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R. Benmoussa

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Eco-design Pilot Improvement Based on TRIZ and ASIT Tools

R. BENMOUSSA

ENSA Marrakesh, Cadi Ayyad University, benmoussa.ensa@gmail.com

Abstract. Eco-design is a relevant research topic because of the need of powerful and confirmed systematic methods that can support companies in their efforts to develop green products within acceptable time and costs. Eco-design Pilot, developed by ADEME and Vienna University of Technology, is one of the tools that seeks this purpose. It proposes measures depending on the nature of the environmental impact of the product. However, the assessment phase of the measures proposed by this tool is both subjective and does not stimulate the development of creative solutions. To overcome this major drawback, this paper seeks to rely on TRIZ and ASIT tools to better assess the proposed measures and develop creative ideas within a new framework for Eco-design Pilot measures assessment. This framework has been tested first on the Eco-design Pilot Improvement Objective and Strategy “Reduction Packaging”. As result, 31 realization ideas, that could be used by packaging designers in green context, have emerged from this application. A non-exhaustive research on packaging industry practices has shown that some realization ideas have already been applied to produce innovative solutions. In perspective, we will discuss other Eco-design improvement objectives and strategies in a quest for the framework generalization.

Keywords : Eco-design, Eco-design Pilot, TRIZ, ASIT, Reduction Packaging

1. Introduction

Fast industrial growth and technological advances have recently raised many environmental concerns. As a result, industrial companies are expected to become more environmentally responsible and reduce their negative environmental impact by applying new technologies and especially by delivering eco-friendly products. Additionally, environmental regulations developed recently by the European Union called energy using product, have motivated engineers and designers to more heavily focus on how to create more environmentally friendly products.

Several methods exist for eco-design, to assess and improve environmental impacts. [6,7,8,9,10]. The International Organization for Standardization ISO issued numerous norms, guidelines, and tools. For example, the ISO14040:2006 describes the principles and framework for life cycle assessment (LCA), ISO14044:2006 provides LCA guidelines, and ISO14006:2011 provides guidelines to implement Eco-Design as part

of an environmental management system (EMS) within companies. A number of methods and tools have been developed to support the process of eco-innovation in the last two decades. To the best-known methods belong Eco-Compass, Life Cycle Design Strategy (LiDS Wheel), Sustainability Circle, Eco-design PILOT, Eco-Ideation Tool, Value Mapping Tool, Design for Environment (DfE) and Quality Function Deployment for Environment (QFDE), EcoASIT, Eco-ideation stimulation meso-mechanisms ESMs, 12 Principles of Green Engineering (American chemical society), and other methods. In the field of process engineering should be mentioned in first place Green Process Engineering and Process Intensification (PI), Process Design for Sustainability (PDFS), and other approaches [2].

Despite these countless approaches, 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. To overcome this lack, several works have addressed this issue. This paper focus on the ones that deal with TRIZ (a Russian acronym of “Theory of Inventive Problem Solving”). TRIZ, as a theory for inventive problem resolution has proven its effectiveness in stimulating designer’s creativity in several areas. In green design, several TRIZ utilization attempts exist [1, 2, 3, 11, 12, 13, 14, 15, 16, 17].

The references [2] and [3] have largely addressed this issue. The paper [2] focuses on the comparison of the ideation mechanisms during the eco-ideation phase, to help users generate relevant ideas with a strong potential of environmental impact reduction. In addition to that, some case studies are performed to compare the adapted creativity tool for eco-innovation, regarding its performance. This research also validated the need to place greater emphasis on the ideation phase in the process of eco-innovation. Indeed, environmental knowledge, ideation mechanisms and the structuring of the session are interdependent factors to consider in order to optimize the eco-ideation session and to be closer to the industrial reality. The paper [3] presents a systemic literature review of TRIZ use in eco-design. Indeed, the paper provides information about what is currently performed in connection to creativity methods, when TRIZ is combined with LCA, LCE Eco-efficiency and other integrated methods for eco-design process.

Even if the existing scientific contributions of TRIZ in eco-innovation cited above tackle different Triz tools and Eco-design methods, they share a common purpose. They effectively address the following main research question : “How can TRIZ tools enhance the ideality of green-design methods and tools?”. To contribute to this common purpose, this paper aims to present an exploratory analysis of the contribution of TRIZ tools to green design methods systematization based on the case of Eco-design Pilot [6]. In fact, the main goal of this paper is to analyze Eco-design Pilot in order to improve its ideality through TRIZ tools utilization. Eco-design Pilot proposes measures to improve the environmental impact of products and services depending on the nature of the environmental impact of the product. However, the assessment phase of the measures proposed by this tool is both subjective and does not stimulate the development of creative solutions. To overcome this major drawback, this paper seeks to develop a new framework that rely on TRIZ and ASIT tools to better assess the Eco-design Pilot measures and develop creative ideas of realization. Our methodology is to test this framework first on the “improvement objective and strategy for basic type C

(transportation intensive product)”, namely “Reduction Packaging” and to generalize dealing with other Eco-design Pilot improvement objectives and strategies.

