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Creating Strategy with Demand-side Approach in Early Stages of Ecodesign

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Abstract:

At present, in spite of its increasing diffusion in the industrial world, Ecodesign seems to be not successful from a marketing perspective, i.e. development of successful products. The main reason of this situation can be found in the inability of most companies to persuade customers by appealing to understanding the higher value of their eco-products, which is a critical missing factor that has impeded the success of Ecodesign in the marketplace. With the aim of finding a solution to this problem a detailed study of theories and practices of current Ecodesign was carried out, which brought to light the lack of a well-structured marketing strategy integrated within traditional Ecodesign activities. Following a bottom-up approach, i.e. analyzing several successful case studies, the key factors for the development of competitive eco-products were captured and investigated with the goal of building up a general framework for their introduction into the design process. The output of the study consisted in the development of a novel concept, named Ecodesign Strategy (ES), by means of which designers can take into account and structure the key elements for a successful eco-product: value, customer, system, function and component, and environmental characteristics. The favorable outcome of this approach represents an efficient solution of a new design paradigm, i.e. incorporating marketing issues into Ecodesign activities.

Keywords: product development, Ecodesign strategy, morphological scheme, customer value.

1. Introduction

For some time now, considerable attention has been paid to the development of the so-called "environmentally friendly" products and processes by industries and governments around the world. In fact, a great effort has been made in the last decades to make both the production and the use (consumption) of products more sustainable from an environmental standpoint. As a result, the number of environmentally conscious products (eco-products) available on the market is ever larger, as well as, from the designers' point of view, the spread of numerous guidelines [1, 2, 3, 4, 5] and design tools is registered (e.g.[6, 7]).

As a matter of fact, the use of Ecodesign ("environmentally conscious design") tools can be regarded as a successful way to address designers in the development of eco-products. However, making a deeper investigation on this, it emerges that the implementation of Ecodesign, is very efficacious when focuses solely on the supply-side aspects. On the contrary, such an approach has not necessarily been successful when viewed from the demand-side point of view [8, 9, 10]. This means that Ecodesign still shows room for improvement by manufacturers, starting from the analysis of its weakness in facing with marketing issues.

One of the causes of this situation is that current Ecodesign lacks a method for the effective identification of the appropriate target market, i.e. a group of customers that the company has decided to aim its production, for a specific product [8, 11]. Another problem consists in the difficulty of establishing environmental competitiveness for products just by following traditional Ecodesign methods [12]: actually, they certainly help manufacturers to satisfy mandatory requirements, but they are not sufficient for competitiveness in the marketplace. Based on these, if Ecodesign approaches are to be more successful from a business perspective, "strategies" of Ecodesign (named Strategy for Ecodesign or SfE) must be investigated. It should be emphasized that in this context the term "strategy" is intended to mean "the approach that manufacturers adopt for the purpose of selling their ecodesigned products".

Therefore, this article proposes a concrete and practical methodology which can be utilized by designers to create an ES at the earliest stages of the product development process, obtaining in this way useful information concerning the impact of the product on the market (e.g. how the product could provide value to possible customers) since the first steps of the design process. Needless to say, it is well known that the earlier an intervention is carried out during product development activities, the higher efficiency and effectiveness of results obtained.In details, the paper is structured as follows: Section 2 reveals problems in current theories and practices of Ecodesign and the marketing of eco-products, underlining the lack of strategies for design. Section 3 investigates different aspects that should be taken into account for the development of successful eco-products. In Section 4 the research approach is shown, beginning with the analysis of good practices in industry, up to the identification of design key-factors. Based on these, Section 5 proposes an ES, which can be used at the earliest stages of product design process, following a demand-side approach. At the same time, the procedure for its application and suggestions for the optimization are also provided. Then, in Section 6 results obtained are discussed, whilst Section 7 presents conclusions and implications for future research works.

