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A survey on systematic innovation strategies for product design and development

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Abstract

Purpose:
Aim of this work is a survey on systematic innovation strategies used for the development of new products or in product improvement and optimization processes. In particular, the authors investigate the innovation synergies coming from the combination of TRIZ methods with other problem solving and creativity enhancements methods, and their relationship with particular application fields.

Method:
The survey is based on a literature review of academic publications present in indexed DBs. Twenty-nine case studies were collected and analyzed about non-TRIZ tools used in combination with TRIZ tools. For each case, the level of systematic innovation introduced by the use of the different methodologies is qualitatively evaluated using the so-called individual innovation index. This index is based on two other specific indices: the solution innovativeness and the synergy level. Then a brief overview of the four most used non-TRIZ tools adopted in the selected case studies, quality function deployment, ecodesign, case-based reasoning, and axiomatic design, is offered.

Result:
The analysis of the twenty-nine selected cases gives only partial results, so the introduction of a corrected innovation index, which considers the systematic innovation level of the presented methodologies given the sample size of the different non-TRIZ tools, has been done. The analysis of the application field has been performed as well.

Discussion & Conclusion:
The research highlighted the growing importance of the application of the combination of strategies that uses TRIZ and non-TRIZ tools, as the well-known quality function deployment or the promising ecodesign, the case-based reasoning, and the axiomatic design. Moreover, it seems that there is no explicit relationship between specific innovation strategies and application fields, while it has emerged that systematic innovation is mainly used during the first phases of the product development process.

1 Introduction

The rapidly changing modern marketplace drives companies to seek competitiveness in product/process development, in terms of innovation, quality improvement, sustainable design, and speed to enter the market.
In this time of highly competitive world, innovation is a fundamental source of competitive advantage and even a survival necessity.
As defined in the Encyclopaedia of management [1], innovation is the act of developing a new process or product and introducing it to the market.
Thus, the precise objective of today industrial improvement is the optimization of the innovation processes, to reduce or eliminate waste of resources (time, money, etc.), to develop unique solutions, and to manage the complexity of modern systems.
For these reasons a structured and systematic way for solving innovation issues is needed, namely this challenging task is known as systematic innovation process.

Systematic innovation is usually intended in literature as a synonym of TRIZ, the Russian acronym for theory of inventive problem solving [2,3], but in the last few years systematic innovation is mainly intended as a combination of the TRIZ theory, and of its evolutions, with other troubleshooting methodologies [4-7].
This way, the term systematic innovation is used to cluster all the approaches used for the identification and the resolution of technical and non-technical conflicts which may occur in an improvement process aiming at innovation. In [5], for example, authors distinguish two families of innovation tools, which are used in combination into systematic innovation strategies: TRIZ tools and non-TRIZ tools.
The aim of this work is to conduct a survey on systematic innovation strategies to highlight the synergies due to the combined use of TRIZ and non-TRIZ tools in problem solving.
In particular, this research, starting from the results of previous works, as reported in literature [6,7], wants to investigate if in the last few years market changes have influenced the introduction of new tools into innovation strategies. All of this in order to consider

the introduction of several design for X methods as, for example, the emerging sustainable design, manufacturing, and production strategies.
Also, this survey wants to highlight which tools have been used in published case studies and if there exists some specific relationship between the combinations of these tools and their specific application fields.
This paper is organized as follows.
In the second section the methods used for data collection and data analysis are described, particularly focusing on the criteria used to select the case studies. In the third section an overview of the more frequent non-TRIZ tools used in these systematic innovation strategies is done. In the fourth section the discussion of the analysis results is given. Finally, conclusions and future directions for the research are presented in the last section.

2 Methods

To perform this survey, a wide literature review has been done. In the following paragraphs the procedure used to accomplish this task is explained.

2.1 Data collection

The survey was based on literature review of academic papers and conference proceedings present in on line research DBs.
A DB search has been performed through the use of the following DBs for academic publishing: ScienceDirect [8], SpringerLink [9], Informaworld [10], and Wiley on line library [11].
The keywords TRIZ and systematic innovation have been used individually and in combination. Only papers and conference proceedings published in English language have been considered. All the searches were performed with the advanced search or the expert search tools and for all years available.
Performing the search on ScienceDirect, 666 articles were found using the keyword "TRIZ", and 157 articles were found using the searching string "TRIZ AND systematic AND innovation", for all sciences and all years.
The same search on SpringerLink found 372 articles and 196 articles respectively.
Informaworld search for "TRIZ" returned 96 articles, while for "TRIZ AND systematic AND innovation" returned 35. The Wiley on line library gave back 381 and 105 articles.
Authors are aware that this literature review presents some limitations due to the decision of perform the searches using only a part of the available publication sources and the choice of consider only English language International Journal and Conference Proceeding archives.

