Asian conference proceedings, and other international journals. This would allow a more robust statistical study.

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