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A PROCEDURE TO IDENTIFY EFFECTIVE REDESIGN OPTIONS IN ECODESIGN

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Abstract

The research work investigated the most common ecodesign tools to define optimal criteria for their integration within a proper procedure for the development of environmentally sound products. The study focused on the use of the PILOT and the QFDE methods in the early stages of the design activity.

Keywords: Eco-design, Redesign, Design process, QFDE, PILOT

1 Introduction

The opportunity to evaluate the ability of a product to satisfy certain requisites in an efficient and appropriate way before putting it on the market has already become a fundamental point in the design and development activities of successful products. In fact, the benefits of making "green" decisions in the early stages of the product design can be substantial in order to enhance products' and processes' environmental performances, as well as simultaneously improving companies' economic earnings. There exist a number of ecodesign methods and tools. However, very little research on how to combine multiple tools has been achieved, although it has a potential to produce a synergetic effect.

The aim of the research work carried out was to investigate the most common ecodesign tools now available in order to define the optimal criteria to integrate them within a proper procedure for the evaluation and the development of environmentally sound products. In particular, the study performed focused on the use in the early stages of design activity of the Ecodesign PILOT and its integration with other design tools, such as QFDE and PDM matrix.

The paper proposes the use of a correlation chart specifically developed to aid designers in selecting the best interventions resulting from the application of the PILOT, in order to optimize all the life cycle phases of the product from the environmental point of view. Such a coordinated design approach was verified through its application to a case study, the redesign of a device able to regulate the air flow of an air conditioner for domestic use.

2 The Ecodesign approach

The design and development of new products with a low environmental impact represents, nowadays, the path designers have to follow to contribute in the development of a more sustainable society, in accordance with the recent international environmental policies and regulations. In fact, the pursuance of the new regulations in the matter of products' environmental sustainability is becoming a significant hindrance for companies both because it requires radical modifications of the products' design and manufacturing processes, and because it needs additional costs which companies have to bear.

As shown by many Authors, Ecodesign (also called "Environmental Conscious Design") represents the most powerful design approach to face such problems, through the integration of the environmental performances of industrial products together with the "technical" product's characteristics and aspects [1, 2, 3]. The main goal of the Ecodesign approach consists of evaluating and improving the product's environmental performances during its design and development stages, considering its whole life cycle. The selection stage, i.e. the definition of appropriate criteria on the basis of which to perform the selection among the best design alternatives in the most objective way, is of course, among all design stages the one which can be considered the most important, as well as the most difficult to be correctly satisfied.

On the basis of these considerations, this paper particularly focuses on a detailed study of the design methods and techniques aimed at evaluating and improving environmental impacts related to the entire product life cycle during the initial design stages. These stages, in fact, "allow extensive exploration of alternatives and principles" as well as "entail a choice of the most promising principles and embodiments, and optimization of the product" [4].

More in detail, the study was focused on the integrated use of the design strategy supported by design methods and techniques (i.e. design tactics). As far as design strategy tools are concerned, in literature several models of the design process have been proposed hitherto and, needless to say, all of them are characterized by a similar identification of the main design activities. In particular, the model used in this research work is divided in four main phases: clarifying the problem (task analysis); conceptual design (function analysis and organ structure definition); embodiment design (preliminary and dimensional layout definition, production characteristics' analysis); test (constructive layout verification and validation) [5].

3 The Ecodesign methodologies

The extensive development of new tools and methodologies of recent years is an indicator of the great attention paid to Ecodesign and of the acknowledgement of the important role performed within the burdens of the sustainability of industrial products. On the other hand the need to organize the use of such tools in order to improve their choice and implementation is evident. In fact, in spite of the great number of methods and techniques developed in the field [6, 7, 8], the use of such tools by designers is still partial or not well organized. Numerous errors which reduce their effectiveness and limit their spread are due mainly to:

1. Lack of knowledge of their coordinated use, indeed of the use of multiple design tools within the same project.

2. Mistakes in the correct introduction of the design methods in the proper design process stage.

The research work carried out started in 2004 and was particularly focused on the use of ecodesign tools in the initial stages of the design process and took into account the most common methods aimed at evaluating and improving the environmental properties of industrial products. Among all of them, we considered the tools based on the Quality Function Deployment (QFD) and the Ecodesign PILOT method.

