INTERNATIONAL DESIGN CONFERENCE - DESIGN 2010
Dubrovnik - Croatia, May 17 - 20, 2010.

ECO-VIRTUOSITY: MANAGEMENT OF ECODESIGN ISSUES

M. Fargnoli, S. Bisillo, F. Costantino and D. Geraci

Keywords: ecodesign, ecological profile, EuP directive, product development and management, eco-virtuosity

1. Introduction

Customer awareness of environmental problems is following an upward trend these days, pushing companies to put on the market an ever larger range of "green products". Considerations about environmental aspects of industrial products have become one of the most important needs of companies also because of the new specific laws and regulations aimed at reducing the environmental impacts. This aspect is also underlined by the extension of the scope of the so-called "EuP" Directive [EU 2009], which was recently updated, shifting from "energy-using products" to "energy related" ones. As stated in this directive, it is necessary to increase energy efficiency and the level of protection of the environment of "any good that has an impact on energy consumption during use which is placed on the market and/or put into service, and includes parts intended to be incorporated into energy-related products" covered by the Directive. In such a context, EcoDesign is recognized as the most powerful tool for achieving this goal. Nevertheless, also the product's management aspects have to be taken into account: actually, the conformity assessment of the product under the scope of the directive is requested, as well as the user information about the environmental characteristics and performances of products, advising them on how to use products in a manner which is environmentally friendly. Following such an address, the research work carried out was aimed at defining a procedure, which combines environmental management issues with the use of EcoDesign traditional tools. The research approach was developed throughout its application to the design of a grass trimmer used in home gardening activities, and it was focused on helping companies in combining environmental mandatory issues with traditional EcoDesign tools, in order to manage product development activities efficiently. More in detail, in section 2 motivations of the research work are discussed; in section 3, an overview of the proposed approach and its development steps are presented. Then, in section 4 an EcoDesign case study is described, and in the following sections discussion of results and conclusions are summarized.

2. Background and Motivations

In the last decade, the development of more and more sustainable products has become an essential issue for companies: such a need leads to consider the environmental performances of industrial products as "default requirements" in design and development activities. For these reasons the competitiveness of products must not be individuated only in comparing the green products' characteristics with the ones related to traditional products, but bringing to light the difference existing among the green products themselves.

Furthermore, we must consider that factors which influence manufacturers in adopting EcoDesign measures are related with their bottom-line, i.e. cost savings, competitive advantages, improvement of corporate image, enhancing the quality of their products, and the compliance with mandatory requirements, to which they are subject, as pointed out, among others, by [Borchardt et al. 2009]. Nowadays, as well summarized in [Boks 2006], main factors, which may affect companies' decision-making in developing green products include:

- Pressure from external sources, including legal requirements;
- Economic issues;
- Consumer perceptions regarding the environmental impact of products;
- Development of relevant new technologies.

Needless to say, environmental concerns do not only affect product's development activities: also product management and company management issues play a significant role in tackling this new "green atmosphere", helping enterprises in the relationship with customers and stakeholders. Different studies in literature (e.g. in [Roy and Vezina 2001]) have shown that more and more companies have decided to adopt environmental communication tools, such as corporate environmental reports, eco-label and eco-declarations projects, environmental management systems, with the aim of involving and convincing an ever broader range of stakeholders, including consumers, of their environmental commitment. Such addresses also improve companies' skills in achieving higher economic value of their products, and enable them to competitively participate in the market for friendly environmental products. At the same time, as mentioned in the introduction, the mandatory requisites of environmental directives push companies in taking into account EcoDesign issues, which can be summarized as shown by [Simon et al. 2000] in the following factors:

- motivation arising from external and internal drivers;
- communication and information with all stakeholders;
- relations with suppliers;
- awareness of the potential benefits of environmental improvements and managing the life cycle of products;
- use of the correct and proper tools during the various design phases.

On the other hand, there is a need to translate mandatory requisites of environmental legislation, as well as environmental and innovation policies into useful tools and operative procedures for development and management of sustainable products. All things considered, the research work was focused on giving an answer to the question: "how to combine environmental mandatory issues with traditional EcoDesign tools efficiently, in order to help companies in generating tailor-made solutions?".