2. Ecodesign in Practice

In recent years, the development of products with lower environmental burdens is, indeed, constantly increasing at different levels, where the basic level is represented by the path that companies must follow in order to comply with environmental policies and regulations made by governments [13]. At the same time, the goal is sometimes to satisfy the environmental concerns which come from customers or from other product's stakeholders. Nevertheless, it is already recognized that making effort only on the production side does not solve the problem; instead, addressing both the consumption and the production sides is crucial (e.g. [14, 15]) for the success of the product on the market. Hence, there should be a good balance among the three main agents (i.e. stakeholders) involved in the products' life cycle: manufacturer, customer, and government. A good balance here means a situation where a manufacturer considers, with the same attention, both regulations and customer needs/wants. However, a manufacturer does not have a good balance in a typical case, as shown in Figure 1: the flow of information/communication among the main stakeholders has not the same intensity in all connections (inputs and outputs).

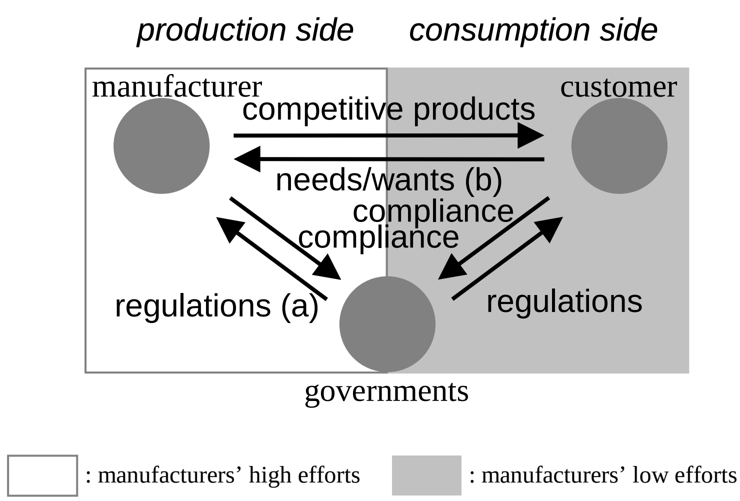

Figure 1. Unbalance in addressing Ecodesign stakeholders by a manufacturer.

To explain this, it has to be said in advance that nowadays environmental performances of products are becoming the target of an ever greater number of laws and regulations in most countries: in particular, the efforts made by the EU (European Union) and the Japanese government must be taken into account. Among them, the following appear to have larger impact on manufacturers:

- Reduction of waste from electrical and electronic equipment (e.g. home appliances) by means of increasing re-use and recycling opportunities, and improving the environmental performance of these products by producers (e.g. WEEE (Waste Electrical and Electronic Equipment) [16]).
- Control of products containing hazardous substances and the extension of producers' responsibility (e.g. RoHS (Restriction of Hazardous Substances) [17]).
- Obligation for manufacturers to consider their products' entire life cycle, as well as to assure their compliance with regulations by means of: internal design control, implementation of an environmental management system, use of eco-labels, etc.
- Procurement of relatively environmentally friendly products under the Green Purchasing Law in Japan, Green Procurement in the EU, etc.

- Improvement of the energy and environmental performances of energy-related products (e.g. the 2009/125/EC Directive in the EU [18], which is a development of the well-known EuP (Energy using Products) directive [19], which sometimes is still called EuP even though it concerns energy-related products).

As a result, these laws effectively make activities such as "design for recycling", "design for waste reduction", "design for reuse", etc. compulsory for a wide range of products, greatly influencing designers' choices. Such a trend affects companies' perspectives concerning the opportunity to enter in the so called "eco-market" and influences their marketing analyses. It also significantly affects companies' strategies for the entire product development process, from planning and design to production and distribution. Thus, they pay significant efforts to address the regulation issue.

On the other hand, most manufacturers have put relatively low, or at least insufficient, efforts on the customer side (see right-side of Fig. 1), as shown from an analysis in the field of environmental marketing (e.g. [10]); this has resulted in disappointment from green consumers, i.e. customers who give priority to environmental characteristics of products in their purchasing process. A meaningful analysis of such a lack of effort can be found, for instance, Stevels [12], who argues that it is difficult to establish environmental competitiveness for products just by following current Ecodesign methods, since many of the environmental properties of products supported by those methods are becoming established in response to regulation or legislation that manufacturers must comply with.

There are indeed methods/tools for addressing customer issues. Most notably in engineering context, the QFD method (Quality Function Deployment [20]) has been developed for this purpose [21, 22, 23, 24], resulting in several different tools [25, 26], that can be regarded as an attempt to improve traditional QFD performances by means of introducing environmental concerns as default inputs to the method. They address neither customer segmentation nor differentiation between needs and wants. At the same time, also other tools more marketing oriented have been used in product development with the aim of taking into account customers' issues, such as Customer Satisfaction techniques and Benchmarking analyses [27].