3.1 The environmental interpretation of the QFD

In recent years many authors have reviewed the QFD [9] method from an environmental point of view, developing several variants based on the use of the "House of Quality" ("HoQ"). The aim of most of these studies is to put together the following aspects:

- the efficiency of the traditional QFD in the interpretation of customer needs and translating them into engineering parameters;
- the analysis of the environmental needs concerning the product itself and its life cycle.

In such a context, two main different approaches can be distinguished, both aimed at increasing the influence of customer needs related to the product's life cycle:

1. to add considerations concerning the product life cycle (or, more in general, environmental concerns) among the traditional customer needs, developing the various HoQs according to the traditional rules of the QFD; depending on the different institutes, this kind of interpretation has been called Environmental Quality Function Deployment (EQFD), Eco-QFD or Quality and Environmental Function Deployment (QEFD) [10, 11];
2. to take into account parameters that characterize the product's life cycle by developing a specific HoQ, separately from the part which considers the traditional product's properties: in this case the name Green QFD is used, where different variants have been proposed (GQFD I, GQFD II, etc.) [12].

Clearly, the similarity between these addresses and above all the great popularity of QFD have brought both to the development of other variants, similar to these ones, as well as to the development of "hybrid" solutions. Beside such approaches, a third one has to be mentioned, that consists in an original interpretation of the QFD: the Quality Function Deployment for the Environment, proposed in recent years by a Japanese institute [13].

3.2 The Quality Function Deployment for the Environment (QFDE)

QFDE [14] is a methodology to support Ecodesign developed by incorporating environmental aspects into QFD. It consists of four phases. In Phase I, voices of customers (VOC) with voices of the environment (VOE), and engineering metrics (EM) for traditional and environmental qualities are correlated, while in Phase II EM and part characteristics (PC) are also correlated. Part characteristics can be regarded as function units or components. For both correlations, semi-quantitative scores are used. This information is generated by a group of product developers, which is called a QFDE team in this paper. The outputs of Phase I and II are the identification of the function units that should be focused in product design when environmental as well as traditional qualities are considered. After identifying the important part characteristics, the QFDE team will examine design improvements for their product in Phase III and IV. They select an improvement option, namely redesign, by identifying the combination of an EM and a PC to be improved, and evaluate the effects of the design change on the VOC and VOE using semi-quantitative information represented in the two correlation matrices in Phase I and II.

There are three approaches when design engineers decide where they should focus. One approach is originated from a specific VOC that is given as a target of the design. For example, when they already have a target of “less energy consumption” VOE, they should seek the EM or PC which could contribute to decrease the “amount of energy consumption”. The other two approaches are examining the most important EM and PC identified in phase I and II, respectively. Although designers, by using QFDE, might know what to be tackled, they themselves have to find how to achieve it.

In conclusion, it can be said that the use of QEFD (and the other methods based on the development of the traditional application of QFD) accompanies the design strategy all the way through: in other words, the various HoQs characterize different stages of the design process. For example, as schematically shown in Figure 1, the first phase of the QEFD is generally developed during the “Task Analysis” stage; the second phase helps designers to complete the conceptual study; the third phase provides useful information for the embodiment design.

Instead, the QFDE represents a very effective tool for the definition and the evaluation of possible design solutions: its use, compared to the traditional QFD one, can be defined as “horizontal” or transversal in relation to the design process flow, as shown in Figure 1. In fact, from our point of view, the application of the various stages of the QFDE can be allocated between the second, when the different alternative solutions are defined, and the third phase of the design process, when the main characteristics of the optimal concept are defined. Of course, the use of the QFDE can also be foreseen in other moments of the design process, when the evaluation among different alternatives is required.

3.3 The Ecodesign PILOT

The Ecodesign PILOT (Product Investigation Learning and Optimization Tool) is a design method, developed by the University of Vienna, as a further development of the Ecodesign Checklist method [15]. The application of PILOT is based on the use of a series of checklists structured in different ways depending on the type of product, the product’s life cycle and the design phases in which we are operating.

More in detail, three different approaches can be performed: PLC (Product Life Cycle), PDS, (Product Development Strategies) and PDP (Product Development Process). The final aim of the method is to identify, by means of a qualitative evaluation, which design characteristics most influence the environmental performances of a product.

Even though it is simple and rapid to use, PILOT often leads to qualitative results that greatly depend on designer skills. In particular, the use of this method alone, because of the general aspect of the results, does not always allow the correct definition of the priority of interventions (design modifications) to solve problems emerging from checklists [16].