3. Research approach

The study presented in this paper is based on the output of a project started in 2007 in collaboration with the National Institute for Occupational Safety and Prevention, which is involved in the management of CE mark regulations in Italy. It has to be noted that the EuP Directive proposes a similar approach to the one adopted in the field of machine safety, i.e. the use of the CE mark demonstrating the compliance of products with environmental mandatory requisites, as well as similar procedures for achieving it. Companies belonging to different production sectors were involved, as partially described in [Fargnoli et al. 2008]. From the experiences collected, it emerged that although the large number of tools at a designer's disposal for improving the eco-efficiency of products, or even for developing completely new solutions, the implementation of environmental requirements in accordance with compulsory regulations is still a very difficult task, especially in small and medium sized enterprises (SMEs). In most cases, even a correct application of environmental policies by a company's management resulted in being less effective than expected, due to operative difficulties in using information and tools concerning design activities.

Based on these considerations, the first goal of the research was the definition of a product's attributes, which are considered important by designers for improving environmental performances of the products. The next step consisted in developing a tool for the assessment of the product's conformity along its whole life cycle, i.e. the evaluation of its Eco-Virtuosity. Then, the integration of such a tool in the EcoDesign activities was investigated. The outcome of this analysis was a procedure that allows designers to both improve the environmental performances of a product and to guarantee that mandatory requirements are satisfied at the same time.

3.1 Eco-Virtuosity of green products

As mentioned above, nowadays most industrial manufacturers put on the market products that have undergone a certain improvement from the environmental point of view, because of legal obligation and/or customer expectation. Hence, considering whether a product can be defined "green" or not, has become a more difficult task than in the past. If a product belongs to one of the categories under the scope of some environmental directives, it is clear that the law defines basic environmental characteristics, and they are mandatory for all the products of the same type put on the market.
Thus, in Europe (EU market), the effort made for increasing the level of the product's environmental performances has to be seen as an improvement over the minimum environmental standards requested by EU legislation. At this point we can introduce the concept of the product's Eco-Virtuosity, i.e. the level of a product's environmental performances over the requisites defined by the law. In Figure 1 the Eco-Virtuosity of two different products is shown.