This paper is organized as follows. Section 2 introduces Eco-design Pilot approach and limitations. Section 3 presents the measures of the improvement objective and strategy “Reduce packaging”. It presents also the new framework application to this objective. A conclusion and perspectives are provided in section 4.

2. Eco-design Pilot

2.1. Presentation

Eco-design Pilot [6] is a web tool developed by ADEME and Vienna University of Technology. It has been proposed as a guide to promote and facilitate the integration of eco-design in businesses in any sector of activity. Starting with the PILOT along product development strategies enables the practitioners to improve an existing product by means of appropriate ECODESIGN measures¹. In order to improve the environmental performance, each product requires specific measures depending on its environmental impact at different stages of its service life. Thus, different measures have to be taken for products with the main environmental impact at the use stage (use intensive) than for products with the main impact during manufacture (manufacture intensive). What measures are appropriate for which product? Working through the checklists will result in a complete list of ECODESIGN measures particularly suited for the product. Eco-design Pilot divides products in Five types :

- Type A : Raw material intensive.
- Type B : Manufacture Intensive.
- Type C : Transportation Intensive.
- Type D : Use Intensive.
- Type E : Disposal intensive.

Figure 01 shows the list of controls used to estimate the relevance and achievement of the assessment² question for the measure “Reduce material input for packaging” of the implementation objective and strategy “Reduction Packaging”.


1 A measure for ECODESIGN Pilot is equivalent to a conceptual solution for TRIZ

2 “Assessment” is the process that seeks to know if a measure (conceptual solution) is relevant for a given product and a given strategy.

Checklist for ECODESIGN analysis

Product

Does the distribution of the product require only a minimum of packaging?

 Can packaging or at least parts of it be avoided? How can packaging of the product be minimized by an optimization of the system product - packaging?

Relevance (R)	Fulfillment (F)	Priority (P)
<input type="radio"/> very important (10)	<input type="radio"/> yes (1)	<input type="text"/> $P = R * F$
<input type="radio"/> less important (5)	<input type="radio"/> rather yes (2)	
<input type="radio"/> not relevant (0)	<input type="radio"/> rather no (3)	
	<input type="radio"/> no (4)	

Measure	Reduce material input for packaging <small>LEARN</small>
Idea for Realization	<input type="text"/>
Costs	<input type="radio"/> more <input type="radio"/> same <input type="radio"/> less because <input type="text"/>
Feasibility	<input type="radio"/> difficult <input type="radio"/> easy because <input type="text"/>
Action	<input type="radio"/> at once <input type="radio"/> later <input type="radio"/> never Responsibility <input type="text"/> Deadline <input type="text"/>

Fig 01 : Checklist of “Reduce material input for packaging” measure [6]

2.2. Measures assessment approach :

The classical approach of Eco-design Pilot measures assessment is as follow [6]:

1. Relevance: Rate the relevance of the assessment question with a view to your product. (10...very important for my product; 5...less important for my product; 0...not relevant for my product).
2. Fulfillment: Estimate the fulfilment of the assessment questions using one of the four possible answers (yes / rather yes / rather no / no); the additional questions support understanding of the assessment question and need not be answered.
3. Priority: Select ECODESIGN tasks with high priority (P) and continue only with these.
4. Idea for Realization: Find ideas to realize these ECODESIGN tasks. The content of the learning part with its examples shall assist you in doing that.
5. Feasibility: Evaluate the feasibility of the suggested ideas (difficult / easy).
6. Costs: Compare the costs of the new ideas with a reference situation (higher / same / lower) and give reason for that.
7. Action: Decide when to carry out the ECODESIGN tasks (at once / later / never) and determine the person or department that shall be in charge of further steps in the realizing the product improvements and fix a deadline.
8. Save: Save the checklist to document the ECODESIGN assessment.

The main limitations of this assessment approach are :

- The Relevance and Achievement of the measure are subjectively estimated. We risk thus missing the right measure.
- The generation of the ideas of realization is not structured. It is in fact based on the intrinsic competence of business experts.

- The generation of ideas of realization does not cover the potential of integrating several measures at the same time.