2.2 Data analysis and index setting

At the end of data collection, the analysis of these data has been performed.
The case studies of interest here have been selected from the previous searches in accordance to two criteria: a) they should have been related to TRIZ and non-TRIZ methods in synergy; b) they should have concerned cases of product or process innovation of engineering interest.
According to these criteria, 29 cases of applications of systematic innovation methods were considered. They are reported in table 1. All the publications describing them regard the time period 2003-2011. Table 1 shows the references for the considered publications, their publication year, the non-TRIZ tools that TRIZ was combined to, and the application field.
The individual innovation Index - III - is defined too. This index, reported in table 1 as well, represents a qualitative measure of the goodness of the proposed systematic innovation methodology. It is defined as the sum of two indices: the solution innovativeness - SI -, focused on the quality of the results of the case studies, and the synergy level - SL -, that considers the level of integration between TRIZ and non-TRIZ tools, case by case, as reported also in table 1.

2.2.1 Individual innovation index

In the SI index, the level of the innovativeness of the proposed solution in the case study is a combination of qualitative evaluations, done by the authors on the basis of the different innovation kinds defined in literature. In particular, in [12], four different dimensions to categorize technological innovations are used. These dimensions are depending from: a) the nature of the innovation or if it is applied to a product or a process; b) the intensity and the degree of changes that the innovative solution takes, if it is a radical or an incremental innovation; c) the effect introduced on the firms as enhancing or destroying competences; and d) the degree of changes introduced to the structure of the product/process as architectural or component innovation.
In reference to the objectives of this research and for the definition of the SI index authors have paid more attention to evaluate the different case studies in function of the nature of the innovation (product vs. process) and to the degree of changes introduced in the product or process structure (as architecture vs. component).
On the basis of these assumptions, the authors have considered the definitions for product and process innovation reported in [13,14] to evaluate the case studies contained in the selected papers. For example, if the innovative solution proposed allows the introduction in the market of a product whose technological characteristics or intended uses differ significantly from before, or whose performances are significantly enhanced, the SI index is set to 1. Otherwise, if the solution proposed is quite well-known, the SI index is set to 0. Also, intermediate values have been used. Similarly, if the solution proposed refers to a process, it is considered innovative if it involves the adoption of technologically new or significantly improved production methods. In this case the SI index is set to 1; otherwise, if the introduced changes are scarcely meaningful, its estimate tends to 0.
The integration between TRIZ and non-TRIZ tools is achieved by the definition of a systematic procedure. The SL index is used to evaluate this integration, so if it is described by means of a clear roadmap, the SL index is set to 1; on the contrary, if the proposed methodology integration is not translated in a clear roadmap but is reached through an unordered sequential use of different tools, the SL index is set to 0. In other words, the SL index witnesses the importance of the definition of a methodology and

represents the robustness of the described procure and its repeatability.

Thus, the value interval for the individual innovation index, intended as the sum of SI and SL, is between 0 and 2.