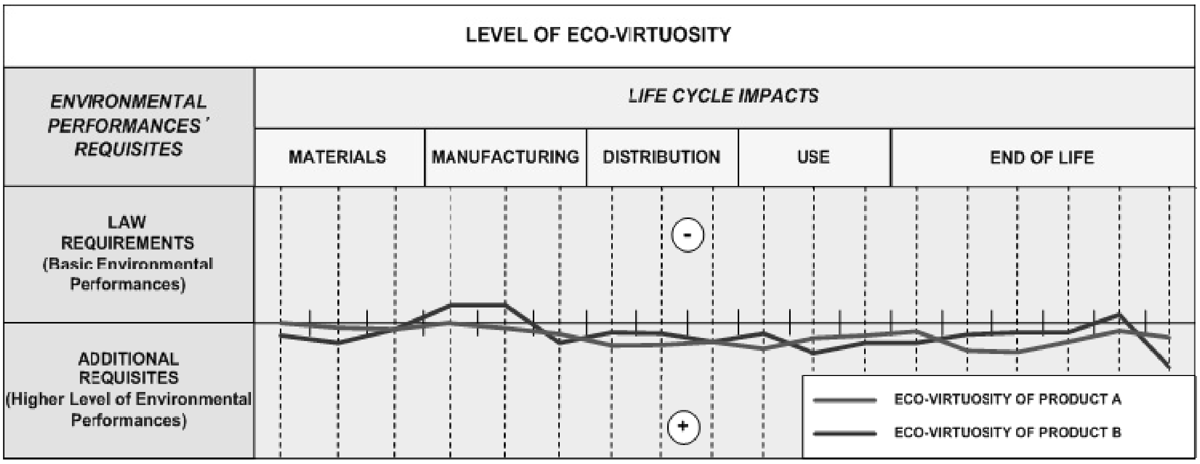

Figure 1. Level of Eco-Virtuosity

Following the definition given above, the level of Eco-Virtuosity of a product might even be negative (e.g. the behavior of product B in Figure 1). This does not mean that the manufacturer did not pay attention to some environmental aspects of the product; it means that some improvements are needed in order to satisfy mandatory requirements concerning those aspects.
Furthermore, it has to be underlined that the eco-virtuosity of the same product can be different depending on the market where it is put (e.g. EU market, US market, etc.), since environmental the requisites of the law are different. This is also true considering a time framework: the evolution of regulations is affected by a continuous improvement. Thus the level of Eco-Virtuosity is a dynamic parameter: in Figure 2 an example of the behavior of the level of Eco-Virtuosity is shown taking into account only the issue and evolution of WEEE, RoHS and EuP directives in last years, since in the present study we decided to take into account the most significant regulations which affect product design activities. Needless to say, other laws should also be considered by manufacturers such as: REACH Regulation (Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals, which entered into force on 1st June 2007) or Large Combustion Plant (LCP) Directive (2001/80) and Solvent Emissions Directive (1999/31), which take into account a factory's environmental impacts. As far as the Eco-Virtuosity level is concerned, the simple satisfaction of law requisites corresponds to the line which divides positive and negative areas, i.e. in this case the value of the product's eco-virtuosity is zero. This is also the reason why we chose the word "virtuosity". It indicates higher environmental performances than the standard ones, which any product belonging to the same category should be able to achieve according to law.

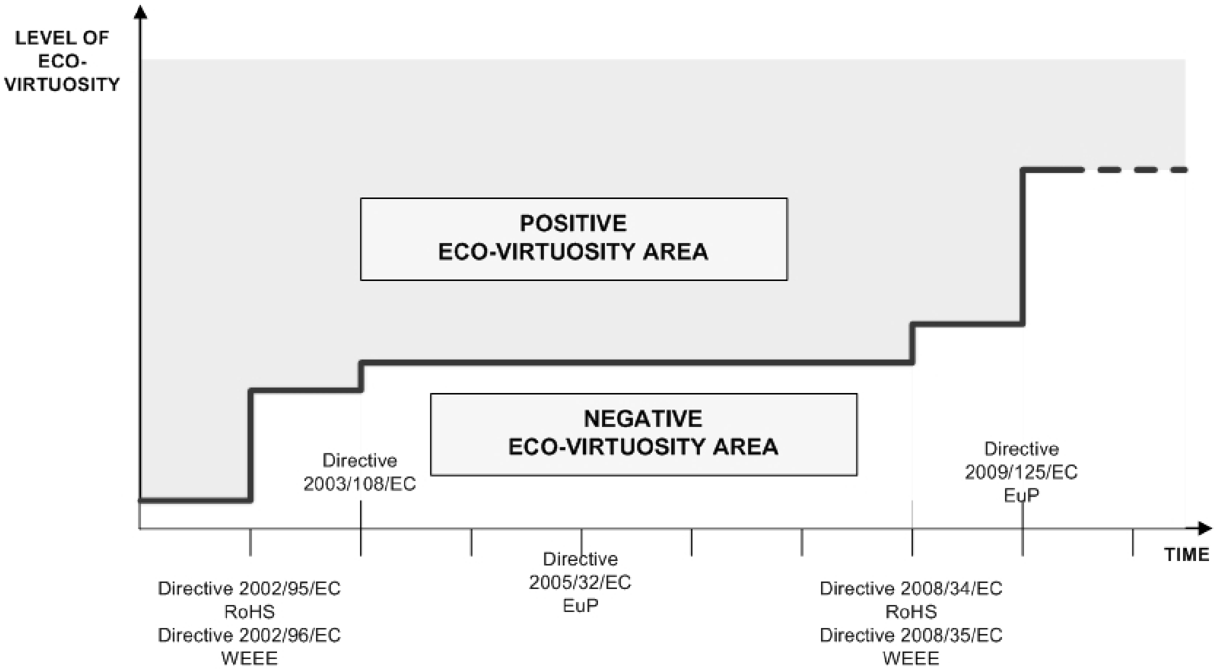

Figure 2. The trend of Eco-Virtuosity in last years

3.2 Environmental attributes of green products

The further stage of the study concerned the definition of criteria on the basis of which environmental performances of products could be evaluated. From a general point of view, we can take into account the fact that the various attributes of an industrial product are usually considered with a variety of purposes, depending on the stakeholders involved in the product's life cycle. In other words, the same attributes of a product are evaluated using different weights of importance, depending on who is assessing the environmental performances of a product (designers, producers, customers, sellers, etc.). It is clear that the environmental performances of a product are influenced by numerous attributes, and the assessment of such properties both allows the designers to develop a measure of the product's environmental characteristics, and at the same time shows which changes should be carried out in order to obtain an improvement of the whole product's environmental quality.