Limiting our analysis to Ecodesign context, it has to be noted that current Ecodesign methods still focus too much on the production side, so that customers' value is not being sufficiently addressed [8, 9, 11]. Therefore, to differentiate a product in terms of value is difficult if manufacturers use only presently available Ecodesign methods.

Looking at product design activities on the whole, in fact, it is recognized that the necessity of marketing competitive products involves the reduction of time-to-market as elemental key-factor: this has led most companies to optimize the process of developing new and innovative products. They must even offer diversified production for the purpose of satisfying different customer needs. In such a context, it has to be realized that traditional product development processes (e.g. the approach and models discussed in [28] or in [29]) do not directly incorporate environmental concerns until the final phases, when most of the characteristics of the product are already defined.

In addition, Ecodesign has often been considered incompatible with the achievement of optimal performances of products: actually, in some cases, it has been regarded as having a negative impact on the "traditional" properties, such as safety, reliability, and aesthetics (e.g. [30, 31]). Furthermore, it is sometimes also feared that Ecodesign increases the costs that companies have to bear (e.g. [32]).

Companies are finding themselves increasingly obliged to consider the production of eco-products; as mentioned above, the reasons for this are both a higher demand for environmentally friendly products by customers and, at the same time, stricter environmental regulations covering a larger range of products. These activities must be standard procedures, not project-based ones. Thus, they are forced to modify their technological background: this often is achieved by improving the production process, i.e. using an approach which could be considered as the middle point of the shift line from "end-of-pipe" interventions (i.e. thinking about how to reduce the impact on the environment only after designing and developing the product) and the "life-cycle-thinking" ones, as schematized in Fig. 2. This approach consists in an often-adopted strategy of upgrading already existing products, (i.e. improving their performances) rather than rethinking the concept of a new product from scratch.

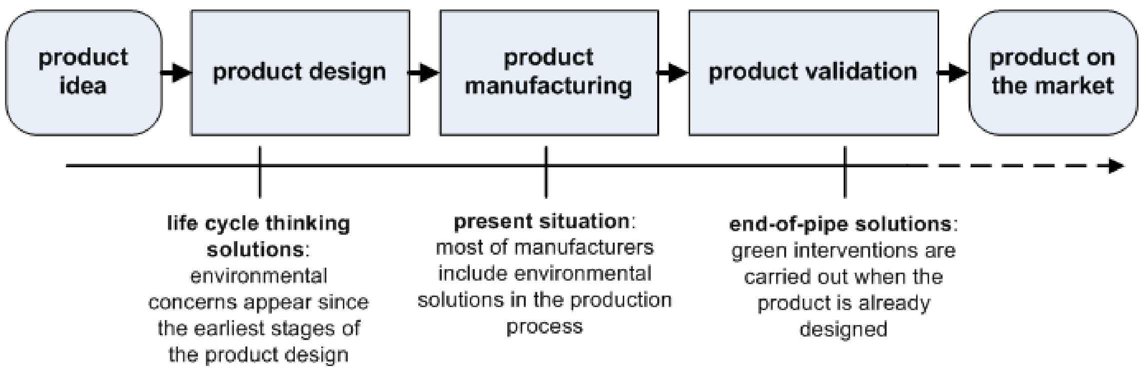

Figure 2. Interventions during the general product development process.

In practice, products generated from the situations recalled above appear to introduce environmental concerns only after the product structure is determined. Even with this weak design solution, manufacturers often send a message about environmental consciousness to their customers in their environmental communication. A large number of eco-products on the market today are the result of such a weak version of Ecodesign. For instance, let us consider a notebook made of recycled paper. This is an ecodesigned product due to its environmentally conscious material selection. However, this sometimes consists of such weak paper that the notebook is quite easily torn to shreds, while significant improvement of the quality of some recycled papers has been observed. This adoption of easily-torn papers is not good Ecodesign for long term use of the notebook; however, it represents a good solution for a memo pad designed simply to record information for a short time. This vague solution of Ecodesign is caused by the absence of effective customer identification [8, 11]. In other words, most of today's eco-products are not really effective, since they lack a product concept and a business strategy appropriate to the environmental consciousness.

