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Triz in ecodesign: an alternative in the choice of environmental solutions without pollution transfer

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Abstract. In the context of product innovation, the environmental dimension takes a new dimension and can not be separated from other product requirements which make it competitive. Tools are available but unfortunately proficiency levels required for their use are at the expert's level, since it requires also expertise and time. In the present work we have adopted an approach using a qualitative evaluation matrix including parameters related to the ease of use of the product related to the organizational preparation for the appropriation of an eco-design approach, in addition to the standard factors of eco-efficiency. In order to help the designer to make a decision, an adapted TRIZ, named EcaTriz method is proposed.

The applicability of this method is justified by the many contradictions in the choices in a study of the life cycle and can help designers and companies to choose an approach to attain a satisfying level of eco-design for the resources invested in it.

Keywords: Ecodesign, TRIZ, Écatriz, Éco-innovation, inventive principle.

1 Introduction

Many eco-design tools are available in the literature. Each one is specific and is based on the analysis of the product life cycle. Their objective is to consider multiple criteria and assess their impacts on human health and environment. Commonly called LCA (Life Cycle Assessment), this assessment tool takes into account the evolution of the product, from the raw materials that were used in its manufacture to its use till the end of life characterized by an important step of destruction and recycling, as well as all the intermediate steps (transport, packaging, storage etc.), which all generate negative impacts on the environment.

Some studies on life cycle assessment simply focus on the stage having the most impact, while others accentuate the entire product life cycle characterized by an important step of destruction and recycling. It is now recognized that the latter is tedious, time-consuming, expensive and difficult to carry out on the following grounds:

- Lack of firm-level experts to implement the tool;
- Most companies prefer, when they stick to the principle, to opt for more simplified tools;
- Lack of spatiotemporal data, or when such data exist, they are fluid and difficult to control, which can seriously affect the impact of the assessment results.

While many methods and approaches exist for eco-design, their analysis however reveals that they are not used nearly enough for three main reasons [1]:

1. Some of them are complicated methods that require a high level of environmental expertise;
2. Mediocre quality of data collected results a large margin of error.
3. Some are expensive methods that require significant human and financial resources.

The proposed methodology in this study is based on a global and multi-criteria simplified environmental through an assessment process. In this stage, we do not directly give the solution to the designers. It will therefore translate the results of evaluation design axes but, in general, the lines proposed are inconsistent or contradictory. Therefore, what we find is a compromise given to the solution.

The challenge we are facing in an industrial reality is that no one should choose in first instance, a compromise solution. TRIZ (*Teorija Reshenija Izobretateliskih Zadatch*) or the theory of Solving Inventive Problems in the field will be reformulated to simplify its use. We will use the contradiction matrix and then intervene with the principles of interpretation resolutions to give possible solutions. The applicability of this method is justified by the many contradictions that confront designers in search of a solution for the life cycle of a service or a product.

Among the strategic tools based on creativity sessions to generate ideas, while taking into account the eco-design,the following tools were presented by the author(s): the Eco-compass [1], the wheel of Brezet [2], the BEC diagram [3]. We have also included some checklists such as the Ten Golden Rules [4]. Among the tools focused on structuring the results of the creative session, Jones [5] studied a tool combining the mind map with eco-design inputs. Other tools from the innovation process, such as those resulting from work on TRIZ or QFD (Quality Function Deployment), can be cited.

It is possible to work on systems other than products [6]. However, some peripheral TRIZ tools seem more relevant in thinking and should be adapted in order to go from a methodology derived from a purely technological context to a context focused on a variety of applications (product, service, use). Dangelico and Pontrandolfo [7] worked on the eco-design tools that can assist engineers in the ecological conception of products.

The work of Cheng [8] described a new model to accelerate the preliminary design of the eco-innovative product by incorporating the benefits based upon reasoning and the TRIZ method. Several examples of eco-design are given to illustrate the capabilities of such a method already starting with the work of Jahau Lewis Chen, Chih-Chen Liu [9]. Hsiang Tang Chang [10] proposed an eco-innovating method based on a design approach using TRIZ. David Russo [11] described a way to use concepts and tools of TRIZ to assess, evaluate and innovate a technical system in such a way that some practical activities to ensure sustainable results can be easily incorporated into the practices of design in everyday life. Vicenti Chulvi [12] compared the trends of evolution in TRIZ with eco-design strategies presented under the name of LiDS Wheel (Life Cycle Design Strategies) to analyze the effects on environmental parameters.