#	Publication	non-TRIZ tools	Application field	SI	SL	III
1	Kobayashi, H., 2006. A systematic approach to eco-innovative product design based on life cycle planning, Advanced Engineering Informatics 20(2), pp.113-125.	ecodesign, quality function deployment - QFD-I	household appliances	0.6	1	1.6
2	Shirwaiker, R., Okudan, G., 2008. Triz and axiomatic design: a review of case-studies and a proposed synergistic use, Journal of Intelligent Manufacturing 19(1), pp.33-47.	axiomatic design	manufacturing	0.9	1	1.9
3	Chang, H., 2004. The conflict-problem-solving cad software integrating triz into eco-innovation, Advances in Engineering Software 35(8-9), pp. 553–566.	ecodesign, analytical hierarchy process	manufacturing	0.8	1	1.8
4	Lucchetta, G., Bariani, P., Knight, W., 2005, Integrated design analysis for product simplification, CIRP Annals - Manufacturing Technology 54(1), pp.147–150.	design for X	manufacturing	0.6	0.8	1.4
5	Cortes Robles, G., 2008. Design acceleration in chemical engineering, Chemical Engineering and Processing: Process Intensification 47(11), pp.2019–2028.	case-based reasoning	Chemical engineering	0.8	1	1.8
6	Cortes Robles, G., Negny, S., Lelann, J., 2009. Case-based reasoning and triz: A coupling for innovative conception in chemical engineering, Chemical Engineering and Processing: Process Intensification 48(1), pp.239–249.	case-based reasoning	Chemical engineering	0.8	1	1.8
7	Li, T.S., Huang, H.H., 2009. Applying triz and fuzzy ahp to develop innovative design for automated manufacturing systems, Expert Systems with Applications 36(4), pp.8302–8312.	fuzzy analytical hierarchy process	manufacturing	0.8	0.9	1.7
8	Li, T., 2010. Applying triz and ahp to develop innovative design for automated assembly systems, The International Journal of Advanced Manufacturing Technology 46(1), pp.301–313.	analytical hierarchy process	manufacturing	0.8	0.9	1.7
9	Lin, C-C., Luh, D-B., 2009. A vision-oriented approach for innovative product design, Advanced Engineering Informatics 23(2), pp.191–200.	morphological analysis	manufacturing	0.9	0.8	1.7
10	Fei, G., Gao, J., Tang, X.Q., 2009. A TRIZ Based Methodology for the Analysis of the Coupling Problems in Complex Engineering Design, Proceedings of the 19th CIRP Design Conference – Competitive Design, Cranfield University, 30-31 March 2009, pp.285-292	axiomatic design	nuclear plants	0.6	0.9	1.5
11	Chen, J., Chen, W.-C., 2007. TRIZ based Eco-Innovation in design for active disassembly. In: Advances in Life Cycle Engineering for Sustainable Manufacturing Businesses. pp. 83-87.	ecodesign	manufacturing	0.8	0.9	1.7
12	Yamashina, H., Takaaki, I., and Kawada, H., 2002. Innovative product development process by integrating QFD and TRIZ, International Journal of Production Research, 40(5), pp.1031-1050	quality function deployment	household appliances	0.9	1	1.9
13	Shen, Y.-T., Smith, S., 2009. Product redesign using TRIZ and contradictive information from the taguchi method. In: Chou, S.-Y., Trappey, A., Pokojski, J., Smith, S. (Eds.), Global Perspective for Competitive Enterprise, Economy and Ecology. Springer London, London, Ch. 46, pp. 487-497.	Taguchi methods	manufacturing	0.5	1	1.5
14	Xie, J., Tang, X., Shao, Y., 2009. Research on product conceptual design based on integrated of TRIZ and HOQ. In: Tan, R., Cao, G., León, N. (Eds.), Growth and Development of Computer-Aided Innovation. Vol. 304. Springer Berlin Heidelberg, Berlin, Heidelberg, Ch. 22, pp. 203-209.	quality function deployment	manufacturing	0.7	1	1.7
15	Li, L., Li, G., Huang, S., 2006. Research on product innovative design method driven by client demands. In: Wang, K., Kovacs, G. L., Wozny, M., Fang, M. (Eds.), Knowledge Enterprise: Intelligent Strategies in Product Design, Manufacturing, and Management. Vol. 207 of IFIP International Federation for Information Processing. Springer US, Ch. 59, pp. 433-439.	quality function deployment	manufacturing	0.5	0.8	1.3
16	Stelian, B., 2009. Concurrent multifunction deployment (CMFD), International Journal of Production Research, 47(19), pp. 5343-5376	quality function deployment	manufacturing	0.5	1	1.5