2.3. Framework presentation

To overcome the limitations of Eco-design pilot's measures assessment approach, a new Framework has been developed (Fig. 02) based on the use of TRIZ and ASIT tools. The following section describes the original steps of this Framework, compared to the classic approach, through its application to the Eco-design Pilot improvement objective "Reduction Packaging".

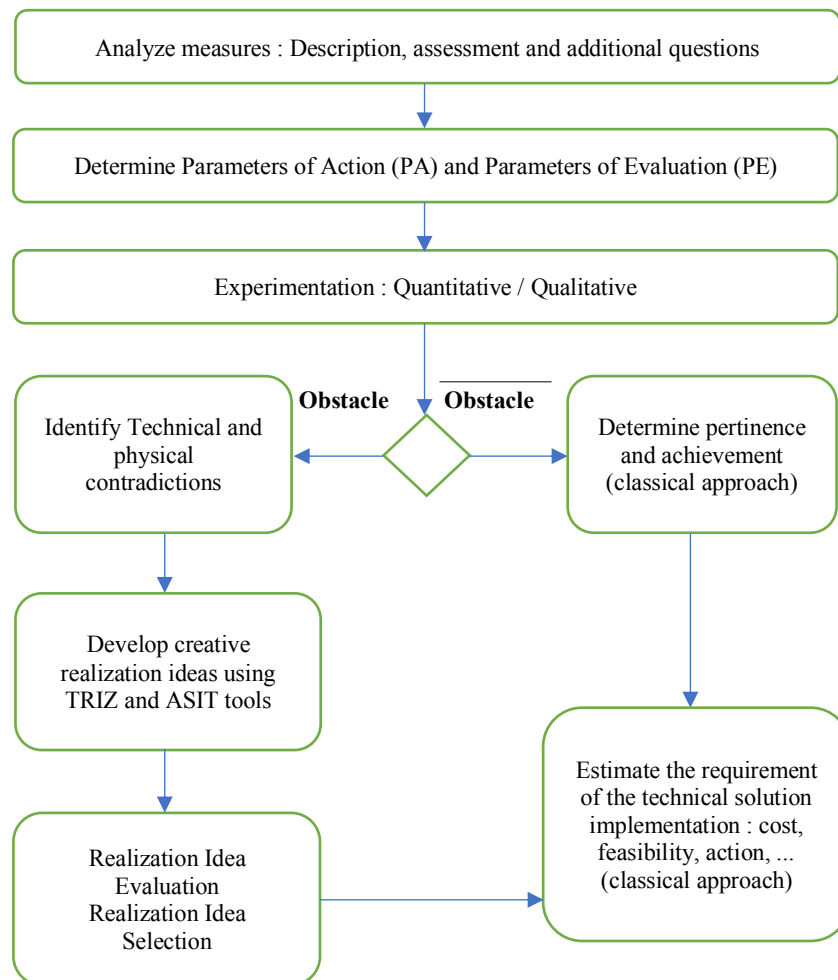


Fig 02. Framework presentation

3. Framework application to “Reduction Packaging” measures

3.1. “Reduction Packaging” measures analysis

As packaging material is useful only for a limited period of time (unless it is returnable) the type and quantity of material used for packaging have to be optimized. Especially with products that have to be transported over long distances, the weight of the packaging material, too, has a great influence on the overall consumption of resources. Is it possible to reduce the weight of the packaging material? Is it possible to use returnable packaging or renewable or recycled materials for packaging?

Eco-design Pilot identify five measures to reduce packaging [6]:

1. Reduce material input for packaging : Minimizing packaging with a view to weight can be realized either by optimization of packaging or by appropriate product design, for instance by casings that endure transportation without or with only a minimum of packaging.
2. Preferably use reusable packaging : Robust packaging designed for multiple use reduces the overall input for packaging. Returnable packaging is particularly advantageous in the case of direct delivery. The supplier can take back and subsequently re-use packaging material.
3. Preferably use renewable raw materials for packaging : The use of renewable raw materials (i.e. non fossil materials, usually made from plant material) not only constitutes an adequate solution for the disposal of packaging material but also takes into account the issue of resources (renewables as an important criterion for sustainability).
4. Preferably use recycled materials or packaging materials suitable for established recycling processes : Using recyclable materials reduces the consumption of primary materials as well as the amount of waste generated. Materials for which there are already well established recycling channels facilitate recycling of packaging materials.
5. Use environmentally acceptable packaging materials : The materials used for packaging should be environmentally acceptable not only as far as manufacture is concerned but also at the time of disposal. Therefore, one has to determine at what point in the whole life cycle the issue of disposal of packaging arises and how disposal can be realized there.