At the base of the Mal'IN and Eco-Mal'IN methods, Kallel [13] developed a new eco-innovation tool based on the invention matrix. Benjamin Tyl [14] proposed the Eco-asit tool to promote eco-ideation of sustainable systems.

Vidal et al. [19] identified and prioritized TRIZ evolution trends that improve the environment. The proposed innovative methodology helps designers to predict technological evolutions for more environmentally friendly products. TRIZ also used to improve the building environment [20] where the enterprise environmental parameters are used to solve the management conflict matrix.

The contribution of all those research through the models developed seems for us to lack support tools that are easily accessible to the uninitiated where applications can be accessible to scantily trained participants. Second point: these days, eco-innovation must support two very important dimensions to say the least: the parameters of use of the product as well as the readiness of companies and designers to eco-design. These two parameters are introduced in our methodological approach and are considered as factors of eco-efficiency to support any project of eco-innovating design.

2 The Methodology

The methodology has been developed through the following steps (see Fig. 1):

- Simple qualitative, comprehensive and multi-criteria evaluation, followed by a prioritization of impacts;
- TRIZ method for resolution of uncompromising problems;
- Choice of eco-efficiency factors related to engineering parameters;
- Establishment of an eco-innovative matrix;
- Justification of design parameters.

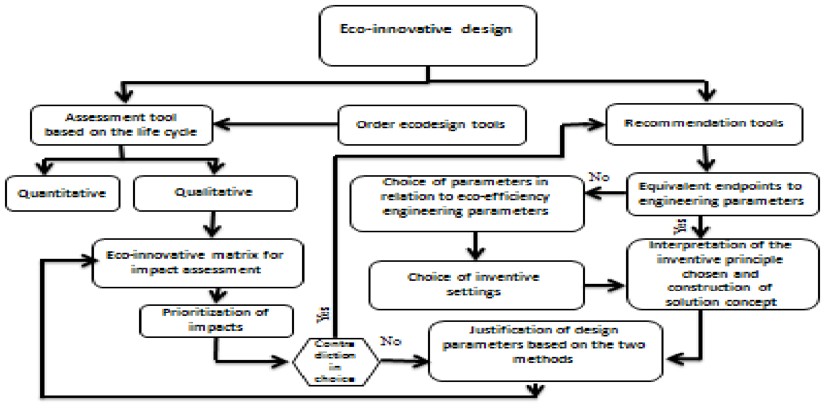

Fig. 1. Initiative of the eco-innovating process

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 solution principles database that can overcome some contradictions.

To apply TRIZ in the field of eco-innovation, we built a simpler eco-innovative matrix from 39 engineering parameters (EP). These EP are classified and grouped under five types of eco-efficiency parameters selected from the WBCSD (*World Business Council for Sustainable Development*), considering materials, energy and waste (liquid, gaseous and solid).

We introduced two other new settings, which was the first time this had ever been done: parameters used by the designer or user of the final product in general (shape, stability, strength, etc.) and the degree of ownership of ecodesign (culture, the degree of involvement in eco-design within SMEs, etc.).

The importance of introducing the use parameters that need to take care of, in addition to environmental factors, social needs of the user in the context of a eco innovative approach.

The second criterion introduced for the first time, which is a priority in our opinion, is the degree of ownership of the designer of the company or service provider ecodesign.

In order to exploit the matrix of engineering parameters and adapt it to eco-innovation chosen parameters, it was necessary to combine engineering parameters by category eco-innovation parameters considered.

We considered the introduction of these two parameters important in the case of innovative design, for the first case, and for the appropriation of eco-design by the company's designer in the second case.

The eco-efficiency factors retained for this study are presented (see Fig .2) .These choices are justified by the fact that recyclability, renewable resource use, product lifetime, as increased product or service intensity can be incorporated into materials or discharges. Inventive principles were selected and grouped from the initial matrix according to their frequency of occurrence.

2.1 TRIZ in our methodological approach

The improvement of a parameter selected on the y-axis (vertical column) can degrade another one placed on the abscissa (horizontal line): the solution is to have generic principles that allow to eliminate the conflict rather than to be a compromise. Once the conflicting parameters (to be improved and deteriorating) have been choosen, the designer will be placed in the contradiction matrix. The inventive parameters from 1 to 40 which can be a solution to the contradiction at the root of the problem are given by the matrix at the intersection of the conflicting parameters.

For some inventive principles that appear most often in the 39x39 matrix engineering it is clear that their consideration leads to a high success rate for solving innovative design.

To apply TRIZ in our field of eco-innovation we have built a new matrix by combining engineering parameters in relation to eco-efficiency corresponding parameters (see Fig .3).

