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Natural Process Design and Optimization Method Based On TRIZ/Eco-Innovation

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Abstract

This article presents a workflow to solve multi-contradiction problems for natural processes, in an eco-friendly way, using the Eco-innovation Elements and TRIZ (the theory of inventive problem solving).
The suggested workflow is based on a mixture of the most popular TRIZ tools and the elements of Eco-innovation, it starts with a problem context analysis and scope definition, and it ends with a sequential brainstorming and evaluation of the solutions. The Ideal Final Result (IFR) tool is used as a comparison element to assess the solution. The method handles all the contradictions in a prioritized way, giving more chances for the solution to converge toward the IFR.
The method aims to bypass contradictions instead of finding consensus. Indeed, as it is described, the workflow brings systematic step-by-step procedures to solve complex problems and differs from other toolsets that leave the choice to the solver's convenience.

Keywords
TRIZ, Eco-Innovation, product design workflow, product development.

1. Introduction
Human genius through inventions and innovations made life easier, we now live longer and in better conditions than ever before, but the other side of the coin is less pleasant, we humans have not only taken the natural environment for granted, but we have literally plundered and abused nature to serve our growing needs of food, energy, and material. If the environmental aspect is not considered during the resolution phase of our problems, the result will be catastrophic (Huppes and Ishikawa 2007). The need of an effective systematic methodology has been developed in this paper, it shows that many approaches have been presented in the literature, however green design remains a relevant research topic because of the lack of powerful and confirmed systematic methods that can support companies in their efforts to develop green products within acceptable time and costs (Ben Moussa et al. 2019).

The contribution of this paper to solve this issue is twofold. First, it presents an overview of the methods so far developed and presented in the literature, the need of eco-efficiency innovation tools, and last, presents a workflow that could solve the issue, while keeping in mind the ecological aspect. It has been proven that eco-efficiency elements have a link with TRIZ tools, and this led us to choose the most popular, easier, and more effective TRIZ tools to be used in our approach.

The method addresses all the contradictions at the same time and aims to by-pass them instead of finding consensus. Indeed, as it is described, the workflow brings systematic step-by-step procedure to solve complex problems and differs from other toolsets that leave the choice to the solver's convenience.

2. The need for Eco-Innovation workflow
The urge of developing guidelines for eco-friendly problem solving is not a claim of this paper. Much effort has been invested; this promotes a transformation from unsustainable development to one of sustainable development (Wang et al. 2019) (Yu et al. 2013). To maximize the eco-efficiency of the solution, procedures have been developed to be put in action in the early stage of the design phase. Many eco-design methods have been established to guide design engineers to reduce the environmental impact of their creations throughout its lifecycle. Nevertheless, those methods focus on industrial technical product and on one parameter at a time. Fiksel (2009) in his book "*Design for environment*" gathered an exhaustive list of tools and methods used for different industries and purposes but missed to provide a universal systematic methodology for problem solving. Some researchers have found that the various classical TRIZ tools are effective in solving design problems and in improving product eco-efficiency (Lim 2016). Others work consists of establishing a link between Eco-efficiency elements and TRIZ principles (Sheng and Kok-Soo 2010), while others focused on the resolution of multiple-contradiction eco-efficiency problems (Chang and Chen 2004). Methods to solve chemical process problems, respecting the environment has been the topic of another research (Ferrer et al. 2012). However, dealing with multi-contradiction problems for natural processes has never been addressed. From this opportunity, a concise multi-contradiction problem solving method has been developed in this paper, to serve as a guideline for solvers. The methods particularity is tackling all contradictions along the innovation process and bringing synergy to the ultimate solution.

2.1 TRIZ and Eco-efficiency Elements.
TRIZ the theory of inventive problem solving was developed in the 1940 by the soviet inventor Genrich Altshuller and his colleagues (Chechurin and Borgianni 2016), in the former USSR. TRIZ is a systematic problem solving, analysis and forecasting tool, derived from the study of patterns of invention in the global patent literature, it includes methodology, tool set, a knowledge base and model-based technology for generating innovative solutions for problem solving. Initially TRIZ was developed to give guidance to engineers to solve product design problems and develop next generation technologies and products in a more organized and systematic way.
Rantanen et al. (2018) in their book "*Simplified TRIZ"* proposed some of the key concepts of TRIZ that makes it valuable for new product and innovative design:

- Contradiction: one of the main pillars of TRIZ, a contradiction is a conflict in the system between two properties of the same or different objects. The problem is considered solved when the contradiction has been removed.