17	Robles, G. C., Hernández, G. A., Lasserre, A. A., Martínez, U. J., Gomez, R. P., Gomez, J. M., González, A. R., 2009. Resources oriented search: A strategy to transfer knowledge in the TRIZ-CBR synergy 5788, 518-526.	case-based reasoning	automotive	0.9	1	1.9
18	Liu, S., Shi, D., Zhang, Y., 2009. A planning approach of engineering characteristics based on QFD-TRIZ integrated. In: Tan, R., Cao, G., León, N. (Eds.), Growth and Development of Computer-Aided Innovation. Vol. 304. Springer Berlin Heidelberg, Berlin, Heidelberg, Ch. 13, pp. 117-126.	quality function deployment	manufacturing	0.2	0.8	1
19	Cortes Robles, G., Alor Hernández, G., Aguilar Lasserre, A., Posada Gómez, R., 2009. Accelerating the knowledge innovation process. In: Kurosu, M. (Ed.), Human Centered Design. Vol. 5619. Springer Berlin Heidelberg, Berlin, Heidelberg, Ch. 22, pp. 184-192.	case-based reasoning	furniture	0.8	1	1.8
20	Grote, C. A., Jones, R. M., Blount, G. N., Goodyer, J., Shayler, M., Sep. 2007. An approach to the EuP directive and the application of the economic eco-design for complex products. International Journal of Production Research 45 (18), 4099-4117.	ecodesign, design for X	household appliances	0.6	1	1.6
21	Sakao, T., Sep. 2007. A QFD-centred design methodology for environmentally conscious product design. International Journal of Production Research 45 (18), 4143-4162.	ecodesign, quality function deployment for environment	household appliances	0.8	1	1.8
22	Chen, Z., Tan, R., 2006. Study on Integrating Application Method for AD and TRIZ. Vol. 207 of IFIP International Federation for Information Processing. Springer Boston, pp. 421-432.	axiomatic design	manufacturing	0.7	1	0.8
23	Serban, D., Man, E., Ionescu, N., Roche, T., 2005. A TRIZ approach to design for environment. In: Talabă, D., Roche, T. (Eds.), Product Engineering. Kluwer Academic Publishers, Dordrecht, Ch. 6, pp. 89-100.	ecodesign	automotive	0.8	0.8	1.6
24	Stratton, R., Aug. 2003. Systematic innovation and the underlying principles behind TRIZ and TOC. Journal of Materials Processing Technology 139 (1-3), 120-126.	theory of constraints	manufacturing	0.4	0.6	1
25	Ahmed, R., Koo, J. M., Jeong, Y. H., Heo, G., Jan. 2011. Design of safety-critical systems using the complementarities of success and failure domains with a case study. Reliability Engineering & System Safety 96 (1), 201-209.	axiomatic design, fault tree analysis	nuclear plants	0.6	0.8	1.4
26	Albers, A., Rovira, N. L., Aguayo, H., Maier, T., Oct. 2009. Development of an engine crankshaft in a framework of computer-aided innovation. Comput. Ind. 60, 604-612.	genetic algorithms	manufacturing	0.5	0.5	1
27	Yang, C. J., Chen, J. L., Feb. 2011. Accelerating preliminary eco-innovation design for products that integrates Case-Based reasoning and TRIZ method. Journal of Cleaner Production. In Press	ecodesign, case-based reasoning	manufacturing	0.6	1	1.6
28	Trappey, A. J. C., Chen, M.-Y., Hsiao, D. W., Lin, G. Y. P., 2009. The Green Product Eco-design Approach and System Complying with Energy Using Products (EuP) Directive. Advanced Concurrent Engineering. Springer London, pp. 243-254.	ecodesign, quality function deployment for environment	manufacturing	0.6	1	1.6
29	Sheu, D. D., Lee, H.-K., 2011. A proposed process for systematic innovation. International Journal of Production Research 49 (3), 847-868.	quality function deployment	manufacturing	0.6	0.9	1.5

Tab. 1 The selected case studies and related information.

3 Overview on non-TRIZ tools

This section reports an overview of the most used non-TRIZ tools highlighted by the survey.

3.1.1 Quality function deployment

Quality function deployment - QFD - is a well known and a powerful method for quality planning.
As reported in [15-17], the QFD structured method is used to translate customer desires into product characteristics during the design and development phases.
As a product development and quality management method, it was first introduced in early nineties in Japan as a quality improvement tool.
One model of the QFD is the four-phase one, which includes the House of Quality - HOQ -, parts deployment, process planning, and production planning.
Among the different stages, the HOQ is the most commonly used one, and its aim is to reflect customers' desires. The HOQ is a matrix style chart that correlates identified customer needs with technical characteristics. This chart presents the characteristic shape of a stylized house. It consists of several sub-matrices joined together and derived by crossing consumer wants and needs (consumer attributes) with technical

characteristics. This is a valid method, used by product managers and design teams, mainly in the initial stages of new product development processes [15].

