KNOWLEDGE MANAGEMENT AND ECO-INNOVATION: ISSUES AND ORGANIZATIONAL CHALLENGES TO SMALL AND MEDIUM ENTERPRISES

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Abstract

At the design stage of a product or process, the environmental dimension is becoming a major issue, but designers are poorly equipped to handle it. The design or re-design expected in the product cycle is done with resources that are combined, which are associated, leading to the generation of new knowledge. To help SMEs in the development of their product, we propose a methodological approach that will allow to respect eco-innovative goal. As a starting point, a qualitative multi-criteria matrix will allow prioritization of all impacts for environment. A customized application of the inventive TRIZ principles (Russian acronym for theory of solving inventive problems Teorija Reshenija Izobretateliskih Zadatch) will help to choose eco-innovative solutions. To this aim, we have created a new approach: Eca TRIZ, based on new contradiction matrix. It was tested in various situations presented during the "24 Hours of innovation" competition. Some of them are presented in this research paper.

Keywords: Ecodesign, Innovation, Knowledge management, TRIZ, LCA

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1 INTRODUCTION

The difficulties for taking into account the environmental impacts caused by Small and medium enterprises (SMEs) production practices are recognized today. Also, one should note that the traditional environmental assessment to implement a process of eco-innovation is long and arduous; neither does it directly provide solutions to designers. In addition, SMEs employees responsible for innovation recognize the absence of data, and sometimes, if they are available, there is the difficulty of collecting them and the time needed to treat them is very long (Cherifi and Gardoni, 2015).
For all these reasons the companies is quickly paralyzed when the time is coming to use eco-design tools (Rennings, 2000). Recognizing this reality, we were encouraged to reflect on the need to propose a methodological framework which is at the level of a non-environmental expert.
Starting from the methodological approach to problem solving based on TRIZ associated with the use of knowledge already available within the SMEs we propose a framework that can enable SMEs to develop eco-innovation practices. This tool is robust because it is not only convenient and it could be used by non-expert. Potential users are the designers of products or services, organizations or SMEs or any person involved in eco-innovative design.

1.1 Background and realities of innovation in SMEs

SMEs must integrate the innovation imperative, both in their strategic and functional practices. Indeed, SMEs are characterized by specific aspects that make them vulnerable, especially for their market, their context, their environment as well as with regard to their customers and competitors. They operate very often based on intuitive strategies, driven by the founding manager. The latter must therefore create the climate and conditions necessary to promote the requirements for successful innovation. Among the key success factors of innovation projects distinguishes:
a) the contractor's capabilities and their involvement;
b) the presence of adequate human and financial resources;
c) control of tacit and explicit knowledge needed to create new knowledge that must materialize innovation (xu et al. 2013).
d) companies focus on the backlog and the eco-design aspects are not a priority even if they feel concerned.
c) They do not have the tools and operational approaches of innovation adapted to their size.

1.2 The need for eco-innovation in SMEs: challenges and problems

Eco-innovation allows taking into account environmental constraints (Limiting the emission of CO2 or other products, for example, preferring such material ...), which enables to connect with the objectives that promote sustainable development. The applied dimension of eco-innovation goes hand in hand with the life cycle analysis model of the product or service. The eco-innovation solutions must therefore integrate environmental compliance parameters as stipulated by the ISO 14062 standard, based on the development and support optimization of the eco-efficiency ratio.

2 STATE OF THE ART

The purpose of eco-innovation is the development of methodologies involving creative new values of innovative solutions to create new solutions. Eco-innovation calls upon a set of strategy and perception approaches with prevention and thinking in terms of life cycle, as the focus of eco-innovation (Falk and Ryan, 2001).
It is therefore a response to the current practice of eco-design allowing only one approach to reduce environmental impacts and optimization of current economic practices, whereas sustainable development requires more radical changes in products and services (Tyl, 2011; Dewberry and Monteiro de Barros, 2009). Eco-innovation proposes therefore a new vision of environmental approach and business strategy.
Moreover, eco-innovation enables, from an economic perspective, many opportunities, including the one of improving the competitiveness of companies to open new markets for desirable goods (Baroulaki, 2007).
It is therefore important to have a twofold understanding of the term 'eco-innovation' (Tyl, 2011)

- The first one, through a horizontal reading, allows us to see the variety of definitions which have evolved in a recent past (Klemmer, 1999).

- The second one, by a vertical reading, allows putting eco-innovation in its appropriate context (Matthieu,2008).