There is no doubt that many research and practice-based approaches to environmental marketing (sustainable marketing) have been recently carried out (e.g. [33, 34, 35]). Some of them (e.g. [10]) target green consumers, which are not dominant at present, even in developed countries. These approaches fail to reach the largest part of the market. Others deal with consumers in general: for instance, Meyer proposed a marketing strategy addressing primarily the costs and benefits applicable to any consumer, rather than beginning with environmental concerns [36]. Benefits such as function, appearance, image, and self-esteem may help customers to find added value in products; but this interesting approach could be much more effective if integrated within the design stage.

In conclusion, there are several approaches that are effective with respect to specific aspects, but they are not integrated with various concerns from the entire production and consumption system. Even the QFD-based methods are not sufficient due to the lack of strategy issues. An attractive approach to improve the success of Ecodesign has to target the earliest stage of the design process, where all the relevant issues are defined. This might be more or less correct in product development due to the already-established shift from “technology push” to “market pull”. For example, customer identification using the concept called Persona [37, 38] has recently received much attention in general design [39]. Based on these considerations, the present article analyzes how Ecodesign should operate from a business perspective, in order to improve it, i.e. with the aim of giving an answer to the following research question: how companies can match marketing strategies together with environmental issues, while designing environmentally conscious products? Bearing this in mind, the first step consists in the understanding of which are the characteristics of environmentally conscious products, and which aspects should be taken into account while designing them.

3. Characterization of Environmentally Conscious Products

The development of a proper strategy of Ecodesign is strictly interwoven with the nature of the product to be ecodesigned. In other words, when designers have to decide the focus and the level of eco-friendliness of a product, it is fundamental to consider the fact that its characteristics are usually perceived in different ways from the various stakeholders involved in its life cycle (e.g. manufacturers, customers, society, etc.). Obviously, this is true also in the evaluation carried out by stakeholders, consciously or unconsciously, of different aspects related to the characteristics of eco-products.

From a general point of view, we have to take especially into account different types of industrial products, as discussed in [40][1]. Starting from these assumptions, a more detailed analysis can be carried out, considering that the environmental sustainability of a product is influenced by other numerous product properties such as reliability, safety, maintainability, manufacturability, durability, modularity, etc. [41, 42][2] Actually, the assessment and improvement of those product’s properties both allows designers to develop a measure of the product’s sustainability, and shows which characteristics must be modified.

Therefore, making a good strategy for Ecodesign requires a holistic approach, which considers the product from the following different four perspectives:

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[1] Products can be designated as durable products, consumer goods and the so-called “time zero” products, as discussed by [40]. Each one of these categories has a different environmental profile considering their whole life cycle.

[2] As a matter of fact, a product is influenced by numerous properties, which could be distinguished in internal properties (technical aspects, such as dimensions, tolerances, etc.) and external properties (the characteristics which can be detected directly by customers, users, etc.) [41, 42]. More specifically, “external properties” can be identified, from the engineers’ viewpoint, for any kind of product. The most effective address which can be followed with the aim of achieving such a goal can be considered the methodical design theory, e.g. the systematic approach based on a continual improvement of all design stages proposed by Hubka and colleagues in the 80s. This theory has been followed by a large number of researchers in design-research communities. They have focused on design activities in product development and led development of design activities as an independent discipline in the engineering field (Design Science).

- Product considered as a system, which allows designers to consider not only the improvement of its life cycle, but also eventual infrastructures and/or supports for its end-of-life (e.g. by means of optimizing disassembling, reusing, recycling, etc.). This is suggested due to the required holistic approach.
- Product value, i.e., the value that customers assign to a certain product. From the production viewpoint, producers must look for the product's qualities (i.e. the performance the product can offer in order to meet customers' needs) in order to meet customers' value, including the ones that are not explicitly requested (the so-called "unspoken quality" of a product). Yet, the customers' viewpoint shouldn't be forgotten either.
- Product function, i.e. the function the physical product is designed for (in other words, what the technical system should do in terms of transforming an input to an output or creating an effect[3]), following the fundamental model proposed by the above mentioned Hubka's approach, which abstracts technical systems as a general transformation system [39].
- Product components (i.e. physical parts of the product), focusing for example on the choice of materials, number of components, number of parts, etc. Needless to say, this influences the product's properties (e.g. recyclability, reliability, assembling, disassembling, etc.) and thus its whole life cycle.

