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AN ECO-INFORMATION TOOL BASED UPON LIFE CYCLE THINKING

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1. Introduction

At present, as it is known not only by technicians but also by public opinion, problems related to environmental impact of products and processes have become relevant. It is clear that it is necessary the evaluation of the whole Life Cycle of the product, as each phase can exert a more or less important influence on environment.
As shown by many Authors in the field, in spite of the high number of design tools developed and available in the literature, most of them are focused only on how to solve specific problems related, in particular, to the improvement of already existing products, and do not focus on design, belittling the link with Industrial Design approach.
Moreover, taking into account the definition of "*sustainability limit*" [Manzini, 2002], expressed by formula (1):

$$T * C = K \quad (1)$$

Where T = technology and C = culture, K = constant; it is clear that all sustainable situations should be characterized by means of relationship (2):

$$T * C > K \quad (2)$$

i.e. Sustainability requires both cultural and technological improvement.
The research work carried out is set in this sphere: in fact, on the basis of a deep investigation concerning both of the aspects above mentioned, which can be considered as two "strategy families" for sustainability, authors developed an "*eco-information tool*", which can provide designers an easy to use eco-information system and allows them to choose the right strategies for the specific application, without disregarding customer needs, design requisites and standards/laws obligations.

2. Scientific Background

Nowadays it is absolutely clear that the evaluation of the whole life cycle of the product is necessary, from raw material acquisition, through production, use and disposal, as each phase can more or less have influence on product sustainability. Decisions that have to be taken mainly concern the following problems:

1. choice of materials and processes which allow a minimum environmental impact;
2. consumption at use stage (e.g. energy consumption);
3. the extension of the product life span;
4. the easy disassembly and recycling;

5. the extension of material life;
6. dematerialization.

In such a context it is deemed that the "Environmentally Conscious Design" is the most interesting and useful tool for designers: such an approach, which has been defined "the design that addresses all the environmental impacts of a product throughout its complete life-cycle" [Mc Aloone, 2000], can be considered as a gradual and systematic way of proceeding, which is based on four fundamental strategic levels, (as shown in Figure 1):

- (S) - Analysis of the structure of the product (environ. impacts at use stage, etc.)
- (A) - Analysis of the components of the product (reduction of materials, etc.)
- (T) - Functional analysis of the product (new concepts, functional optimization, etc.)
- (O) - Analysis of the product system (end of life optimisation, life extension, etc.)

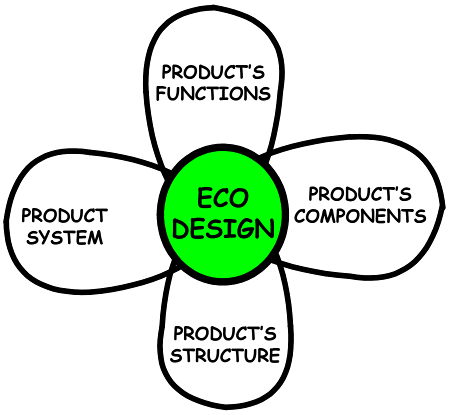

Figure 1. S.A.T.O.E. Flower: S+A+T+O = Ecodesign [Fargnoli, 2003]

Results of an intensive research carried out on Design for the Development of Sustainable Products, show that there are certainly good examples of design approaches and methodologies which take into account the above mentioned aspects; although they represent all important advances towards the field of Ecodesign, they are disconnected one from each other, or focused only on solving a particular problem, or concerning a particular stage of the product life cycle.

Furthermore, we have to take into account that the great variety and peculiarity which distinguish one product from another make the problem particularly complex.

It is clear, then, that the main difficulties to be solved do not concern the absence of design tools at the designer's disposal, but mainly regards the lack of information or guidelines which can lead the design team towards the right choices.

On the other hand, it is also true that, on the users` point of view, information about the product and its environmental performances is poor, as well as the fact that the knowledge about product's functions, structure and materials is often roughly defined.