- Resources: Resources are things, information, energy, or properties of the materials that are already in, or near, the environment of the problem. Resources are very useful to remove contradictions.
- The Ideal Final Result (IFR): the Ideal Final Result is the solution that resolves the contradiction without compromise. Resources are used to go from the contradiction to the perfect solution, Ideally the contradiction should be removed without the use of resources.
- Ideality is a metric that measures how close the system is to the Ideal Final Result. If the useful feature improves, the ideality improves. And if the less than desirable feature decreases, the ideality also improves.
- Patterns of Evolution: they provide a mean to predict how systems evolve, predict the directions of evolution, and ultimately could be used to move forward to the evolution direction.

The endeavor of analyzing patent, which is the foundation of TRIZ, led to three key findings:

- Problems and solutions are repeated across industries and sciences.
- The innovations used scientific effects outside the field in which they were developed
- Every product obeys certain evolution patterns; they provide a mean to predict how systems evolve and the directions of evolution. It could ultimately be used to move forward through the evolution direction.

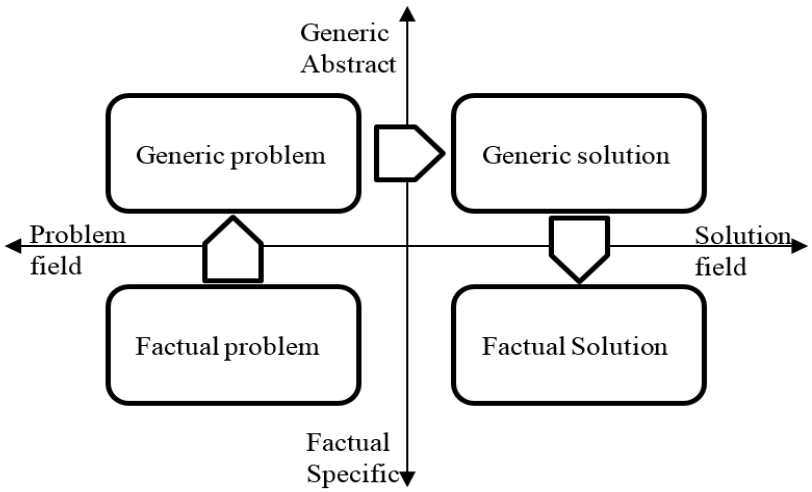

Figure 1. TRIZ method: transforming the problem from specific to abstract, solving the abstract problem, and transforming the abstract solution to the specific initial field (Gadd 2011).

Among the multiple TRIZ tools, the 40 Inventive principles, the Ideal Final Result, functional analysis, and contradiction Matrix are the mostly used tools (Ilevbare et al. 2013). TRIZ lack of specificity makes it ideal to be combined with other methods, and has been used in a wide range of applications from home appliance to mechanical and electrical engineering (Spreafico and Russo 2016), while others have use it for different fields such as architectural design (Labuda 2015) green supply chain (Ben Moussa et al. 2017) etc.

TRIZ has been spread around the world, thanks to the effort of many authors who reported positive feedback from integrating the method in universities, whether is it for teachers (Sire et al. 2015) or for students (Belski 2011), unfortunately recent study showed a global interest decline (Abramov and Sobolev 2019).
Eco-efficiency was initially defined by the World Business Council for Sustainable Development (WBCSD) in 1992. WBCSD states that eco-efficiency is reached by "the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity."