The two studies done by Carrillo-Hermosilla (2010) and Matthieu (2008) allow for a comprehensive view of all these definitions.

Dangelico and Pontrandolfo (2010) worked on the eco-design tools that can help engineers in the ecological design of products. Other works describes a new model to accelerate the preliminary design of an eco-innovative product incorporating the concepts based on reasoning and on the TRIZ method (Yang and Chen, 2011). Several examples of eco-design are given to illustrate the capabilities of such a process already from the work of Liu and Chen (2001).

Russo et al (2009) describes a way to use TRIZ concepts and tools to analyze, evaluate and innovate a technical system in sustainability and which can be easily incorporated into the design practice in daily life.

Other works compared the trends in the evolution of TRIZ with the eco-design strategies presented in the framework of the name of the LiDS wheel (Lifecycle Design Strategies) to analyze the effects on environmental parameters (Chulvi and Vidal, 2009).

Some authors present a new forecasting model to acquire new ideas and to help design environmentally friendly products while following the new design assessment to see if it is more effective than those currently available (Houssin and Coulibaly, 2010).

Based on the Mal'IN *(Méthode d'aide à l'innovation)* and Eco-Mal'IN methods, a new eco-innovation tool based on the matrix invention has been developed (Kallel, 2010). Other authors have proposed the 'Ecological Advanced Systematic Inventive Thinking' (Eco-Asit) tool for promoting the eco-ideation of sustainable systems (Tyl, 2011).

3 THE METHODOLOGICAL APPROACH

One should therefore translate the environmental impact evaluation results of each assessment into design axes, for practical purposes. But, in general the proposed axes are inconsistent or contradictory, so that on a compromise solution has to be looked for. However, a solved problem by compromise in the context of the industrial reality often has an insufficient long-term solution. Therefore, we have developed and tested ECA-TRIZ based on TRIZ, wich is a method that has proven itself in other areas to find a solution avoiding compromise.

At first we built a matrix to determine the environmental profile, in general of the potential product from a series of questions related to the life cycle of the product. The impact assessment is made at each stage of the product's life cycle.

The advantage of such a matrix are:

- Ease of use and ownership.
- The consideration of all environmental concerns (multi-criteria) throughout the (global) product's life cycle.
- Does not require data figures since the assessment is qualitative.
- Introduction of new eco-efficiency factors, including the perception of the product from the user's point of view and the level of ownership of eco-design at the companies' level.

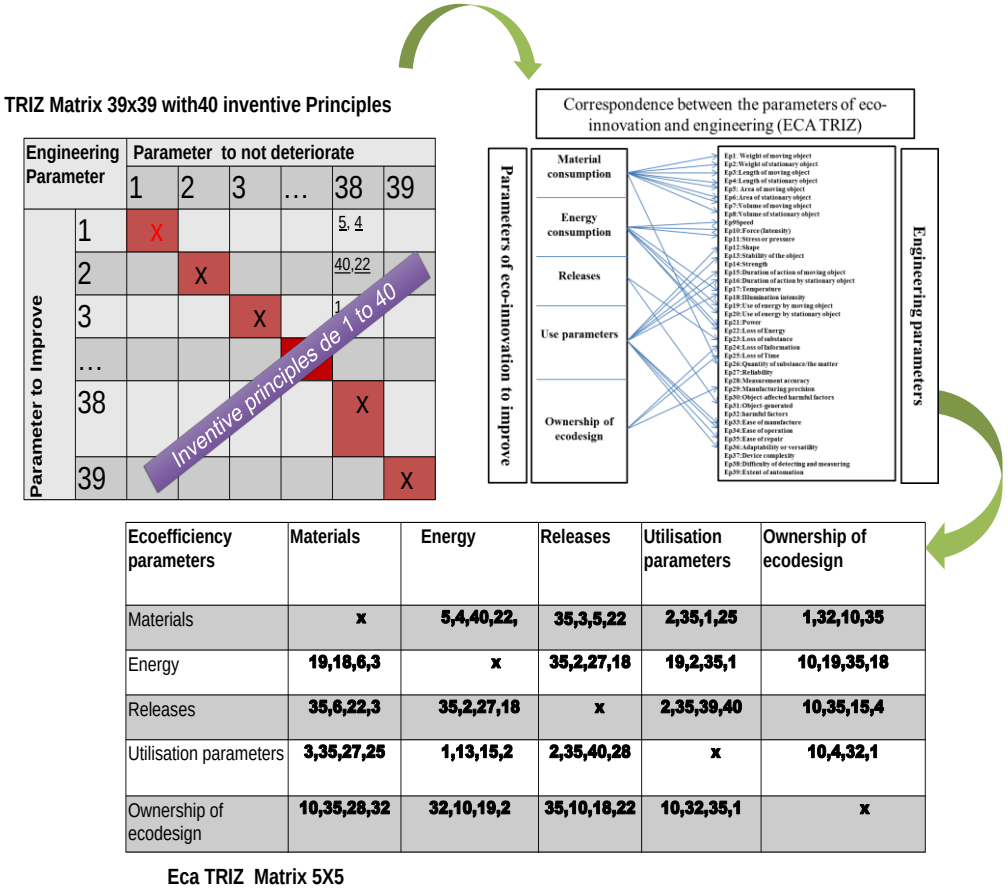
TRIZ is based on the similarity that may exist between an inventive problem and a solved similar problem in another context or field. The TRIZ matrix is a solutions principles database that can overcome some contradictions.