On the other hand, it is also to be underlined that in the early stages of design process the information about the product is poor, as well as the fact that the knowledge about the product’s functions, structure and materials is only roughly defined.

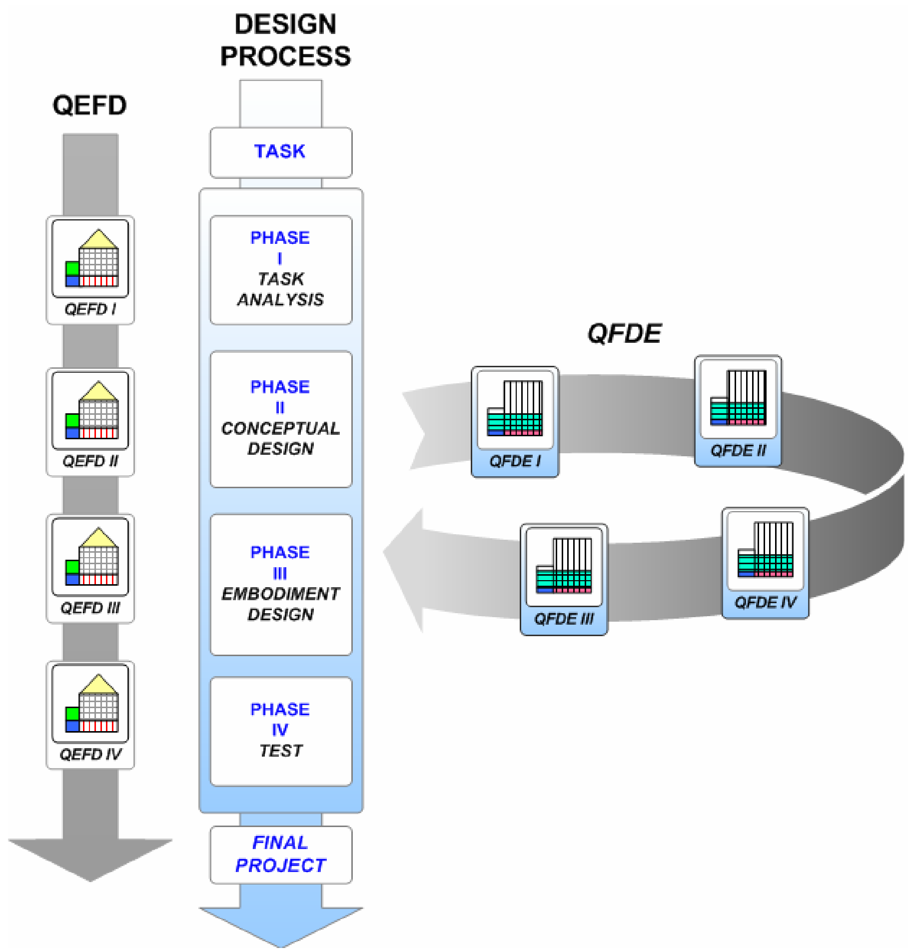

Figure 1. Differences in the integration of QEFD and QFDE into the Design Process.

4 The research approach

For these reasons, in order to optimize the use of such tools a design procedure has been developed that is characterized by the application of several ecodesign methods aimed at clarifying which interventions/modifications can be carried out during the product's design and development process. Figure 2 shows the overview of the proposed approach, which integrates QFDE and PILOT together with other methods in the initial stages of the design process. In details, the following tools have been considered:

- Product Design Matrix (PDM), which allows us to give the correct environmental burden to the characteristics of the product in relation to the stages of its life cycle [17].
- Ecoindicator 99, that allows the analysis of the environmental impacts of the life cycle of a product through a rapid and easy to use evaluation procedure [18].
- Ecodesign Strategy Wheel (ESW), is a very useful tool for representing and analyzing results of environmental assessment [19].