From the definition eco-efficiency elements are reduction of material, energy and toxicity in goods and services. Other eco-efficient elements are increase in the usage of renewable resources, durability, and service intensity of the product. Combining the popularity of TRIZ and the necessity to practice eco-efficient and eco-friendly design was subject to multiple attempts, a significant number of methods and proposals of integrating TRIZ with eco-design methods are presented in the literature. As stated in the previous section, TRIZ is an organized method for problem solving, which

is considered as supporting ideation and creativity component of eco-innovation and eco-design (Lim 2016) (Sheng and Kok-Soo 2010), (Chang and Chen 2004).

3. Proposed workflow

All major discoveries were derived from an observation of the nature, and now more than ever before, we witness unpredictable natural behavior due to the human impact on the environment. A fast-growing population, scarcity of resources, pandemics, and climate change may well lead to reduced environmental quality and a diminishing quality of nature, ultimately jeopardizing the quality of human life and even human life itself (Huppes and Ishikawa 2007), the last two years were a clear message that the lifestyle we have is not to be taken as granted. The need of revisiting the way we get inspiration from nature could be a solution to get more environmentally respectful solutions. The focus in this paper is on natural process.

Natural processes are all processes undertaken by natural elements to get a useful outcome for humans; plant growth, Honey production, bio-waste treatment are natural processes for example. Natural processes challenges are generally a complex set of contradictions, that needs to be solved in an eco-friendly way, and TRIZ being a reference tool for solving contradictions, seems to be ideal for those kinds of problems. This chapter proposes a workflow to solve natural multi-contradiction problems from its analysis to the solution development.

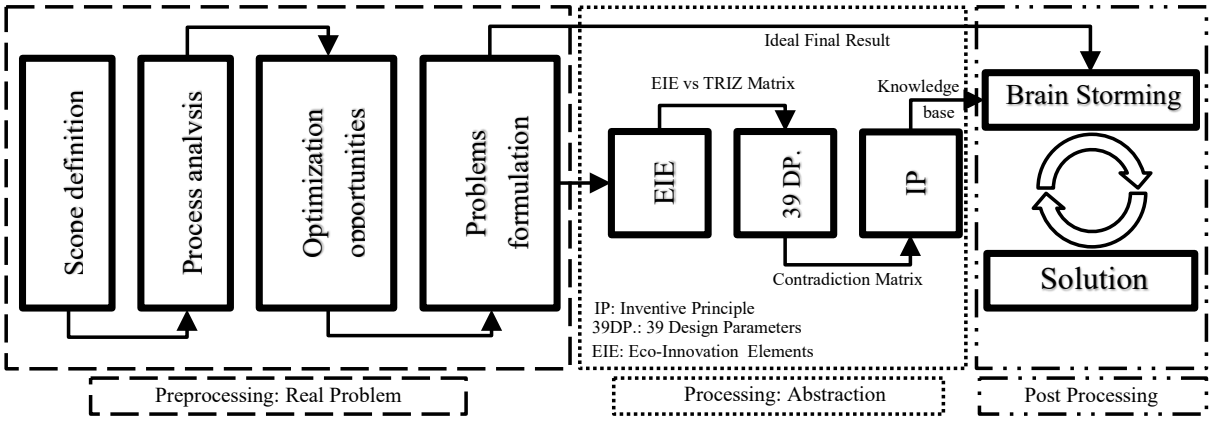

Figure 2. Workflow of the Eco-innovation and TRIZ method to optimize natural process

The proposed workflow (Figure 2) claims that by following the tree phases of the process we will systematically come up with a solution to the initially defined problem. The assessment of the solution is done by a comparison to the Ideal Final Result formulated in one of the steps of the process. It consists of 2 main components and ends up with an iterative phase to further refine and correct the proposed solution.

As mentioned in Figure 1 the approach is based on a transformation of the problem from the real word to the abstract solution world, resolving the problem with the help of TRIZ tools and the Eco-Innovation elements and lastly brings back the problem to the real word.

Before initiating any innovation exercise, it's mandatory to have a perfect image of the state of the art in the field and the best practices. The innovation's motivation is a lack of existing solutions to a given problem, this can practically be done by numerous ways, benchmarking for example.
Scope definition: consists of a clear sentence emphasizing the system in question and the harmful function to reduce or the beneficia function to maximize. The scope would be a delimiter of the solution. It aims first to define the range of actions for our innovation.