To apply TRIZ in the field of eco-innovation, we have built a simpler eco-innovative matrix from the 39 engineering parameters (EP). These EP are classified and grouped by type of five eco-efficiency parameters selected from the WBCSD (*World Business Council for Sustainable Development*) considering the materials, energy, waste (liquid, gaseous and solid). We introduced for the first time two other new settings related to the use of the eco-design by the designer or user in general (shape, stability, strength,) and to its degree of ownership (ease of use, etc ...) (Cherifi and Gardoni, 2015).

- The inventive principles were selected and grouped according to their frequency of occurrence from the initial matrix.

To maximize the probability of occurrence of each parameter in the eco-efficiency parameter we selected a maximum number of settings. We obtain a new matrix composed of eco-efficiency parameters, x-axis and y-axis, with new inventive numbers.

Figure 1 gives an overview on the passing stages from the TRIZ matrix to the new matrix called ECA-TRIZ (Ecological TRIZ).



Ecoefficiency parameters	Materials	Energy	Releases	Utilisation parameters	Ownership of ecodesign
Materials	x	5,4,40,22,	35,3,5,22	2,35,1,25	1,32,10,35
Energy	19,18,6,3	x	35,2,27,18	19,2,35,1	10,19,35,18
Releases	35,6,22,3	35,2,27,18	x	2,35,39,40	10,35,15,4
Utilisation parameters	3,35,27,25	1,13,15,2	2,35,40,28	x	10,4,32,1
Ownership of ecodesign	10,35,28,32	32,10,19,2	35,10,18,22	10,32,35,1	x

Figure 1. The approach to obtaining the ECA-TRIZ matrix

The overall methodological approach is given in Figure 2.