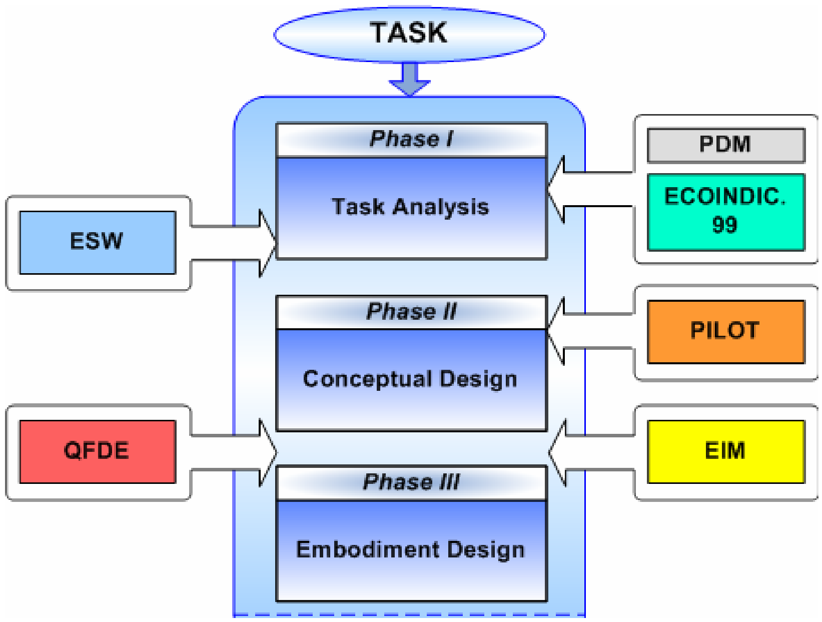

Figure 2. The integrated design approach proposed.

Furthermore, a novel design method, called "Eco-Impact Matrix" (EIM) has been developed with the aim of analysing and selecting the best interventions resulting from the application of the Ecodesign PILOT, which have to be further developed throughout the use of the QFDE. To make the application of such a tool together with the PILOT and QFDE methods clear, a scheme of their integration is shown in Figure 3. By following this approach, designers can identify the ways to modify the product by using the important elements of a product from Phase I and II of QFDE and the prioritized improvement options from the Eco-Impact Matrix. Such an approach was verified through its application to a case study, the redesign of a device able to regulate the air flow of an air conditioner for domestic use.

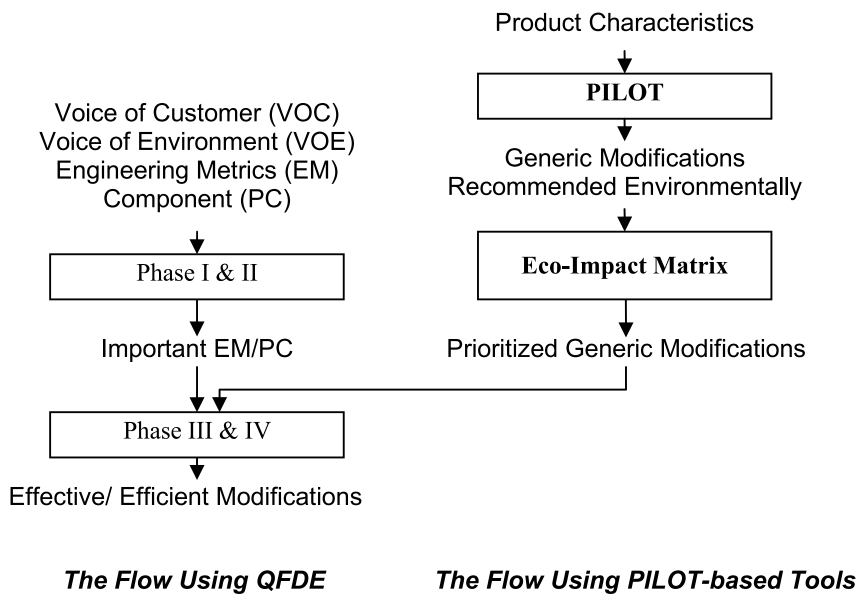

Figure 3. Integrated use of the design tools.

5 Case study

The mechanical system to be redesigned consists in a device able to regulate the air flow of an air conditioner for domestic use, which is made mainly by plastic components (polyamide PA 6.6 and acetyl resins) directly produced by the company: in Figure 4 a general scheme of the internal part of the system is shown.

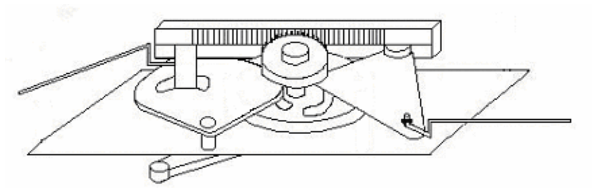

Figure 4. General scheme of the product.

The main components of the system, which are inside a box and a cover both made of plastic, are: four control levers; a cam; a rack; a sprocket and two tie rods.