On the other hand, it is necessary to define some criteria for each one of such aspects with the aim of obtaining a more precise and objective evaluation of the product. Moreover, not all of them are of the same relevance: actually, some of them ought to be considered as more important than others depending on the nature of the product, as well as the specific needs of the stakeholders: in some cases the environmental aspects might even be in conflict with one another. In order to obtain an objective assessment of the product performances, a set of indicators was developed, considering the main stages of the product's life cycle. More in detail, for each one of the product's life cycle steps, the most significant environmental requisites were considered, starting from the environmental issues which emerged from the analysis of:

1. Environmental Legislation, based on the EuP, WEEE and RoHS Directives;
2. Standards for Environmental Declarations and Labelling, based on ISO 14021:1999, ISO14024:1999 and ISO 14025:2006;
3. Requisites which design activities should satisfy to be in compliance with ISO 14001:2004 and EMAS Regulation (Regulation (EC) No 761/2001 and further amendments).

First two types of characteristics were used in order to identify indicators for the assessment of the product's conformity along its whole life cycle. The evaluation of the environmental behavior of the product along its whole life cycle is carried out throughout the analysis of the product's environmental performances in comparison with the requisites of environmental legislation. In Figure 3 a scheme of this approach is shown. The latest aspects were used in order to determine the integration of the questionnaires' results into the product development process, as explained in the next section.

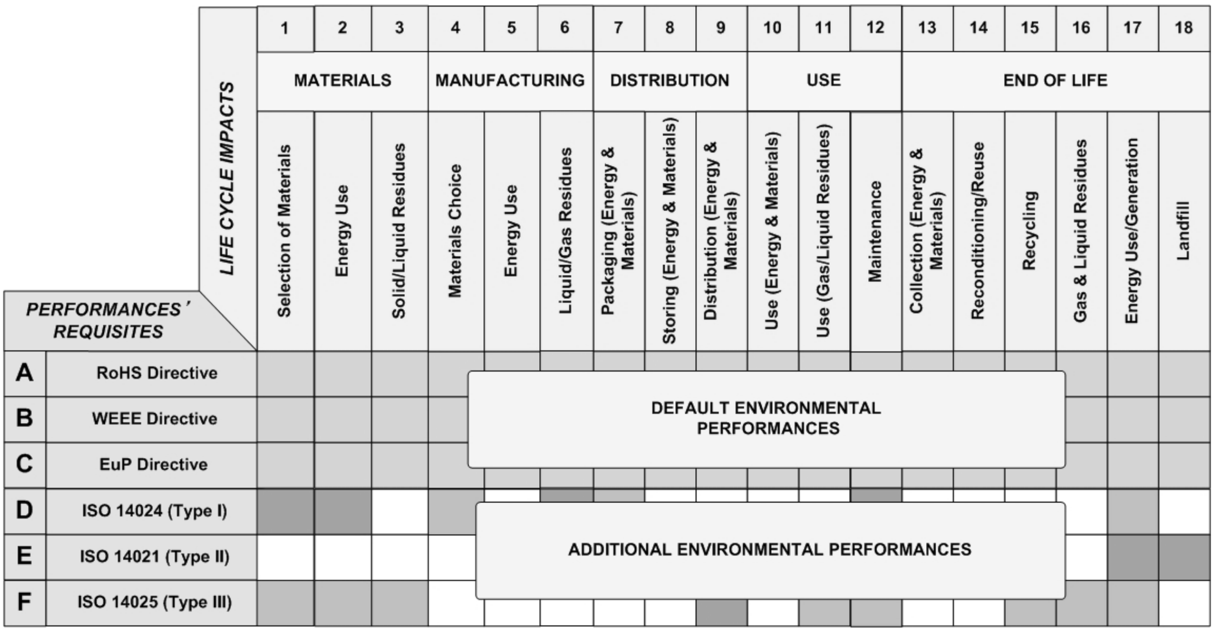

Figure 3. Criteria for the Eco-Virtuosity evaluation

For each one of characteristics which emerged from the analysis, and can be considered as "indicators", proper criteria of evaluation were defined.