3.1.2 Ecodesign

Ecodesign recognizes the environmental impacts of product during the design process in addition to existing design criteria and it is based on the integration of some environmental considerations during the design phase of a product or process [18,19]. Ecodesign aims at reducing the product environmental impact without creating a negative trade-off with other design criteria, e.g., costs, functionality, etc.
In 2003, the European Commission defined the EuP directive for setting ecodesign requirements [19-21].
The World Business Council for Sustainable Development has identified seven major eco-efficiency elements for companies which develop eco-friendly products or processes, in order to reduce their environmental impact. These elements are: material reduction, energy reduction, toxicity reduction, material retrieval, increase usage of renewable resources, product durability extension, and increase intensity of product service.

3.1.3 Case based reasoning

Case based reasoning - CBR - is a problem solving methodology that can be used in the initials steps of design processes. CBR derived from Schank's research on human memory and dynamic memory [22], so CBR is a memory based methodology. The general principle applied to CBR is that similar problems have similar solutions. Thus, for solving a problem using CBR, it has to be described first, and then its similarity with other problems for finding similar solutions has to be measured. Finally, these solutions may be reused for solving the problem. The CBR methodology is based on a cycle, namely the R4 model, composed by four phases: retrieve, reuse, revise and retain [22-24].

3.1.4 Axiomatic Design

Axiomatic Design - AD - is a theory developed by Suh in late 1978. This theory provides a systematic problem analysis based on the consideration of all the parameters involved in that problem. The AD approach involves splitting a design problem into functional requirements and then mapping them into design parameters [25]. In AD theory there exist four domains: the customer domain, the functional domain, the physical domain, and the process domain. Solution alternatives are developed by mapping the design requirements specified in one domain to a set of characteristics parameters of another domain. This way, concept design is represented by the mapping between customer and functional domains, product design is the mapping between functional and physical domains, and the process design corresponds to the mapping between physical and process. The mapping process is done by means of mathematical expressions. This theory is based on the use of two axioms, the independence axiom - maintain the independence of the functional requirements - and the information axiom - minimize the information content of design - [26].

4 Discussion of results

The amount of data collected and analyzed in this research based on the twenty-nine case studies pointed out that systematic innovation strategies use quite often the combination of TRIZ and non-TRIZ tools. The non-TRIZ tools found are generally represented by problem solving or creativity improvement tools as: quality function deployment - QFD -, ecodesign, case-based reasoning - CBR -, axiomatic design -AD -, analytical hierarchy process - AHP - and fuzzy AHP, design for X - DFX - (e.g. design for manufacturing or design for assembly), fault tree analysis, morphological analysis, Taguchi methods, theory of constraints, and genetic algorithms.
Nine papers report the use of TRIZ and QFD in synergy. Eight publications present cases of the combined use of TRIZ and ecodesign for the development of eco-innovation product and processes. In five cases a combination of TRIZ and CBR is used. Four cases report the use of TRIZ and axiomatic design together. Three case studies use TRIZ in combination with AHP or fuzzy AHP, while two cases are related to TRIZ and DFX methods.
Other five individual cases report the use of TRIZ with morphological analysis, Taguchi methods, theory of constraints, genetic algorithms, and fault tree analysis respectively.
A graphical representation of the distribution of the non-TRIZ tools regarding the case studies considered in this research is given in fig. 1.

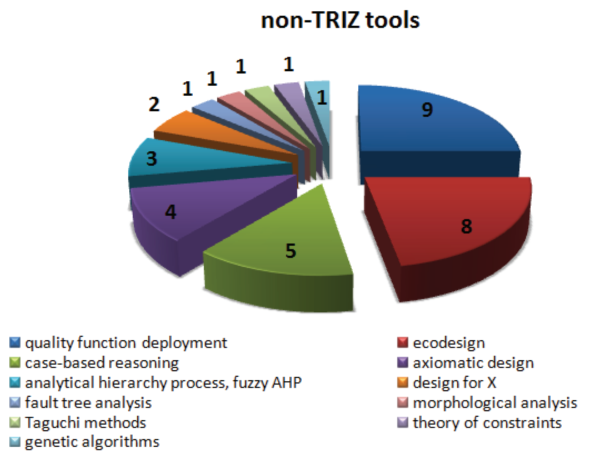

Figure 1. Classification of non-TRIZ tools of the case studies considered in this research