5.1 Task analysis

The analysis of the design task was performed with the specific aim of identifying the weaknesses and the strengths of the environmental attributes of the product: for this purpose the already existing product was analyzed by applying both the Econdicator 99 and the PDM method (Figure 5).

PDM	Environmental Aspects					Total
	1 Materials	2 Energy Use	3 Solid	4 Liquid	5 Gas	
A Pre-Manufacturing	(A.1) 4	(A.2) 3	(A.3) 3	(A.4) 3	(A.5) 3	16
B Manufacturing	(B.1) 4	(B.2) 1	(B.3) 3	(B.4) 5	(B.5) 5	18
C Packaging & Distribution	(C.1) 4	(C.2) 5	(C.3) 5	(C.4) 5	(C.5) 5	24
D Use & Maintenance	(D.1) 3	(D.2) 2	(D.3) 3	(D.4) 5	(D.5) 5	18
E End of Life	(E.1) 4	(E.2) 3	(E.3) 3	(E.4) 5	(E.5) 5	20
Total	19	14	17	23	23	192

Figure 5. Application of the Product Design Matrix.

Furthermore, considering the whole life cycle of the product, in order to understand which aspects required more effort to be improved from the environmental point of view, the results obtained were implemented in the Ecodesign Strategy Wheel diagram (Figure 6).

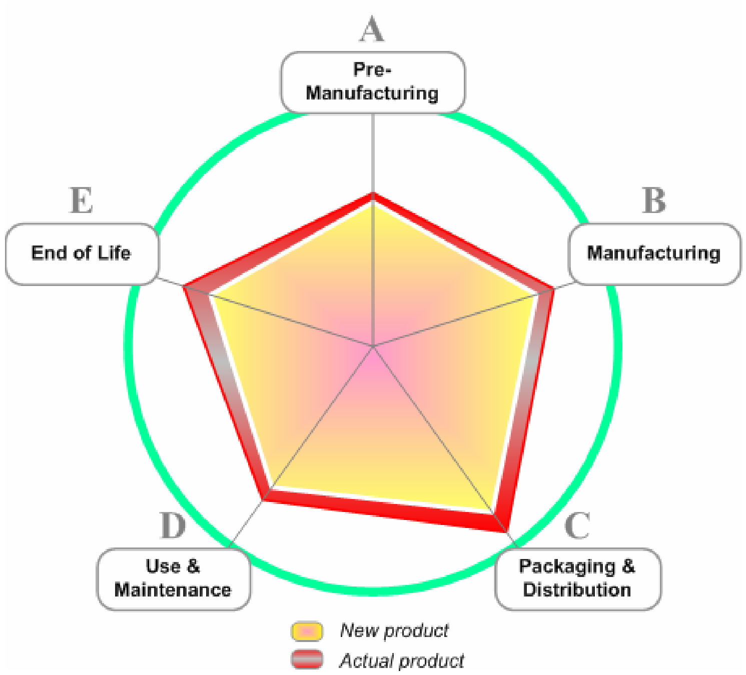

Figure 6. Results of the preliminary environmental analysis summarized in the ESW diagram.

Then we applied the PILOT method, choosing the PDP (Product Development Process) approach, whose most significant results are summarized in Table 1. The application of the Ecodesign PILOT was performed together with technicians of the company that produces the system. Measures with the highest priority "Pr" (30 or 40) are those to which the greatest attention must be paid (the higher the score, the higher the priority of the intervention).

Table 1. Highest priority measures obtained using the Ecodesign PILOT (PDP approach).

PDP Pilot Measure	Pr
Preferably use refurbished components as spare parts	40
Create new or use existing collection system	40
Ensure high return rate	40
Reuse of components in other products	40
Chose environmentally acceptable means of transportation for distribution of product	40
Prefer materials from renewable raw materials	40
Ensure reworkability of worn components	40
Use standardized elements, parts, and components for easy reuse	40
Provide for over measure of material with a view to the reuse of components	40
Take into account end-user's opportunities for disposal and provide for instructions for disposal	40
Preferably use renewable energy resources	40
Preferably use regionally available energy resources	40
Use of materials with a view to their environmental performance	30
Reduce material input by design aiming at optimum strength	30
Provide for testing and measuring devices for the refurbishing of components	30

5.2 Conceptual design

On the basis of the preliminary environmental analysis it was possible to apply the first phase of the QFDE: in fact, the results obtained in the first stages of the design activity were used as the starting point in order to define the "whats" in the I QFDE matrix (Figure 7).