3.3 Questionnaires development

The result of this first part of the study was the development of a series of checklists which takes into account all the above mentioned properties:

- Checklist 1, for the selection of materials with a low environmental impact;
- Checklist 2, for the reduction of the use of different materials;
- Checklist 3, for optimizing the production process;
- Checklist 4, for improving distribution activities;
- Checklist 5, for reducing the environmental impact during the use phase;
- Checklist 6, for improving the use phase characteristics;
- Checklist 7, for optimizing the end-of-life phase.

Each checklist provides general information about the characteristics considered and the criteria for the evaluation. In Table 1 an excerpt of the part concerning the Checklist 1 is shown. In some cases, the indicator can be associated with a formula. In other cases, when the evaluation of indicators is based on a personal judgment made by the designers, some assessment criteria are proposed in order to carry out a qualitative evaluation (e.g. correlating an assessment definition, such as "satisfactory", "very satisfactory", etc., with an opportune score). These checklists are the core of a questionnaire developed with the aim of allowing companies to quantify the product's eco-friendliness throughout a self-evaluation. The questionnaire follows the product's life cycle stages: there are seven sections (based on the above mentioned Checklists) and each one of them has an associated indicator I_i, which is aimed at providing an evaluation on the environmental behaviour concerning that specific aspect. Even if indicators are based on the requisites of the above mentioned EU directives, they are of a general nature so that they can be applied to any kind of product, also to the ones which are not under the scope of the EU directives and/or in order to apply environmental declaration or labeling standards.

Table 1. Synthesis of Checklist 1 (selection of materials with low environmental impact)

Checklist 1	RoHS	WEEE	EuP	ISO 14024	ISO 14021	ISO 14025
1.1 Use of non toxic/noxious materials	Art. 4, Art. 5 R1, R2, R3, R4, R5, R6, R7		Art. 11 Annex I, 1.1; 1.2; 1.3	D1, D2 D3, D4 D5, D6 D7, D8		Section 6.8.2 Section 7.2.1 Section 7.2.3
1.2 Use of renewable resources		Art. 1, Art. 4, Art.7, Art. 10	Art. 11, Art. 13 Annex I, 1.1; 1.2; 1.3			
1.3 Use of recycled materials		Art. 1, Art. 4 Art. 7, Art. 10	Annex I, 1.1; 1.2; 1.3		Section 7.7 and 7.8	Section 7.2.3

This decision was made also because a large number of products fall in the scope of environmental directives only if we consider their nature (e.g. some electronic appliances), but they are not in the scope because of other limitations. For example, article 15 of the EuP Directive excludes from its scope products which have a volume of sales and trade lower than 200.000 units a year within the EC.

4. Methodology

The methodology developed in order to verify the effectiveness of the research approach is based on the integration of the questionnaire for the assessment of the Eco-Virtuosity of products within the design activities. With this aim in mind, the design process selected is the one proposed by the IEC 62430:2009 standard, as it is the latest achievement of studies concerning design and development models. Nevertheless, it has to be noted that such a flow diagram is very similar to the ones introduced by the ISO TR 14062:2002, and the IEC Guide 114:2005. All of them represent a translation of schemes of traditional design processes (e.g. the models proposed by Hubka, Pahl and Beitz, etc.) into the environmental context, and very few differences can be found among them. Main phases of the process are the following:

- Product Planning, which includes activities aimed at describing the boundaries of the product's system, the identification of all requisites of the environmental legislation, and the customers' requirements throughout the whole product's life cycle.
- Conceptual Design, which is focused on generating possible feasible solutions, taking into account technical, environmental, and economic criteria.
- Detailed Design, i.e. the definition and dimensioning of the product's layout, and its assessment, considering the whole life cycle.
- Testing and Prototyping, which is aimed at performing the final verification and validation of the project.

Several EcoDesign tools were selected, in order to evaluate and improve the environmental properties of industrial products. Among the most common EcoDesign methods, we focused our attention on the following tools:

- Quality and Environmental Function Deployment (QEFD);
- Product Design Matrix (PDM);
- Intervention Chart (IC).

The reasons why these tools were chosen can be found in their widespread presence in the field (which guarantees fewer difficulties for even small companies in finding enough information concerning their use), and in their effectiveness in being used since the early stages of the design process, as underlined in [Fargnoli and Kimura 2006].

Beside these tools, also design methods for the improvement of properties related to the environment were taken into account. In particular, the well known Failure Modes and Effects Analysis (FMEA), and the Preliminary Hazard Analysis (PHA) methods were selected for increasing the level of reliability and safety respectively. In Figure 4 the overall methodology is represented (the questionnaire for the evaluation of the Eco-Virtuosity is named QEV in the figure).