After the attribution of the individual innovation index values to all the twenty-nine case studies, an overall evaluation was done.
Table 2 shows the non-TRIZ tools grouped into eleven families. For each family, the total number of cases in which the specific tool has been used is reported. It has to be noticed that the sum of these values differs from the sample size because in many of the case studies a combination of these non-TRIZ tools was used, and this is clear the same in fig.1. In this phase, an overall innovation index is calculated, as the sum of the individual innovation indices. This value cannot be considered a good indicator for the innovation purposes reached by the different combinations of tools. For example, the overall innovation index of non-TRIZ tool families with a single member distorts the outcomes of the evaluation. To overcome this problem, a corrected

innovation index is considered, by introducing specific weights calculated according to the sample size of the non-TRIZ tools families and to the average value of the individual innovation index. For example, the corrected innovation index for the quality function deployment (QFD) tool is the result of the product between the QFD average innovation index and the QFD percentage of use.

non- TRIZ tools	Times used	percentage of use	Overall innovation index	Average innovation index	Corrected innovation index
quality function deployment	9	31.03%	13.90	1.544	0.479
ecodesign	8	27.59%	11.70	1.463	0.403
case-based reasoning	5	17.24%	8.90	1.780	0.307
axiomatic design	4	13.79%	5.60	1.400	0.193
analytical hierarchy process , fuzzy AHP	3	10.34%	5.20	1.733	0.179
design for X	2	6.90%	3.00	1.500	0.103
fault tree analysis	1	3.45%	1.40	1.400	0.048
morphological analysis	1	3.45%	1.70	1.700	0.059
Taguchi methods	1	3.45%	1.50	1.50	0.052
theory of constraints	1	3.45%	1	1	0.034
genetic algorithms	1	3.45%	1	1	0.034

Table 2. Non-TRIZ tool families and the computation of the corrected innovation index

A graphical representation of the situation is given in fig. 2.

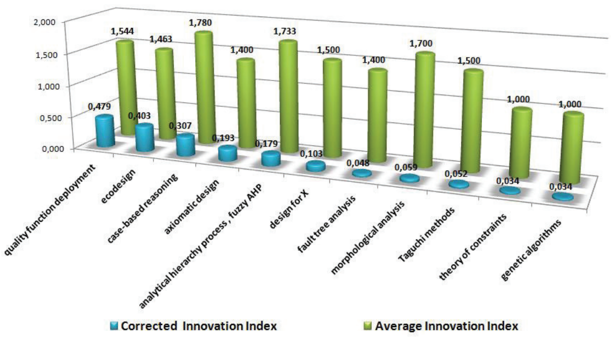

Figure 2. Non-TRIZ tool families and the overall innovation index values.

As a result, this corrected innovation index highlights that QFD is the most performing tool which can be used in systematic innovation purposes, followed by ecodesign, case-based reasoning, and axiomatic design.

In comparison to other similar studies [6,7], the presence here of ecodesign and case-based reasoning testifies the introduction of these two new and promising tools to be used in synergy with TRIZ.

4.1 Relationships between non-TRIZ tools and application fields

There are other important considerations concerning the relationships between tools and the case studies application field.

Twenty-four case studies are related to industrial product innovation, while five to chemical or nuclear process improvement and optimization.

In tab. 3 the relationships between the four most frequent non-TRIZ tools and their application field are summarized.

In particular, the nine cases relative to QFD application concern manufacturing or household appliance industries. In all the case studies, QFD is applied for highlighting product characteristics, focusing the attention on a specific problem, to highlight the possible technical parameters or contradictions which can be considered for the adoption of TRIZ.

In three out of nine case studies, QFD has been customized in order to match the particular application field, usually for environmental design purposes.

In all the nine cases the proposed innovation strategy is used during the first phases of product/process development for product planning and conceptual design purposes.

In regards of the eight ecodesign case studies, four cases belong to manufacturing industries, three belong to the specific household appliance sector and one to the automotive. Moreover, for all the eight case studies, ecodesign is the main target of product development, and ecodesign guidelines predominate on the design process. Thus, TRIZ is usually considered a tool which has to be customized for the particular environmental purposes, for example for the problem of material reduction which is usually considered as a problem of part number reduction.