QFD for Environment *Phase I* — Voice of Customer (VOC)	Customer Weight (CW)	Possible angle of wind direction	Resistance for controlling	Sharpness of the shape	Weight	Volume	Number of parts	Number of different materials	Possibility to get dirt	Durability	Energy consum. for material prod.	Amount of recycled materials	Noise vibrations	Toxicity of materials
		Engineering Metrics (EM)												
Highly variable direction of the air flow	5	9		1										
Easy to control the air flow	3	3	9		3									
Quiet	3												9	
Safe to end users	2			9										
Reliable during operation	5									9				
Easy for assemblers to install	1				3	3								
Reduction of raw material	4				3	3	1	1		1		9		
Ease of manufacturing and assembling	2				3	3	9	3						
Ease of trasportation and storage	3				9	9				3				
Less energy consumption	5	9									9			
Protection of the environment during usage	5												9	
Easy to reuse	2						1	1	9	9				
Ease of disassembly and of ordering parts	3			3			9	3		1				
Ease of dismantling and material classifying	2						3	9						
Safe incinerating	3							1						9
Safe landfilling	5													9
Safe emissions	4													3
Reduced need of attention during disposal	2							3						3
	Importance	99	27	32	57	48	57	48	18	79	45	36	72	90
	Relative Weight	0.14	0.04	0.05	0.08	0.07	0.08	0.07	0.03	0.11	0.06	0.05	0.10	0.13
	Rank	1	12	11	5	7	5	7	13	3	9	10	4	2

Figure 7. First phase of the QFDE (shaded part concerns the environmental aspects).

Results show that the “Possible angle of wind direction”, “Toxicity of materials”, and “Durability” are respectively the most important EM (engineering metrics). The next step was to define the functional structure of the product and several alternative concepts: the input for carrying on these activities was the application of the second phase of the QFDE, which has shown that “Box and cover”, “Cam”, and “Rack and pinion” are the most important PC (part characteristics) in this order. It was found that “Box and cover” is important because of its large volume and weight, while “Cam” and “Rack and pinion” have large effects through their functionalities.

5.3 The use of the Eco-Impact Matrix

The results obtained by the PILOT application have been developed in order to transform them in practical interventions following the priorities suggested by the PILOT method and they are correlated to possible modifications/interventions in order to evaluate and define their inter-relationships. For this purpose the Eco-Impact Matrix has been developed: this matrix considers all the changes that can be carried out in the design and that can influence one of the phases of the life cycle of any system. Such changes are those contained in the heading of the columns (Figure 8). On every line a high priority measure is reported; the realisation of such a generic measure can be correlated in various ways to the real possible interventions/modifications (columns). In addition to the environmental analysis, a feasibility study of all possible interventions has been carried out (implementation risk). The “Number” in the first column represents the identification code of each measure in the PILOT software. In other words, the measures are characterised by a priority and every possible intervention/modification can be correlated in different ways with different measures; by supposing that a linear combination is reasonable, a priority number can be attributed (total in the matrix of correlation) to each intervention.