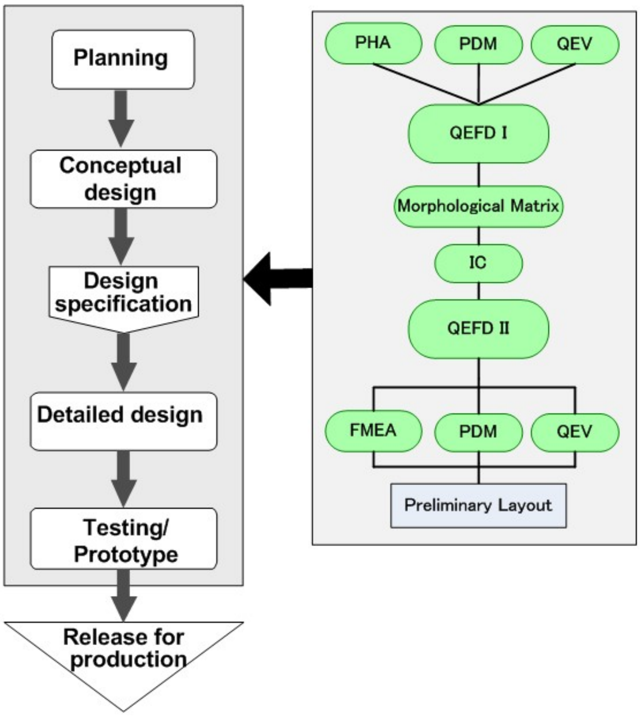

Figure 4. Design methodology adopted

The methodology developed allows both redesigning an already existing product improving its environmental and technical characteristics (which is a very common need of SMEs), as well as developing a new product starting from the analysis of stakeholders needs. In the scheme the use of the Morphological Matrix [Hubka et al. 1998] is also foreseen.

5. Case Study

The effectiveness of the methodology was verified throughout its application to a case study. Because the aim of the study was to test the use of the Eco-Virtuosity questionnaire during design stages, a product with a low complexity was chosen. Moreover, the trimmer for house gardening presents other interesting aspects, which are worth being investigated. First of all, traditional properties such as Safety, Ergonomics, Aesthetics, etc., appear to be relevant for its competitiveness on the market, since it is intended to be used in home gardening, i.e. appropriate for non professional users. Then, analyzing the sector of this kind of product, it came out that there is a large number of types available on the market, characterized by different technologies (e.g. two or four stroke engine, electric motor with power cable of battery supply, etc.). In particular, the latest models, which use electric power, can be considered as an electronic appliance and thus falling in the scope of RoHS and WEEE directives. In case, under certain conditions, they could be affected by the EuP requisites as well, or in a further development of such a directive.

5.1 Product planning

The analysis of the task was carried out in collaboration with a company which produces gardening equipments, taking into account a very widespread model of grass trimmer equipped with a two-stroke engine (power: 0, 73 kW), a cutting tool made by a nylon string (cutting diameter: 40 cm), and a total weight of about 7 kg. Before applying the first phase of QEFD, which is aimed at bringing to light the product's main characteristics both from a technical and an environmental point of view, the level of safety and of the environmental impact was carried out using PHA and PDM methods (Table 2). At the same time, also the Eco-Virtuosity questionnaire was filled in by the manufacturer. In this case, because of the nature of the product analyzed, the questionnaire's use was mainly aimed at making the manufacturer aware of possible environmental impacts of the product, as well as at investigating whether attention was paid to environmental concerns or not.

Table 2. First application of the Product Design Matrix

LIFE CYCLE STAGE	Environmental Concern					
	Materials	**Energy Use**	**Solid Residue**	**Liquid Residue**	**Gaseous Residue**	**TOTAL**
Premanufacture	2	2	2	2	2	10
Product manufacture	2	2	2	2	2	10
Distribution/packaging	3	0	2	2	2	9
Use, maintenance	3	2	2	0	0	7
End of life	2	3	0	0	3	8
TOTAL	**12**	**9**	**8**	**6**	**9**	**44**

The output of the first phase underlined the high level of impact of the product during the use phase: as shown in Table 2, this life cycle phase obtained the lowest score. From the safety point of view, the need of a protection for the user, as well as the reduction of the weight in order to prevent possible muscle and skeletal injuries resulted in being the most significant aspects.