3.2. Determine Parameters of Action and Evaluation

The parameters of action (PA) are those on which we can act to improve the environmental impact as well as the functional quality of the packaging. The analysis of “Reduction Packaging” measures makes it possible to identify the following PA :

- The shape of the packaging (morphology) (S).
- The Material Type (M): reusable, recyclable, with little environmental impact, ... etc.

- The thickness of the surface (T).

The parameters of evaluation (PE) are those that measure the environmental performance as well as the functional quality of the packaging. The analysis of “Reduction Packaging” measures makes it possible to identify the following PE:

- The resistance to shocks during transport, storage and use (R).
- The quantity of substance for one use of the packaging (mass (Q)): it is obtained by dividing the total quantity of substance by the number of uses of the packaging during its life cycle. The environmental impact is quantitatively calculated or qualitatively estimated according to the CO2 and non-renewable energy emissions perceived during the life cycle of the packaging depending on the quantity of substance and the type of material.

3.3. Experimentation

The experiment consists first of all to:

- Formulate the desired objectives for the PE: $(R > r)$ & $(Q < q)$.
- Identify all the solutions available in the business and feasible in the context of the study (involvement of business experts) for PA.
- Then test (quantitatively or qualitatively) all the possible combinations of PA.

Table 01: Specification of experimentations

S	M	E	R	Q
1	1	1	R1	Qn
...
n	n	n	Rn	Qn

3.4. Experimentation analysis

In the case that the experimentation table presents scenarios that make it possible to achieve the objectives set for the (PE), the relevance and achievement for each of these scenarios can be determined using the same rating proposed by the classic approach of Eco-design Pilot, by answering evaluation and additional questions of measures. It is nevertheless more relevant because it will be estimated directly in relation to the action parameters of the Idea of Realization (Conceptual Solution). The estimation of the costs and the feasibility of the realization idea (Technical Solution) selected could be done similarly as the classic approach.

In the case that the experimentation table does not present any scenario that makes it possible to achieve the objectives set for the PE, the relevance and the achievement lose their classic meaning of Eco-design Pilot and enforce the search for creative ideas that are not obvious for business experts. In this case, TRIZ and ASIT tools are helpful and can be exploited to generate creative ideas of realization. Thus, section 3.5 presents the

realization ideas generated from TRIZ tools. Section 3.6 presents the realization ideas generated from ASIT tools. Without being exhaustive, table 02 presents some technical solutions already used by the packaging industry that belong to some realization ideas proposed by this new framework.

3.5. Generate realization ideas with TRIZ tools

The analysis of the obstacles in relation to the objectives set for the PE (Resistance and Quantity of substance) makes it possible to identify the technical contradiction between these parameters. It also makes it possible to highlight among the PA (S, M, E) those which present a physical contradiction. The 40 inventive principles as well as the principles of separation in time and space [4] could be used to develop innovative realization ideas.

3.5.1. Generate realization ideas with the 40 inventive principles

According to the matrix of technical contradictions [4], the contradiction between the quantity of substance (Factor to improve PT26) and resistance (Factor that degrades PT14) suggest the following principles: 14, 35, 34, 10.

IR1: principle 14 (spheroidability), suggests for packaging to replace rectilinear parts, surfaces, or forms with curvilinear ones, move from flat surfaces to spherical ones; from parts shaped as a cube (parallelepiped) to ball-shaped structures.

IR2: principle 35 (Parameter changes), suggests to change the physical state of the packaging, to change the concentration or consistency of the packaging material, to modify the degree of flexibility of the packaging, to modify the temperature of the packaging.

IR3: principle 34 (Discarding and recovering), suggests to make portions of the packaging that have fulfilled their functions go away (discard by dissolving, evaporating, etc.) or modify these directly during operation.

IR4: principle 10 (Preliminary action), suggests to perform before it is needed, the required change of the packaging (either fully or partially) or to pre-arrange objects (packaging, products) such that they can come into action from the most convenient place and without losing time for their delivery.

3.5.2. Generate realization ideas with the separation principles

The principles of separation in time and space make it possible to solve the problem at the level of physical contradictions involving the parameters of action: the shape, the material and the thickness of the surface of the packaging. The packaging life cycle consists of the following phases: product packaging, transport, storage, use and end of life.

The separation in time principles suggest the following realization ideas:

IR5: the packaging has a different shape during its life cycle.

IR6: the packaging is composed from different materials during its life cycle.
IR7: the packaging has a different surface thickness during its life cycle.
The separation in space principles suggest the following realization ideas:
IR8: the parts of the packaging have a different shape.
IR9: the parts of the packaging are made from different materials.
IR10: the parts of the packaging have different surface thickness.