On the basis of these considerations, the following aspects can be outlined as significant issues for the design of successful environmentally conscious products:

- Value and customer acceptance (i.e. aspects concerning the market sphere);
- Product system, function and components (i.e. aspects related with the product structure and functions);
- Environmental performances (i.e. aspects regarding environmental burdens and the compliance of the product with environmental legislation).

These represent different aspects which have to be taken into account by manufacturers in product planning and development activities. They can be seen as the merging of traditional Ecodesign approaches (more focused on technical aspects) together with business-oriented ones (aimed at marketing and company strategies). Integrating these aspects on life cycle thinking with traditional design processes is impeded by the lack of a well-defined design framework. Their successful integration, instead, would solve the design hindrances and limitations caused by the many different requirements (both from a technical standpoint and from the customers' point-of-view) and by the need for respecting environmental standards and regulations.

4. Research Approach

Our research approach consisted in a bottom-up approach, i.e. analyzing several successful case studies, we tried to capture some key factors for the development competitive eco-products and then we

[3] It is fundamental for designers to understand the proper function of a product in order to develop a good which completely satisfies customers' expectations, avoiding over-designing. As a matter of fact, it is quite common, especially in the sector of electronic appliances, to put on the market products able to perform a large number of functions, most of which are never used by the average customer (e.g. mobile phones, household appliances, etc.). This overload also affects the environmental characteristics of the product.

investigated them with the aim of building up a general framework for their introduction into the design process.

4.1. Good Examples

A research work carried out in this ambit has shown that there exist several examples of company's design teams who tried to give an answer the research question mentioned at the end of Section 2. For instance, the following case studies concerning successful eco-products can be taken into account.

The first example of good practice is represented by the hair dryer [43] produced by Hitachi in Japan. It is obvious that customers in general have different tastes with respect to color. This product has succeeded in allowing customers to choose their favorite housing colors (taking advantage of the usage of system element). Normally, this might have been achieved by preparing differently colored plastics. However, this option is not attractive in terms of recyclability; colored plastic is more difficult to recycle than half-transparent plastic, because the latter can be utilized in processes before getting colored. Actually, the housing of this dryer is half-transparent, with the ability to place one of three differently-colored sheets inside the housing. Therefore, users can enjoy their preferred colors by exchanging the sheets as shown in Figure 3.

(a) Components (b) Coloring structure

Figure 3. Hitachi hair dryer with option for changing housing color [43].

The cooking pan "Green-Pan" (Figure 4), produced by the Italian company Bialetti Industrie S.p.A.: this product was developed paying a significant attention to environmental issues (a high percentage of recycled materials (e.g. aluminum) and bio-materials (e.g. handle made by bamboo)), improving at the same time the product's aesthetics and ergonomics [44]. For instance the use of bamboo, which is a renewable raw material from agro-forestry having a very good strength-weight ratio, also constituter an attractive element appearance point of view, as well as a trendy element per se (bamboo is often considered as an "exotic" fashionable material in western Countries).

A further example concerning a different type of products is represented by the eco-cell-phone manufactured by NEC. It was introduced in the Japanese market (see part of an advertisement for this product in Figure 5) in late 2005. This design project began with the motivation to develop an environmentally-friendly cellular phone. During the initial step, there was a risk of failing to implement customers' value when making the product environmentally friendly [46]. However, they avoided losing customer value or having to use "environmental consciousness excuses".

Figure 4. The “Green-pan” [45]

Figure 5. Part of an advertisement of the eco cell-phone [46].

Analyzing these examples, some common key-points emerged, allowing us to bring to light significant elements which can be implemented in a general Ecodesign framework for the development of a specific design procedure able to answer to our research question.