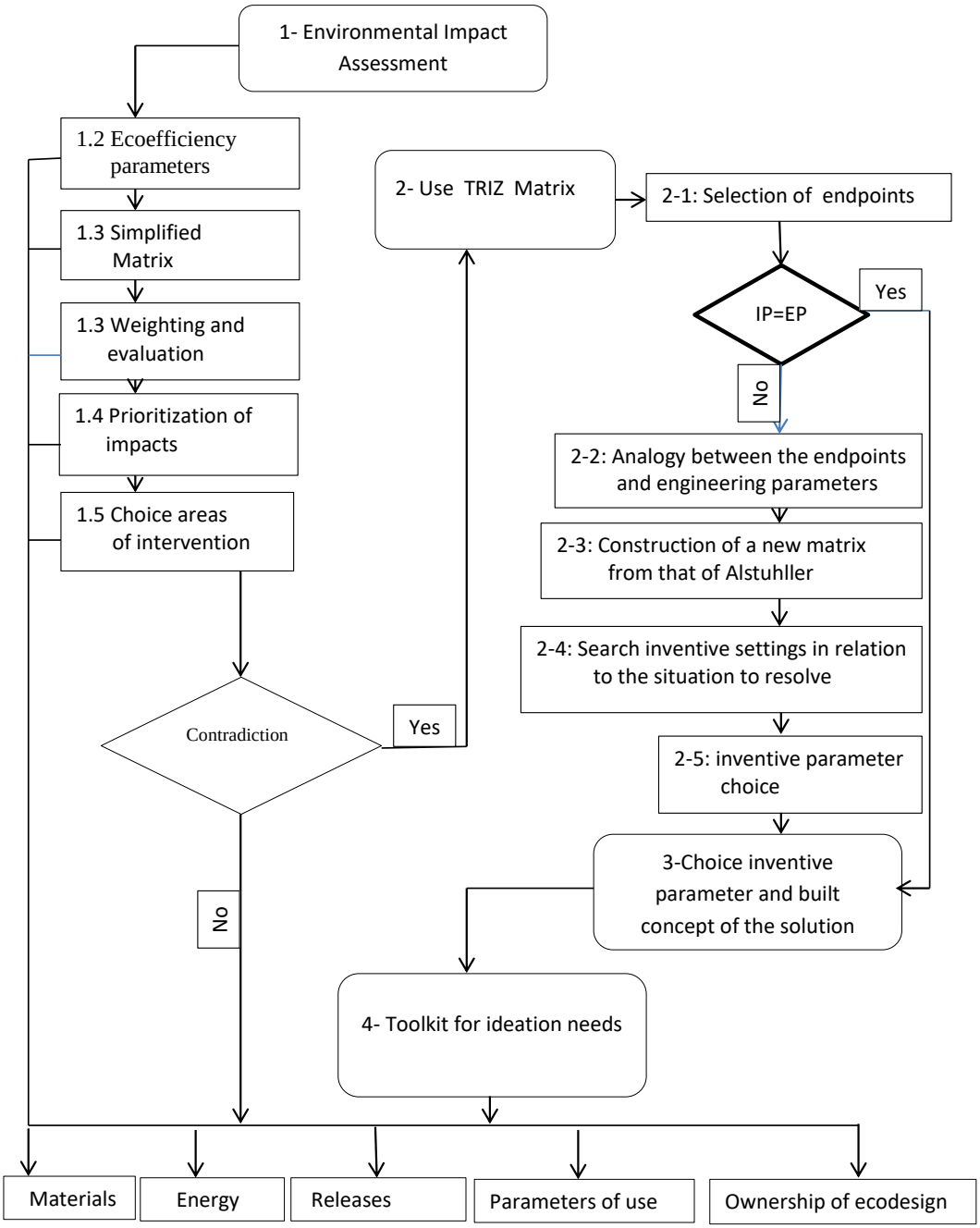


Figure 2. Initiative of the eco-innovating ECA-TRIZ process

A set of rules to improve a particular aspect in the life cycle must be given. This is a state of the art of the avenues to explore to achieve eco-design products. We could make use of technical troubleshooting tools that have proven themselves in other areas, such as the generation of new concepts that may be tested in eco-innovation. Figure 3 shows the eco-innovative ECA-TRIZ approach in the product cycle.

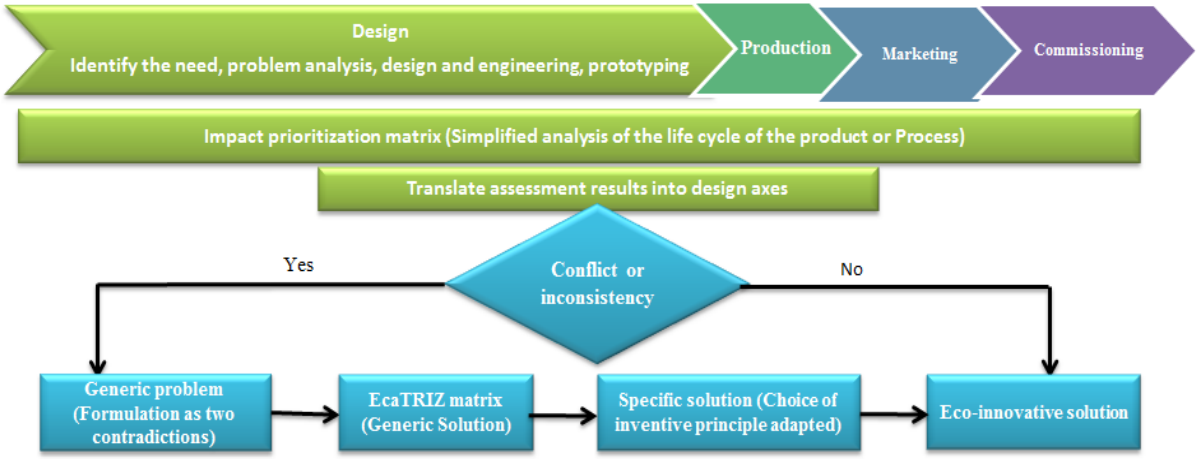


Figure 3. Eco-innovative ECA-TRIZ a in the product cycle

4 RESULTS USING OF THE METHOD

Thus, for each situation of settings to improve (vertical axis of the matrix) and the parameters not to damage (horizontal axis of the matrix) the potential inventive principle numbers will match.
After grouping according, a set of 39 engineering parameters in the eco-innovation context according to their frequency, the selection of these thirteen principles is motivated by the frequency of occurrence of these tracks of solution in the new matrix called levers for eco-innovation (Segmentation, extraction, inversion, sphericity, periodic action, prior action, mobility, color change, vibratory action, composite material, cheaper object).
The designer will choose among these selected inventive principles and will use the suited one for solving the problem in accordance with the given situation (Figure 4).