5.2 Conceptual Design

The use of the Morphological Matrix (MM) allowed us to organize alternative solutions for each function of the system, and to combine them to generate solution variants, each of which can potentially satisfy needs and requisites which emerged from the previous phase. On the other hand, the MM makes the identification of the best concept difficult, because the assessment of possible alternative solutions of each function might mislead designers from the original goal of the design task. For this reason, the Intervention Chart (IC) was used. An excerpt of such an application is shown in Figure 5: actuators deriving from the Morphological Matrix are evaluated using the Intervention Chart estimation criteria. The output of this phase consisted in the definition of the optimal concept, which is characterized by an electric motor supplied by batteries (2 rechargeable NiCd batteries) allocated in the operator body harness. In this way, the weight the operator has to bear was significantly reduced.

5.3 Preliminary layout definition

The next step consisted in the definition of the product's characteristics, in order to bring to light design specifications. For this purpose, the second phase of the QEFD was applied. Once the main features of the redesigned product were defined, it was possible to analyze it more in details, following the scheme proposed in Figure 4. In this stage, both the PDM and the Eco-Virtuosity questionnaire were used again, with the aim of verifying the improvements achieved. In this case, the use of assessment of the Eco-Virtuosity of the project could be carried out effectively.

FUNCTION		ACTUATORS			
N°	To allow the system's holding	A	B	C	D
7.1	To allow the system's holding	Single handle	Double handle		
8.3.1	To change working height of the cutting system	Feeler gauge	Bolt & key	Spring & Cotter pin	Absent
8.4.1	To allow the generation of energy	2-stroke internal combustion engine	4-stroke internal combustion engine	Electric motor	
8.4.2	To provide energy	Gasoline reservoir	Batteries for electric motor	Power supply	
8.4.3	To allow power supply	Conducting wire	connection with batteries	Carburettor	Embedded batteries

		RELATIONSHIP: 1 = min 5 = max	IMPORTANCE	ACTUATORS					
				FUNCTION 8.4.1			FUNCTION 8.4.2		
				A	B	C	A	B	C
ENVIRONMENTAL ASSESSM	LIFE CYCLE	MATERIAL USE	3	3	2	4	2	3	2
		PRODUCTION	3	3	2	4	1	3	2
		HANDLING	9	3	2	4	1	3	2
		RELIABILITY	9	3	2	4	1	3	2
		DURABILITY	9	4	2	4	1	4	2
		ENV. SAFETY	9	3	2	4	1	3	2
		MAINTAINABILITY	3	3	3	3	2	3	2
		REPAIRING	3	3	2	4	3	3	2
		DISASSEMBLING	3	3	2	4	3	3	2
		REUSING	3	3	2	4	3	3	2
		RECYCLYNG	3	3	2	5	3	3	2
		TOTAL A		180	117	228	87	180	114
IMPLEMENTATION RISK		FUNCTIONALITY	3	3	2	4	1	3	2
		EASY-TO-USE	9	3	2	4	1	3	2
		ERGONOMICS	1	4	2	4	1	4	2
		SAFETY	9	3	2	4	1	3	2
		AESTHETICS	1	3	3	3	1	1	4
		PERFORMANCES	9	3	2	3	1	1	4
		PRODUCTION COST	3	3	2	3	3	3	4
		OPERATIVE COST	3	3	2	2	3	3	3
		DISPOSAL COST	3	3	2	5	3	3	3
		TOTAL B		124	83	148	59	104	114
		TOTAL A + B		304	200	376	146	284	228

Figure 5. Excerpt of the use of Morphological Matrix and Intervention Chart

6. Discussion of Results and Conclusion

The output of the Eco-Virtuosity questionnaire is summarized in Figure 6, where C1, C2, etc. represent the value of the indicators associated to the seven checklists mentioned in section 2.3. As emerged from the comparison of results obtained before and after the design activities carried out, weak points from the environmental point of view, such as material selection, energy consumption during use, and disposal activities, were improved significantly, implementing more sustainable solutions. Of course, a more detailed analysis of the new product (i.e. at the detailed design stage of the design process) could allow us to better define its environmental performances. But the aim of the study was focused on understanding how to combine traditional EcoDesign tools with environmental legislation requisites. In such a context, positive results were achieved, because the tool developed (the Eco-Virtuosity questionnaire) resulted in being very effective in addressing company's designers in coupling mandatory requirements and the traditional external properties of products. These requirements were used as inputs of the design activity, rather than as ex post criteria for the conformity assessment, as in the case of most common tools for design review. In other words, the developed approach (and the definition of the concept of "Eco-Virtuosity") allows designers to shift from control to management of the design activities, increasing their awareness about the way they are paying attention to environmental issues while designing. Starting from these first results, the research work is currently in progress: the proposed approach is going to be applied to more complex case studies, in order to optimize its use, e.g. by increasing the number of indicators and/or by making the scoring system less dependent on subjective evaluations.