2.2 From the TRIZ matrix of engineering parameters to eco-efficiency parameters for innovation

The environmental impact evaluation results of each assessment must therefore be translated into design axes, for practical purposes. However, the proposed axes are generally inconsistent or contradictory; hence, a compromise solution must be sought.

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

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

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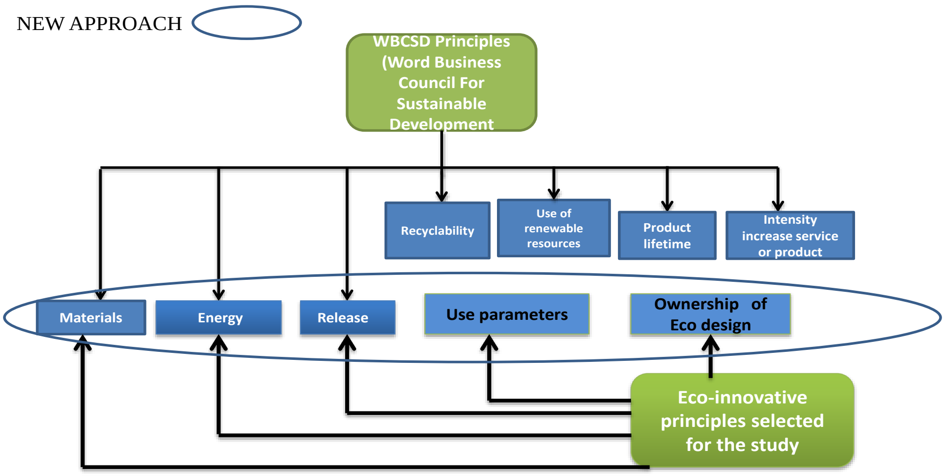
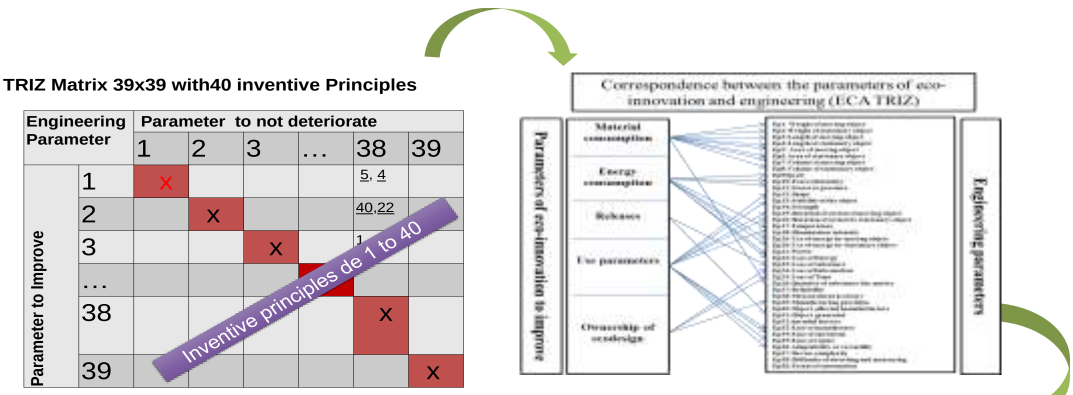


Fig. 2. Choice of ecoefficiency parameters

To maximize the probability of occurrence of each parameter in the eco-efficiency parameter, we established a maximum number of settings. We obtained a new matrix, 5X5, composed of eco-efficiency parameters, and an x- and a y-axis, with new inventive numbers. A set of rules to improve a particular aspect in the life cycle must be given. This constitutes the core of a state-of-the-art exploration approach used to achieve eco-design products. In this approach, we could use technical troubleshooting tools that have proven themselves in other areas, such as the generation of new concepts that may be tested in eco-innovation.

The matrix is composed of the same engineering parameters (Horizontal to be improved and vertical not to deteriorate). Each situation of pairs of contradictory parameters chosen will correspond to numbers of inventive principles (cross in the matrix) that may be possible solutions to the problem.

Figure. 3 presents the TRIZ matrix to the new matrix called *Ecatriz* (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

Eca TRIZ Matrix 5X5

Fig. 3. The approach to obtaining the Eca-triz matrix

The levers or actions developed in Fig. 4 allow the *Ecatriz* matrix to be more user-friendly for designers, who find the principles to solve it need in the rectangle. The matrix aims to improve the product development process or establish environmentally friendly procedures in an innovative approach and uncompromised solution. It can be applied to the launching of a new product or used to improve an existing one.