For these reasons the study of the "*eco-information*" has been deepened and in particular it was focused both on cultural and technical aspects.

3. Methodology

From the cultural point of view, in order to give to users of a specific product all environmental information, the problem is the "design" of the technical communication in all fields, such as school, divulgation, instruction for use, professional formation and so on.

With this aim in mind, it is possible to apply the theory of Design Science to develop a "methodical design" of communication, which can be articulated in the following steps [Biggioggero, Rovida, 2001]:

- *terminal behaviour*, corresponding to the behaviour of the user after communication [Fargnoli, Rovida, 2004].

- *concepts*, i.e. knowledge portions to be organized in logical and hierarchical order and to be derived from an analysis of the terminal behaviour.
- *communication unit*, i.e. part of communication devoted to the transmission of each concept, that has to be constituted by an informative and an applicative part (respectively "rule" and "example") and that can utilize different communication means, such as written, graphical, multimedia.

From the technological point of view, the fundamental problems which can be underlined regard the following aspects:

1. design of a product with good sustainable behaviour.
2. choice, among a given number of products, of the "best" one from the sustainability point of view.

In particular, we focused on the second point, since design tools which can also be used by users, taking into account environmental considerations, have not been developed enough. The choice phase needs evaluation and comparison of the given products with regards to their behaviour in respect to the life cycle: it is possible to choose with different precision levels, according to requirements and to consequent considered part of the life cycle of the product [Baragetti, Pighini, Rovida 2000, 2001]. Table 1 shows general and specific phases of the life cycle.

Table 1. General and specific phases of the life cycle

1.1.1.1 General phases	Specific phases
Raw material acquisition	Choice of reseller Material transportation
Production	Part construction Assembly
Distribution	Packaging Charging Transportation Discharging
Utilization	Behaviour Maintenance Aesthetics
Liquidation	Reuse Recycling Elimination

Each phase can be regarded from the customer/user requirement point of view:

simplicity, efficiency, sustainability, safety, economy

The aspects can be derived from the requirement (in particular sustainability) of each phase: in Table 2 an example of determination of the aspects related to the "reuse" phase (requirement "simplicity") is shown.

4. Improvement of Sustainability

Improvement of sustainability can be reached by means of two fundamental steps:

4.1 Technical step (principally for designers of industrial products)

The aspects derived in the above mentioned analysis could be utilized with two aims.

4.1.1 for better environmental behaviour of the product.

In such case, from the general aspect Ai, the related "design rules" Ri1, Ri2,…Rin can be deduced.

For each rule Ri, in the industrial field j, the "design examples" EGij1, EGij2,…EGijk could be proposed.

The collection of all rules R and design examples EG could be utilized to develop a "designer handbook" or for specific expert system software development.

4.1.2 for the choice of the "better" product that performs a given function.

For the same general aspect Ai, the behaviour of m products P1, P2,…Pm can be expressed in terms of a numerical evaluation (score). The choice could be made by means of numerical tables or by using expert systems.

Table 2. First aspect list for "liquidation" general phase

LIQUIDATION		
1. Reuse	1.1 simplicity	ease of essential repairs; possibility for the product to perform an inferior function; easy dismounting and separation of components through a: • small number of connections • easy recognition of connections • accessibility to connections • easy disconnection.
	1.2 efficiency	functions integration; easy dismounting and separation of components through a: • small number of connections • easy recognition of the connections • accessibility to the connections • easy disconnection.
	1.3 safety	reliable design of the reusable components; safe dismounting; easy dismounting and separation of components through a: • small number of connections • easy recognition of the connections • accessibility to the connections • easy disconnection.
	1.4 sustainability	reuse possibility of the whole product; dismounting without contaminating operations; dismounting without contaminating substances; dismounting without excessive energy consumption; exclusion of pollution through reuse of product; exclusion of excessive energy consumption by the reused product.
	1.5 cost	easy dismounting and separation of components through a: • small number of connections • easy recognition of connections • accessibility to connections • easy disconnection.