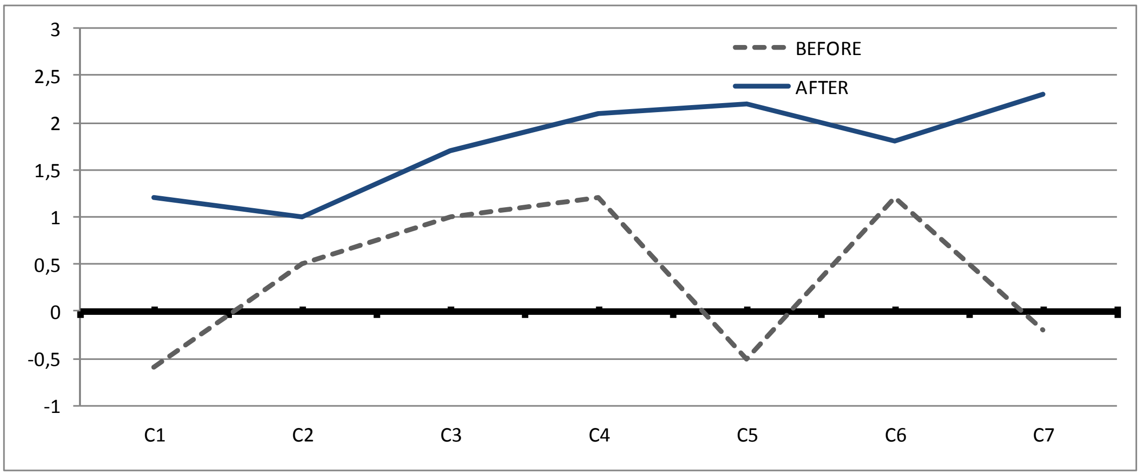

Figure 6. Eco-Virtuosity Level

Acknowledgement

The research work was partially supported by the National Institute for Occupational Safety and Prevention.

References

Boks, C., "The soft side of ecodesign", Journal of Cleaner. Production, Vol. 14, 2006, pp. 1346-1356.

Borchardt, M. et. al., "Adopting Ecodesign Practices: Case Study of a Midsized Automotive Supplier", Environmental Quality Management, Autumn 2009, Vol. 19, 2009, pp. 8-22.

EU, "Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products", 2009.

Fargnoli M., Di Gravio G., Costantino F., Bisillo S., "Environmental Regulations in Life Cycle Design activities", EGG Care Innovation 2008 Conference, September 8th-10th, Berlin,2008, pp. 467-472.

Fargnoli, M., Kimura, F., "Evaluation of Design Methodologies for Sustainable Product Development", Proc. of TMCE 2006, edited by I. Horv'ath and J. Duhovnik, Ljubljana, Slovenia, 2006, pp. 669-680.

Hubka, V., Andreasen, M.M., Eder, W.E., "Practical Studies in Systematic Design", Butterworths, 1988.

Roy, M.J., Vezina, R., "Environmental Performance as a Basis for Competitive Strategy: Opportunities and Threats", Journal of Corporate Environmental Strategy, Vol. 8, No. 4, 2001, pp. 339-347.

Simon, M., Poole, S., Sweatman, A., Evans,S., Bhamra, T.,Mcaloone, T., "Environmental Priorities in Strategic Product Development", Business Strategy and the Environment, Vol. 9, Issue 6, 2000, pp. 367–377.

Ing. Mario Fargnoli, PhD
Technical Director
Ministry of Agriculture, Department of Rural Development, SVIRIS I
via XX Settembre 20, I-00187 Rome, Italy
Telephone: +39 06 4665 5052
Telefax: +39 06 4881 707
Email: m.fargnoli@politicheagricole.gov.it