The designer will choose the best-suited of these selected inventive principles to solve the problem in accordance with the given situation (Fig 4).

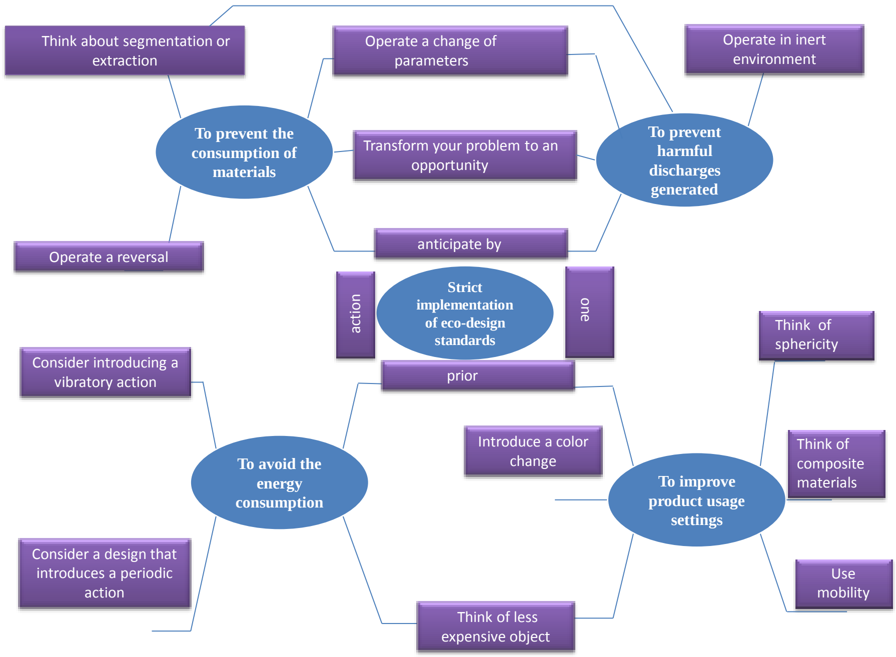


Fig. 4. Summary of the main possible actions for eco-design innovation based on the *Eca-triz method*

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Thirteen principles 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, and cheaper object) are choosen.

The designer will choose the best-suited of these selected inventive principles to solve the problem in accordance with the given situation.

The results of this matrix will help the designer to focus his vision on one or more stages of the life cycle related to one or more environmental (eco-efficiency factors) to be considered.

2.3 Looking more for creative ideas with Ecatriz

The inventive principles obtained, which are potential levers which assist the designer in the ideation phase, are divided into two categories, as shown in Figure 5.

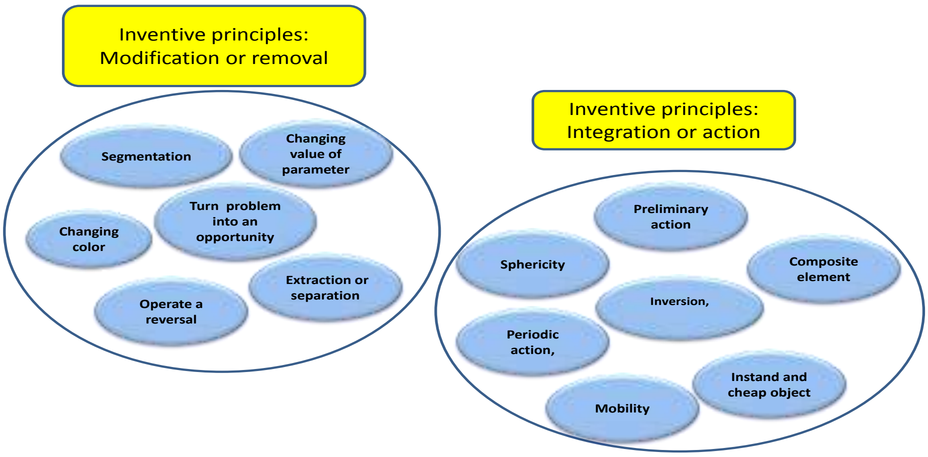


Fig. 5 - Categorization of the inventive principles obtained

At this stage, we can choose strategies (deconstruction of the problem) that have been adapted to eco-innovation.

The idea generation phase consists in building stimulating sentences from 4 product phases (words of the problem);

1- raw materials   3-use phase
2-product phase   4- end of life phase
and 2 actions promoting life cycle thinking:

-modification or removal (six inventive principles)

-integration or action (seven inventive principles)

A summary of 52 sentence possibilities (6X4 + 7X4) is given in Figure 6. To generate creative ideas, the Ecatriz eco-innovation approach can be made operational and enriched by knowledge management elements developed in the following chapter.