It has to be underlined that the selection of case studies was not carried out taking into account the sales data (i.e. the most sold products for each product family/category)[4]. Instead, we selected some products put on the market, which combine high environmental performances together with an added value which makes them more attractive from the customer point of view. Moreover, manufacturers of the selected products use the solutions implemented to make their products “greener” (e.g. the phone shell made by bio-plastic or the pan handle made by bamboo) as means of producing an added value on the product. In other words, while environmental aspects of a product usually tend to be a limit or a constraint to other products' properties (such as aesthetics, ergonomics, functionality, etc.), instead in these cases the environmental improvements provide also a higher qualitative product value for consumers, augmenting the above mentioned product's properties. For these reasons, we considered the selected case studies as examples of good practice in Ecodesign, i.e. successful solutions from environmentally conscious design standpoint.

As mentioned above, the analysis of several case studies was performed in order to gain information concerning the strategy followed by companies in the development of their products. The goal of this study was the identification of common steps/elements which led to the development of successful eco-products, and their relationships with the Ecodesign issues discussed both in Section 2 and in Section 3. In order to make this bottom-up approach clearer, the analysis of the eco cell-phone is discussed in details.

4.2. Case study

The example considered consists in the analysis of the solutions achieved in designing an "eco cell phone" for the Japanese market. The use of cellular phones (or handsets) has become indeed widespread in last decade, and phones are often seen both as a necessary means for communication, and as a fashion item to be purchased and changed to follow the latest trends. Several studies have analyzed their life cycle impact from an environmental point of view (e.g. [47, 48, 49]), and imply that the environmentally conscious design of a cell phone can be a huge project considering its complexity. In addition, this product is one of the numerous products affected by the environmental regulations mentioned above[5]. The company has individuated as target customers women in their 20s, 30s and 40s. They succeeded in implementing value of the third and fourth type: feeling nature from the appearance of fibers on the surface of the chassis (see Figure 6). The material for the chassis is so-called bioplastics made from corn with plant (kenaf) fibers[6], instead of pure petroleum plastic. This considerably reduces GHG (Greenhouse Gas) emission from a life cycle perspective according to the product brochure [50][7] and uses renewable resources. It is true that the kenaf fibers play an important role in the strength but they are, at the same time, critical for customers to feel nature. The authors' independent survey discovered that a relatively higher proportion of target customers would pay for this property.

[4] As far as sales data are concerned, in accordance with information collected from manufacturers and some retailers (respectively in Japan and in Italy) at the time the present research work was carried out, these products achieved a good popularity on the market; nevertheless, market shares were not considered quantitatively.

[5] Actually, apart from health and safety obligations (e.g. the indications of the World Health Organization concerning the ELF (Extremely Low Frequency) emissions, etc.), rules regarding the environmental impact of the product and its components have to be considered (e.g. the WEEE directive, which explicitly mentions this kind of product).

[6] Although 10 % is still from petroleum plastic, the other main ingredients are from renewable resources. Therefore, this is a type of bioplastics: in details, kenaf is a natural fiber used as reinforcing agent for the polylactic acid (PLA); kenaf fiber is used to enhance the PLA's heat resistance and rigidity. According to the company's report, 20% Kenaf fiber reinforced PLA composite of impact strength can be higher than 20% glass fiber reinforced ABS. Moreover, this fiber from an the East Indian plant Hibiscus has a notable carbon fixation effect (1.5 t of CO_2 in the air is absorbed per 1 t of kenaf). Additional information can be found in: [51].

[7] It should be noted that some assumptions exist. Scientific studies of environmental impacts of bioplastics are shown in e.g. [52].

The most relevant characteristic of the product is represented, then, by the shell, which is made of a kind of bio-plastic (i.e. plastic based on renewable resources [51]) obtained from corn. The environmental characteristic of this material is potential reduction of resource consumption (due to decreasing the usage of fossil fuel and natural gas) and carbon dioxide [CO_2] emissions[8] (read more details in [52, 53, 54]). At the same time, this characteristic represents also a successful factor for customers, due to the possibility for them to choose by their own the cover they like most, as well as to change it whenever they want.

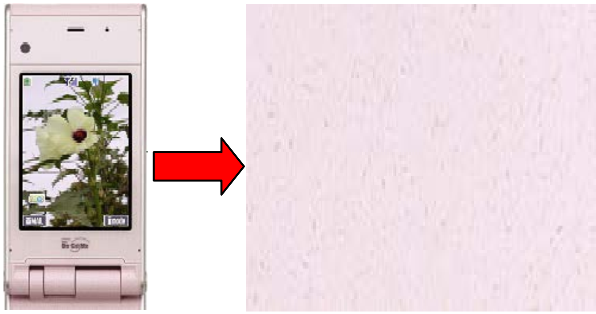

Figure 6. The surface of the chassis (edited from [46]).