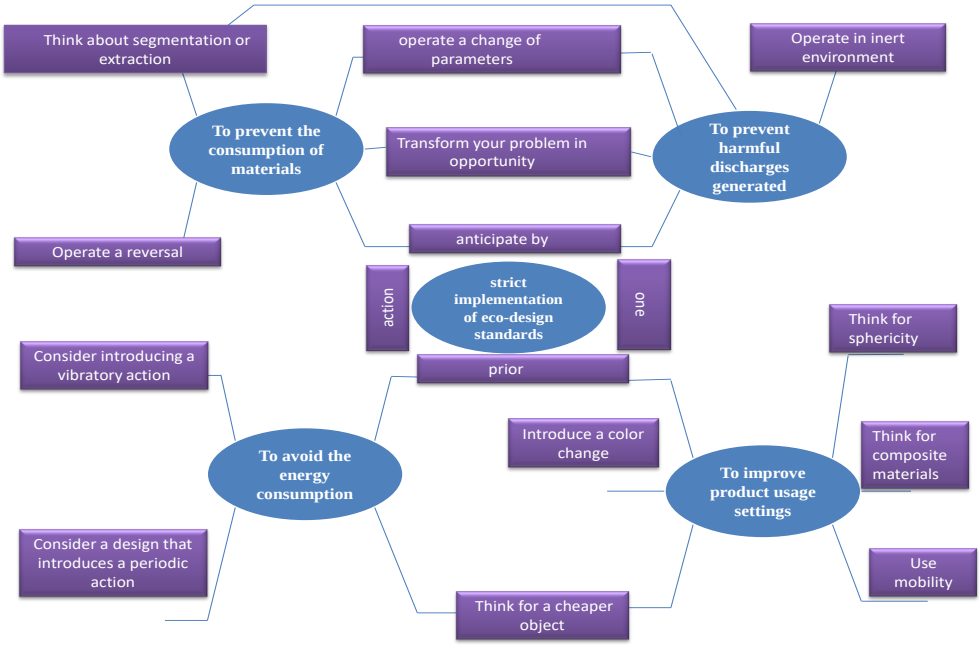


Figure 4. Summary of the main possible actions for eco-design innovation based on the ECA- TRIZ method

The levers or actions developed in Figure 4 allow to *ECA-TRIZ* matrix to be more user friendly for the designers, he has to choose his need in the oval and find the principles to solve his need in the rectangle. It aims to improve the product development process or environmentally friendly procedures in an

innovative approach and uncompromised solution. It can be applied to the launching of a new product or to improve an existing one.
Given the situation of SMEs (scarcity of resources, limited staff, etc.), designers can rely on the tacit and explicit knowledge of company has. This knowledge will help to find new solutions to improve the analysis of the life cycle as well as the ratio of eco-efficiency. Eco-innovation initiatives should be structured thanks to the knowledge creation model of Nonaka and Takeuchi (1995), (Table 1).

Table 1. Matrix of Nonaka and Takeuchi

	Tacit knowledge	**Explicit knowledge**
Tacit knowledge	Socialization	Outsourcing
Explicit knowledge	Internalization	Combination

An example is given in Table 2 in the case of the consumption of material.