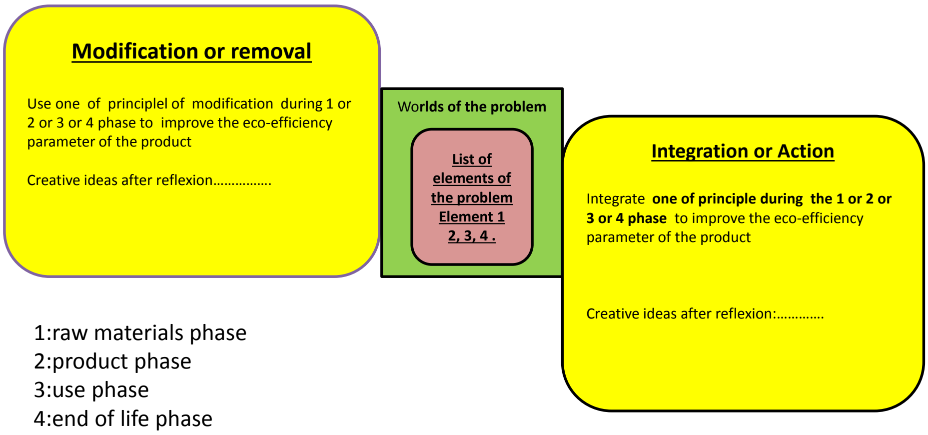


Fig. 6- Stimulating sentences from words of life cycle and tools composed by inventive principles

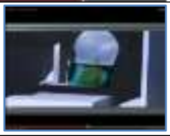
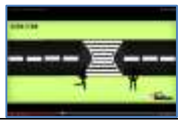
3 Application of the *Ecatriz* method

3.1 Challenges of 24H of Innovation competition

We applied the *Ecatriz* method to assess the solutions proposed by the student teams to meet the challenges of the '24 hours of innovation' competition. The goal of the international *Les 24h de l'innovation* competition is to encourage teams from all over the world to find creative solutions to challenges put forward by participating businesses and companies, public institutions, citizens, and others. Solutions are judged by local juries and by an international jury based in Montreal. As part of the 24 hours of Innovation, a marathon during which students must answer problems created businesses, we established a simplified evaluation grid which helps participants conduct an ecological evaluation of a suggested design. The idea here is to take into account the environmental aspects of the product, employing a simple, easy-to-use tool, which can be applied rapidly, and does not rely on a database, thus making the application quantitative.

The best concept of solutions provided by participants generally agreed with all the *Ecatriz* principles. Table 1 provides an overview of the best eco-innovative solutions proposed to cope with some of the challenges.

Table 1.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 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	 

3.2 Patents published in the area of eco- innovation

Another interesting application we considered was the use of *Ecatriz* to assess the published patents for products designed with the eco-innovative method (Table 2)

Table 2. 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 et al., 2007) Publication number EP1928277A	Choosing a shape and sole with improved strength, that minimize energy consumption and are 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 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)

Conclusion

The methodological approach implemented has given quite interesting results which can be a direct and easy application for any user. The developed tool has helped to build an inventive matrix that will guide the designer towards eco-innovative solutions, particularly in situations of contradiction in the choice of eco-design solutions. The basis of our initiative is the idea of using a 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. Potential inventive principles for possible solutions are obtained. Some of these principles may not apply to cases of design. However, the matrix can help the designer to reduce the scope of his creative investigations.

The results obtained were tested on recognized case studies and published patents and related to situations of resolution of environmental issues.

We note for the eco-design case, the inventive principle 10, namely that the "prior action" is found in all cases. This is in accordance with the principles of eco-design for early action in terms of environmental protection.

Among the inventive principles obtained, when we want to improve the strength of a product without consuming materials, principle 40, i.e. the use of composite materials, is a perfect example to test our approach, which is consistent with the practices used before.

The results of our methodological approach applied to the different situations considered show perfect consistency in the choice of the strategies used for solving problems occurring.

This method can be applied to any resolution of conflicting issues, in particular in a situation of ideation. It can also serve as a referential kit for businesses' objectives for improvement and innovation of their products or processes with support for environmental concerns without transfer of pollution.

Moreover, it is worth noting that this tool, which was developed to be a solution approach, can not explain some design problems which are only determined by a thorough and detailed analysis.

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