LIQUIDATION		
2. Recycling	2.1 semplicity	few materials; easily recognisable materials; materials easy to separate.
	2.2 efficiency	few materials; easily recognisable materials; materials easy to separate; recyclable materials of high value.
	2.3 safety	few materials; easily recognisable materials; materials easy to separate; materials safe to separate.
	2.4 sustainability	few materials; easily recognisable materials; materials easy to separate; materials safe to separate; biodegradable materials; possibility to burn materials without production of toxic substances; absence of toxic substances.
	2.5 cost	few materials; easily recognisable materials; materials easy to separate; low cost separation; recyclable materials of high value.

4.2 Cultural step (principally for designer of communication)

In order to reach cultural improvement in terms of sustainability, human behaviour should be modified and specific behaviour rules should be formulated with regard to the generic aspect Ai.
In this way each aspect should be transmitted with regard to the product field and user's cultural level.

5. Case Study

In order to test the effectiveness of the tool developed, even though it is still in a draft release, we applied it to a glass bottle with plastic cap. In the phase "Recycling" (in terms of materials or energy), by using the mentioned method it is possible to recognize some aspects with regards to the requirements of such phase:

1. *simplicity* (few components, easy recognizable components, components easy to disassembly).
2. *efficiency* (few components, easy recognizable components, components easy to disassembly, components with high value).
3. *safety* (few components, easy recognizable components, components easy to disassembly, components with high value, components safe to disassembly).
4. *environmental impact* (few components, easy recognizable components, components easy to disassembly, components made of biodegradable materials, components made of materials easy to burn without toxicity, components made of non-toxic materials).
5. *economy* (few components, easy recognizable components, components easy to disassembly, low cost separation, components with high value).

It is possible to take into consideration, as an example, the following aspects:

A1 = easy recognizable materials
A2 = materials easy to disassembly

If we choose "Design for sustainability", in terms of technical step, we can consider the following design rules:

R1.1 different colour
R1.2 different shape
R1.3 different texture
R1.4……….
R2.1 hand disassembling
R2.2 disassembling with simple equipment
R2.3………………..

Each rule should have corresponding design examples in each industrial field.
For the choice of the "best" product we can develop and use a table similar to Table 3 in which an application of a score expert system method is shown.

Table 3. Application of a score expert system method to the glass bottle with plastic cap

Aspects	*Bottle 1*	*Bottle 2*	*Bottle 3*
Easy recognizable materials	2	1	3
Components easy to disassembly	2	2	2
Total evaluation	4	3	5

The same aspects should be considered in the cultural level, i.e. instructions for use.
The aspect A1 could be explicated by:

- R1: description on how to recognize that cap and bottle (in the specific field) are made of different materials.
- EG1: Picture.

The aspect A2 could be explicated by:

- R2: description of the necessary operations (only using hands?, is any equipment necessary?, how the operator should use such an equipment?) to separate glass bottle and plastic cap.
- EG2: Picture.

The complex R+EG (instruction unit to transmit the given concept, i.e. aspect) should have the fundamental requirements of clarity, immediateness, completeness and should be univocal; immediateness requires expressing the major number of information in graphic form.

6. Conclusions

In the present paper authors developed an "eco-information tool", which can provide designers an easy to use eco-information procedure and allows them to choose the right strategies, without disregarding customer needs, design requisites and standards/laws obligations.
Following the design guidelines proposed in this paper, the concept "*design for sustainability*" could be enlarged to the product and to related communications.

6.1 Future work

The developed approach have been considered positive so much that at moment the research work is going on, focusing in particular the following aspects:

- development of a graphical language, applicable to all fields, such as instructions for use, safety advertising, road signs and so on;
- development of a life cycle model, in order to evaluate environmental performances of products, that takes into account customer behaviour too.

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