Table 2. Example of an application of the knowledge base

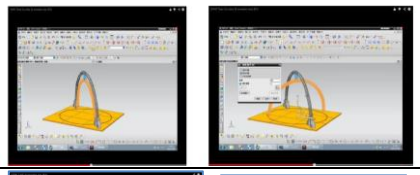
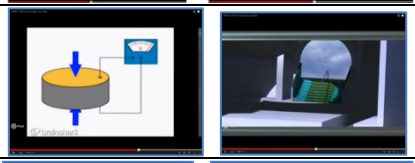
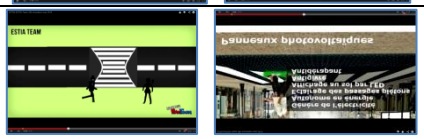
Eco-efficiency factor	**Principles**	**Actions (new knowledge)**	**Bases to generate the new knowledge**	**Activities for generating new knowledge)**
Material consumption	-Segmentation -Extraction -Converse action -Transform the problem into an opportunity -Change settings -Prior action	-Splitting an object into independent parts -Make the object removable -Increase the degree of segmentation. -Separate parts of the object -Inverse action, returning. -Use adverse factors, eliminate the detrimental effect, amplify the damaging effect until it disappears	Tacit knowledge Explicit knowledge Benchmarking External databases Internal database Experience from previous projects	Socialization Outsourcing Combination Internalization 6 Price actions

5 APPLICATION OF THE ECA-TRIZ METHOD

5.1 Challenges of 24H of innovation competition

We applied ECA-TRIZ method to assess the solutions proposed by the student teams to the challenges of the '24 hours of innovation' competition.
The best concept of solutions provided by participants, generally agree with all the ECA-TRIZ principles. The table 3 provides an overview of the best eco-innovative solutions proposed to cope with some of the challenges.

Table 3. Summary of the main applications (Source: http://24h innovation.agorize.com/)

Title challenge	Problem	Solution provided by the method	Solution given	Illustration
Reduction of the size of the tent poles in a circus	Impact on the visibility of some seats behind the mats. Increase their values in the sale of tickets in circus.	-Sphericity -Composite materials	-Structure in bow -light alloy	
Re-inventing the stairs	Find new ways to increase the use of stairs	-Prior action -Change colour	-Piezo-electric recovery -Effect colour for better visibility	
Road sharing	How to promote safe road sharing	-Sphericity -Mobility and prior action	-Linear curve forms-Generation of electricity	

5.2 Application of ECA-TRIZ to asses the patents published in eco-innovation

Another application we considered interesting was to apply ECA-TRIZ to assess the published patents for products designed in eco-innovative method (Table 4).

Table 4. The methodological tool applied to examples of published patent

Name of concept or product	Presentation	Choice of inventive parameter consistent with our approach
Shoe sole (Olivier and al, 2007) **Publication number EP1928277A**	Choosing a shape and sole with improved strength, with minimizing energy consumption and recyclable. Concept: antibacterial composite yarn, three-dimensional textile structure and multilayer	**To improve** EP 12: Shape EP 13: Stability EP14: Strength Without damaging: Energy, materials and releases **inventive principles selected from the method** 40: Composite materials
Ceramic based on clinker garbage (Vincent, 2007) **Publication number EP 1215182 B1**	The present invention relates to a crystalline based material of clinker. It finds particular use in the field of the crystalline ceramic-like materials. Objective: Save energy by lowering the temperature while maintaining the mechanical properties.	**To improve** - Energy consumption **Without damaging** shape, strength and stability Inventive principles: 19,2,35,1 **inventive principles selected from the method**: 35 (parameters change)
Cross railroad (Eric, 2013) **Publication number EP2539508A1**	Composite rail sleepers essentially polyurethane material typically, with excellent mechanical properties.	**To improve** - use parameters (EP 14: Strength, EP12: shape, EP 13: stability) **Without damaging** - Releases **inventive Principles:** 2,35,40,28,35,2,40,14 - Material consumption Inventive Principles: 40,1,29,27 - Energy consumption. Inventive Principles:14,2,6,40 **inventive principle selected**: 40 (Composite)

6 CONCLUSION

The idea of replacing the engineering parameters by the parameters of eco-efficiency is an approach justified by the analogy that may arise from the many contradictions of environmental factors and to adapt our approach to the situation.
Our main contribution is the creation of the simplified matrix taking into account the life cycle of the product or of the process with a multi-criteria approach and a resolution of contradictions by using a suitable TRIZ principles selection. Indeed, potential inventive principles for possible solutions are obtained. Some of these principles may not be applied to all of the design configuration. However, the matrix can help the designer to reduce the scope of his creative investigations.
The results obtained with ECA-TRIZ method were compared with the solutions given by students during the '24Hours of innovation' competition and also with published patents and related to situations of resolution of environmental issues. Our methodological approach can be applied to the different situations and shows perfect consistency in the choice of the principles used to solve the problems. It can also serve as a referential kit for businesses' objectives for improvement and innovation of products or processes with support for environmental concerns without transfer of pollution.
The results obtained by the ECA-TRIZ method will guide the designers on potential eco-innovative tracks.

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