Process analysis: is a clear and structured description of the current process, its input, and outputs, the metrics that defines it and the history of human interventions in it. this brings a deep understanding of the problem context.

Optimization opportunities: with critical eyes the process analysis should disclose multiple pain points or optimization opportunities, this step is where these opportunities are listed and will be filtered out in the next step, with respect to the earlier defined scope.

Problem formulation: a series of questioning whether the opportunity is related to the predefined scope is conducted, from the filtered opportunities, conflicting sentences are listed. It represents the contradictions needed to be solved. The steps model the problem, with a set harmful action formulated with sentences containing implicitly or explicitly contradictions. In the same step, and with the listed contradictions we can formulate our Ideal Final Result (IFR), which is the Ideal solution to our problem using no resources and having no harmful impact. This result will be the metric to our solutions, the closest to the IFR the better.

The outcome of this phase is to be able to imagine an IFR and have a set of sentences relative to the real problem containing contradictions. The preprocessing is a preparatory phase and doesn't consider the eco-innovation Elements. This way the solver is sure of formulating a constraint free IFR.
We start with a real-world problem, and we end up with a list of generic contradictions, this constitutes the preparatory step to the abstraction transformation needed to use TRIZ tools.

The processing phase is where a translation from the specific problem is undertaken (Gadd 2011), (Ilevbare et al. 2013). We move the problem from the specific problem field to the generic solution field Figure. 1. The outcome of this phase is a set of Inventive Principles (IP). Combining the knowledge base to the selected IP constitute the generic solution field.
This phase is a set of three steps:
Eco-Innovation elements: The harmful actions formulated as series of contradictions (Phase I), will be categorized in one or more of the seven categories of the Eco-Innovation Elements (EIE) as suggested by (Sheng and Kok-Soo 2010), (Chang and Chen 2004):

A-Reduce the material intensity of its good and service (Material reduction)
B-Reduce the energy intensity of its good and service (Energy reduction)
C-Reduce the dispersion of any toxic materials (toxicity reduction)
D-Enhance the recyclability of its materials (Material retrieval)
E-Maximize the sustainable use of renewable resources (Resource sustainable)
F-Extend the durability of its product (Product durability)
G-Increase the service intensity of its good and service (Product Service)

This step gives clarity on which eco-element has priority, the elements that is repeated the most has the most priority. The next step will be to extract the corresponding Design Parameter (DP) from the 39 DPs proposed by TRIZ. From the EIE vs DP matrix. The most recurrent DPs will be extracted and arranged by pairs to constitute the pair (#Improving Parameters; #Worsening parameters), this step can generate a big number of Inventive Principles (IP), sorting them by the recurrence of appearance, gives us the most redundant IP to use for solving the problem. it's the IP that appears the most that will have the most significant impact on the solution.

The last phase, which is the post processing phase, is a reverse migration, from the conceptual solution field to the factual solution field. It is worth mentioning that the IFR and the set of harmful action sentences need to be kept in mind during the solution generation step. The Brainstorming technique, even if it was negatively perceived by Altshuller (1999) and considered the incarnation of trial-and-error method. It could be of a great help if used in a sequentially guided context and meant to generate final solutions from a set of predefined IPs and knowledge base.
The brainstorming will be guided with a set of questions formulated with the question: How can +IP+ Verb + set of harmful effects previously developed.

This step is an iterative step and needs as many iterations as necessary, each solution generated is compared to the IFR as an assessment method. Finally, the ultimate solution will be formulated. The knowledge base gives us a great deal of flexibility and frees the solvers mind from psychological inertia (Savransky 2000).

4.Conclusion

This paper has first demonstrated the necessity of developing a method to solve complex multi-contradiction natural problems in an eco-efficient way, secondly it has developed a procedure to serve as a guideline for problem solver. The step-by-step guide translates the problem to a set of abstract contradictions, and formulate the IFR, the

contradictions are solved by TRIZ tools and Eco-Innovation elements, and then the method proposes a sequential brainstorming to develop the final solution. The method needs to be tried out with a series of case studies on real natural process challenges to assess its effectiveness and its ease of use.

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