Ecodesign is usually used in combination with QFD or CBR and with other DFX tools.

The suggested methodologies are, also in these cases, applied during the first phases of product/process development for conceptual design purposes and in one case also for product planning.

About the five case studies using CBR considered in this research, two of them relate to chemical engineering problems, while the others belong to generic manufacturing, furniture and automotive industries. For all the considered cases, CBR usage represents a valid and well structured methodology for searching previous solutions to similar problems, but only the synergy with TRIZ enables designers to consider innovative solutions, belonging even to other application fields. The use of the methodology is suitable for conceptual design issues.

Finally, regarding the four AD examples considered in the selected papers, two of them belong to manufacturing industries and the others to nuclear engineering.

The proposed methodologies highlighted that AD, during conceptual design phase, must be considered as an effective tool for defining and analyzing the problem, while TRIZ represents a valid technique for generating innovative solutions.

From this analysis two important considerations can be done. First, it highlights that seemingly there is no explicit relationship between the systematic innovation strategies and the application fields. Second, the considered systematic innovation strategies are widely used during the first phases of product/process development as a catalyst for innovative or unusual concepts.

non- TRIZ tools	# Case	Application field	Product/process	Development phase
quality function deployment	1	household appliances	refrigerator	conceptual design
	12	household appliances	washing machine	conceptual design
	14	manufacturing	---	conceptual design
	15	manufacturing	vacuum infuse equipments	conceptual design
	16	manufacturing	pencils	product planning
	18	manufacturing	---	product planning
	21	household appliances	hair dryer	product planning, conceptual design
	28	manufacturing	AC adaptor	conceptual design
	29	manufacturing	high concentrated photovoltaic system	product planning, conceptual design
ecodesign	1	household appliances	refrigerator	conceptual design
	3	manufacturing	correction tape device	conceptual design
	11	manufacturing	screws	conceptual design
	20	household appliances	citrus press	conceptual design
	21	household appliances	hair dryer	product planning, conceptual design
	23	automotive	car-mirror	conceptual design
	27	manufacturing	PC mouse	conceptual design
	28	manufacturing	AC adaptor	conceptual design
case-based reasoning	5	chemical engineering	chromatographic separation process – true moving bed	conceptual design
	6	chemical engineering	chromatographic separation process – true moving bed	conceptual design
	17	automotive	car transmission	conceptual design
	19	furniture	outside living set	conceptual design
	27	manufacturing	PC mouse	conceptual design
axiomatic design	2	manufacturing	air circuit breakers	conceptual design
	10	nuclear plants	reactor cavity cooling system	conceptual design
	22	manufacturing	flatness measurement equipment	conceptual design
	25	nuclear plants	safety injection tank	conceptual design

Table 3. Relationships between the most frequent non-TRIZ tools families and their application fields

5 Conclusions and future work

As stated in the introduction, systematic innovation strategies are now of great interest in the product development processes, as efficient tools for introducing novelty in products and for maintaining competitive advantage.

Aim of the research described in this paper was to realize a survey on systematic innovation strategies in use, highlighting the synergies between TRIZ and non-TRIZ tools for product development purposes. Moreover, this paper would like to be an easy reference for TRIZ and its integrated problem solving tools.

The literature review conducted in this research has shown both the importance of the combination of these tools for obtaining more meaningful results and the possible presence of combination patterns in relationship with the different application domains. This happens for example between QFD or CBR used with ecodesign both for the manufacturing and the household appliances domains, in the cases 1, 21, 27 and 28 of table 1.

Moreover, there seems to be a preference of the combined use of TRIZ with CBR or TRIZ with AD for systematic innovation strategies applied to process improvement, as in the cases 5 and 6 for CBR, and 10 and 25 for AD, always referring to table 1. A rough analysis of the strategies showed that in quite all the cases they are applied during the first phases of the product/process development cycle. Future research directions will consider the qualitative analysis of the methodologies presented in the cases studies given their application domain and their stage of application during product design and development cycle deeper, highlighting the kind of users and the motivation. All of this in order to develop an integrated framework for suggesting the best systematic innovation strategies given the application field, the kind of product/process, and the innovation purposes

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