3.5.3. Generate realization ideas with the intensification tool

Intensification [4] is also a TRIZ tool that allows the resolution of contradictions at the physical level. The application of this tool suggests the following realization ideas:

IR11: the packaging has an infinitely (large, ...) or infinitely (small, ...) shape.
IR12: the packaging has an infinitely (resistant, flexible, removable, recyclable, etc.) or infinitely (fragile, rigid, non-disposable, non-recyclable, etc.) material.
IR13: the packaging has an infinitely large or infinitely small thickness.

3.6. Generate realization ideas with ASIT tools

ASIT [5] is a method of solving inventive problems resulting from TRIZ. It has two rules and 5 tools which can also be used to develop innovative realization ideas.

Before applying ASIT tools to generate realization ideas, we need first to deploy the rule of the "closed world":

- Undesirable phenomenon: the consumer throws away the packaging after use, thus producing waste.
- Objects of the Problem: Consumer, Packaging.
- Objects of Environment: Garbage can.
- Desired Action (DA): Prevent the consumer from throwing away the packaging.

The application of ASIT tools to the Eco-design Pilot's objective "Reduction packaging" suggests the following realization ideas.

From Unification tool :

IR14: the consumer will (DA).

IR15: the packaging will (DA).

IR16: The garbage can will (DA).

From Multiplication tool :

IR17: an object of the same type as "the consumer" will (DA).

IR18: an object of the same type as "the packaging" will (DA).

IR19: an object of the same type as "the garbage can" will (DA).

From Division tool :

IR20: the object "consumer" will be divided into [list of parts] and will be reorganized in time or space to (DA).

IR21: the object "packaging" will be divided into [list of parts] and will be reorganized in time or space to (DA).

IR22: the object "the Garbage Can" will be divided into [list of parts] and will be reorganized in time or space to (DA).

From Suppression tool :

IR23: Remove the "consumer" will (DA).

IR24: Remove the "packaging" will (DA).

IR25: Remove the "garbage can" will (DA).

From Break symmetry tool :

The object {"the consumer", "the packaging", "the Garbage can"} has [list of characteristics]. For packaging, the list of characteristics is given in section 3.2 : shape, material, thickness.

Symmetry in space:

IR26: in different places of "the consumer", there will be different values for the chosen characteristic.

IR27: in different places of "the packaging", there will be different values for the chosen characteristic (shape, material, thickness).

IR28: in different places of "the garbage can", there will be different values for the chosen characteristic.

Symmetry in time:

IR29: at different times, there will be different values for the chosen characteristic of the "consumer".

IR30: at different times, there will be different values for the chosen characteristic of the "packaging".

IR31: at different times, there will be different values for the chosen characteristic of the "garbage can".

4. Conclusion

The literature has shown the existence of several attempts to improve the effectiveness of Eco-design methods using TRIZ tools. However, this paper presents Eco-design Pilot's first attempt to this focus. This work aimed first to study Eco-design Pilot, then to state a new framework for the ideation phase to fill the limits of this tool. Several results emerge from this study. In the technical level, 31 realization ideas were developed using tools from TRIZ and ASIT concerning reduction packaging. Non-exhaustive research on the web has shown that some of these ideas have already been implemented in the industrial context. The other ideas remain a potential conceptual solutions for packaging reduction to be explored and translated into technical solutions by the designers. Scientifically, some tools from TRIZ and ASIT have generated similar ideas. This is the case of IR11 and IR24 for example. This confirms that ASIT is a method derived from TRIZ.

In light of these results and the exploratory approach conducted through the "Reduction Packaging" improvement objective and strategy, several perspectives emerge:








- Conduct other studies to confirm the effectiveness of Eco-design Pilot new framework for the evaluation phase, dealing with other improvement objectives and strategies.

- Make a comparison between the eco-design methods that attempt to adapt the TRIZ tools to eco-design with our approach.
- Conduct a case study that aims reduction of packaging in a reel industrial context.

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Table 02 . Realization ideas implemented by packaging industry

<i>Solution</i>	<i>Realization Idea</i>	<i>Example</i>
Spherical packaging	IR1, IR8	
Home delivery without packaging	IR11, IR15, IR24	
Bulk distribution with personal packaging	IR11, IR15, IR24	
Packaging with parts that have different amounts of material	IR2, IR13, IR8, , IR9, IR10, IR27	
Packaging reusable several times with or without deposit	IR12, IR15	
Packaging made from renewable materials	IR12, IR27	
Packaging made from recyclable materials	IR12, IR27	
Packaging made from materials with little environmental impact	IR12, IR27	
Garbage can for sorting waste	IR22	