EIM		Row Marerials			Production Process			Packing		Transport		Re - cycling	Reuse		Disposal
ECODESIGN PILOT Measures NUMBER	PRIORITY	Recycled plastic Material	Polypropylene & acetylic resin	Polyamide 6.6 & acetylic resin	Cold molding	Hot – Runner molding	Rotary swaging	Reusable plastic boxes	Cardboard boxes & plastic material	Train	Airplane	Low quality reusable plastic material	Reused parts	Reuse in the production process	Incineration
5 (90)	30	0	0	0	0	0	0	0	0	0	0	0	1	1	0
6 (92)	40	0	0	0	0	0	0	0	0	0	0	0	1	1	0
7 (93)	40	0	0	0	0	0	0	0	0	0.5	0.5	1	1	1	0
8 (94)	40	0	0	0	0	0	0	0	0	0.5	0.5	0	1	1	0
9 (106)	40	0	0	0	0	0	0	0	0	0	0	0	1	1	0
14 (39)	20	0	0	0	0	0	0	1	1	0	0	0	0	0	0
15 (40)	20	0	0	0	0	0	0	1	1	0	0	0	0	0	0
16 (41)	20	0	0	0	0	0	0	1	1	0	0	0	0	0	0
17 (43)	20	0	0	0	0	0	0	0	0	1	1	0	0	0	0
18 (44)	40	0	0	0	0	0	0	0	0	1	1	0	0	0	0
35 (85)	20	0	0	0	0	0	0	0	0	0	0	0	1	1	0
57 (1)	30	1	1	1	0	0	0	0	0	0	0	0	0	0	0
58 (2)	20	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	0
59 (3)	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61 (7)	20	1	1	1	0	0	0	0	0	0	0	1	0.5	0.5	0
62 (8)	30	0	0	0	0.5	0.5	0.5	0	0	0	0	0	0.5	0.5	0
63 (11)	20	1	1	1	0	0	0	0	0	0	0	0	0	0	0
69 (87)	20	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0
71 (110)	20	1	1	1	0	0	0	0	0	0	0	1	0	0	0
84 (91)	40	0	0	0	0	0	0	0	0	0	0	0	1	1	0
91 (105)	40	0	0	0	0	0	0	0	0	0	0	0	1	1	0
94 (101)	30	0	0	0	0	0	0	0	0	0	0	0	1	1	0
95 (102)	40	0	0	0	0	0	0	0	0	0	0	0	1	1	0
103 (113)	40	0	0	0	0	0	0	0	0	0	0	1	0	0	1
108 (16)	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
109 (17)	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Partial scores		100	100	100	25	25	25	60	60	100	100	130	395	395	40
Implememtation risk		0.95	0.6	0.6	0.6	0.6	1	0.8	0.7	0.5	0.7	0.85	1	1	0.9
Totals		95	60	60	15	15	25	48	42	50	70	110.5	395	395	36

Legend: Strong relation **1** | Medium relation **0.5** | Weak relation **0**

Figure 8. Application of the Eco-Impact Matrix.

Needless to say, it is necessary to reflect on the totals, not only considering the priority that comes out from the matrix, but also thinking about the costs and comparing them with other evaluations that are available. At this point it is also important to underline that, once obtained priority numbers of modifications/interventions, only economical considerations can determine whether to carry out all the interventions/modifications analysed or only the first ones. On the other hand, with regard to the matrix, we also have to point out that some choices preclude the possibility to effect other interventions.

5.4 The optimal concept definition

From the application of the Eco-Impact Matrix it resulted that most functions could not be modified so much because the system has to be included in the air conditioner, otherwise a redesign of the whole air conditioner is necessary, which is not the aim of the design task, in accordance with the needs of the system producer. The only aspects which can be modified without changing the general structure of the conditioner consisted in: changing materials; optimizing the internal mechanism which provides the motion of the whole system. For this reason, we focused our attention on the redesign of the internal mechanism, both redesigning its components and choosing new materials and a new production process. Among the various alternatives which have been developed, the one that considers the improvement of the cam, understood as "cam-system", has been chosen as the most effective. In Figure 9 the application of the third phase of the QFDE concerning the improvement of the cam is shown.

Data for Proposal N°.1: "Cam"

QFD for Environment *Phase III* / Engineering Metrics (EM)	Component (PC)						
	Box & cover	User lever	Rack & pinion	Cam	Tie rod	Total Relevance values	EM Improvement Rate
Possible angle of wind direction						0	0.00
Resistance for cotrolling						0	0.00
Sharpness of the shape						0	0.00
Weight						0	0.00
Volume						0	0.00
Number of parts				3		3	0.43
Number of different materials						0	0.00
Possibility to get dirt						0	0.00
Durability						0	0.00
Energy consum. for material prod.	9					9	0.90
Amount of recycled materials	9					9	1.00
Noise vibrations						0	0.00
Toxicity of materials						0	0.00

Concerned Correlation Strength

Figure 9. Application of the third phase of the QFDE to the proposal n. 1 (improvement of the cam).

More specifically, for proposal n. 1, the "cam" is the focus of the improvement, which might be obtained by performing the following interventions:

1. "number of parts": the reduction of the number of components by adopting a cam with an embedded key;

2. "energy consumption for material production": the choice of the hot-running molding instead of the cold molding process;

3. "amount of recycled materials": the improvement is due to both the choice of the polypropylene instead of the polyamide, and the use of the hot molding process.

The evaluation of such an intervention was assessed by performing the fourth phase of the QFDE, that allowed us to evaluate the improvement effect on the environmental performances of the redesigned system (Figure 10).

Data for Proposal N°.1		Engineering Metrics (EM)														
QFD for Environment *Phase* ***IV*** Voice of Customer (VOC)	Customer Weight (CW)	Possible angle of wind direction	Resistance for controlling	Sharpness of the shape	Weight	Volume	Number of parts	Number of different materials	Possibility to get dirt	Durability	Energy consum. for material prod.	Amount of recycled materials	Noise vibrations	Toxicity of materials	VOC Improvement Rate	VOC Improvement Effect
Highly variable direction of the air flow	5	9		1												
Easy to control the air flow	3	3	9		3											
Quiet	3												9			
Safe to end users	2			9												
Reliable during operation	5									9						
Easy for assemblers to install	1				3	3										
Reduction of raw material	4				3	3	1	1		1		9			0.52	2.08
Ease of manufacturing and assembling	2				3	3	9	3							0.43	0.86
Ease of trasportation and storage	3				9	9				3					0.00	0.00
Less energy consumption	5	9									9				0.45	2.25
Protection of the environment during usage	5												9		0.00	0.00
Easy to reuse	2						1	1	9	9					0.02	0.04
Ease of disassembly and of ordering parts	3			3			9	3		1					0.24	0.48
Ease of dismantling and material classifying	2						3	9							0.10	0.20
Safe incinerating	3							1						9	0.00	0.00
Safe landfilling	5													9	0.00	0.00
Safe emissions	4													3	0.00	0.00
Reduced need of attention during disposal	2							3						3	0.00	0.00
EM Improvement Rate		0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.90	1.00	0.00	0.00	▼Σ	▼Σ
Total Improvement Effect															1.76	7.67

Figure 10. Application of the fourth phase of the QFDE concerning the proposal n. 1.

In Figure 11 the final layout of the whole system (on the left) and the details of the redesigned cam (on the right) are shown.

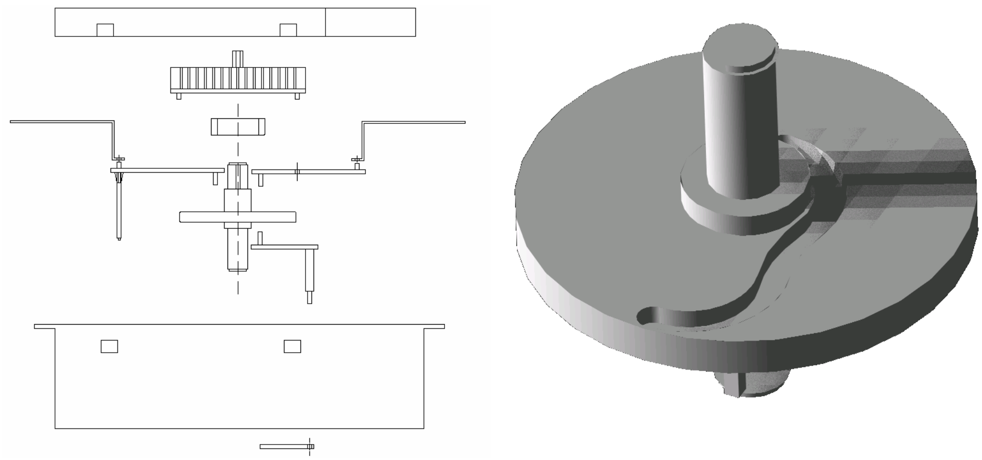

Figure 11. General layout of the redesigned system and particular of the cam.

6 Conclusion

Since the research work carried out up to now has shown a great compatibility between PILOT and QFDE, their use in a coordinated way was studied in a more detailed way, throughout the development of "design modules" which can be used for the solution of partial design problems in different moments of the design process. With this aim in mind, a correlation chart, called Eco-Impact Matrix, has been developed in order to:

- define relationships between the general assessment obtained by PILOT and any possible change/intervention;
- establish the priority of interventions and their impact on the product development;
- provide clear information as input for the application of the QFDE in the embodiment design stage.

The research work carried out from a theoretical as well as a practical point of view, allowed us to significantly reduce the product's environmental impacts. The coordinated use of the ecodesign tools allowed us to optimize the environmental performances of the system and at the same time to make their development economically feasible. It is deemed that this synergy of design tools may be powerful and effective to achieve the best design optimization in this field. The setting up of the methodology and the necessary training with it will require some time, which can be reduced by the execution of further case studies.

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