4.3. Key-factors and design steps

More in details, the main elements which emerged from the analysis of the design activities carried out for the development of the phone shell are summarized as follows along the time line of the design process:

1. From the scientific viewpoint, the company design team took into account possible reduction of usage of resource and CO_2 emissions (*environmental characteristics*) from the shell (*component*) made from bio-plastics.
2. When designers considered *function* of the shell (*component*), which is to protect the contents of the telephone, they found out that there could be a problem of heat resistance if using some types of bio-materials. Thus, they proposed to adopt bio-plastics with plant (kenaf) fibers, which have no practical problem in terms of heat resistance [55]. As this component is newly generated, they performed again the possible environmental assessment of the product.
3. They confirmed that the *component*, the shell, has potential to realize reduction of CO_2 emission from a life cycle perspective, partially due to the kenaf's efficient fixation of CO_2, assuming neither fertilizer nor pesticide is used for growing kenaf [56]. They also foresaw "feel of a natural material" (*value*) originating from the environmental characteristics of the shell (*component*) from the user's viewpoint.
4. They reconfirmed that, on top of functional feasibility, the potential to realize reduction of CO_2 emission and resource consumption is still valid.

[8] It should be noted that some assumptions exist. Scientific studies of environmental impacts of bioplastics are shown e.g. in [52, 53, 54]. Among others, the IFEU [54] reports poly(lactic acid) (PLA) specifically showed lower fossil resource consumption, global warming and summer smog values in comparison with e.g. PET and PP.

5. In order to identify interested customers, a market survey was conducted using the method proposed in [57]. This survey was conducted with 1,000 persons living in Japan in August 2007. They consisted of 10 groups each which were composed of 100 persons who were characterized by age, gender, and occupation (as shown in Table 2). An explanation concerning environmental characteristic (i.e. "this material potentially reduces usage of resource and CO2 emissions, and provides 'feel of a natural material', while its durability is equivalent to that of other types of plastics normally used") was given to the respondents. Table 1 shows the general results of the survey.

   For instance, from Category #1, i.e. businessmen (male) between 20 and 29 years old, the majority (51%) recognized the adoption of this material as a want (corresponding to the Type 4), and fewer (13%) recognized this a need (corresponding to the Type 3). An overall finding was that most of the population (78%) evaluated this product positively at their buying decision.

Table 1. Percentage of respondents from each customer category

Customer category				*Need*	*Want*	Uninter-ested	Else [*]
ID	Occupation	Gender	Age				
1	Business Person	Male	20-29	13	**51**	30	6
2			30-49	21	**57**	22	0
3			50-	25	**50**	23	2
4		Female	20-29	29	**41**	30	0
5			30-49	32	**53**	12	3
6			50-	**44**	43	10	3
7	Housewife		20-29	24	**50**	25	1
8			30-49	26	**60**	12	2
9			50-	37	**50**	12	1
10	Student	Male/ Female	20-29	32	**45**	21	2

[*] This column includes respondents who were judged to be suspicious or recognize the other material as a "want".

The difference between genders is that females showed higher percentages of need than males in every age grouping from the Business Person category. A closer look at the results shows that the eldest businesswomen (Category #6) had the highest percentage (44%) for those who evaluated the bioplastics to be a *need* (as shown in Figure 7). In big contrast to this, the youngest businessmen (Category #1) had the lowest (13%).

From this survey, Category #6 was suggested to be a promising customer category. In addition, other categories, especially Category #1, were found to show relatively low interest in this product. This possibly means a negative influence on other types of customers than Category #6, since this product may not be the best option economically for all the categories. This influence created the need to modify the product concept, and the design team carried out a new investigation concerning the product concept and its functionality.

The output of this analyses consisted in the idea of solving such a conflict with respect to customization system: this type of shell is provided for the concerned customer category, while the other type of shell made of ordinary plastic is for other categories.

They represented the product with the shell made of bio-plastics with plant fiber and confirmed that the elements have no conflict.

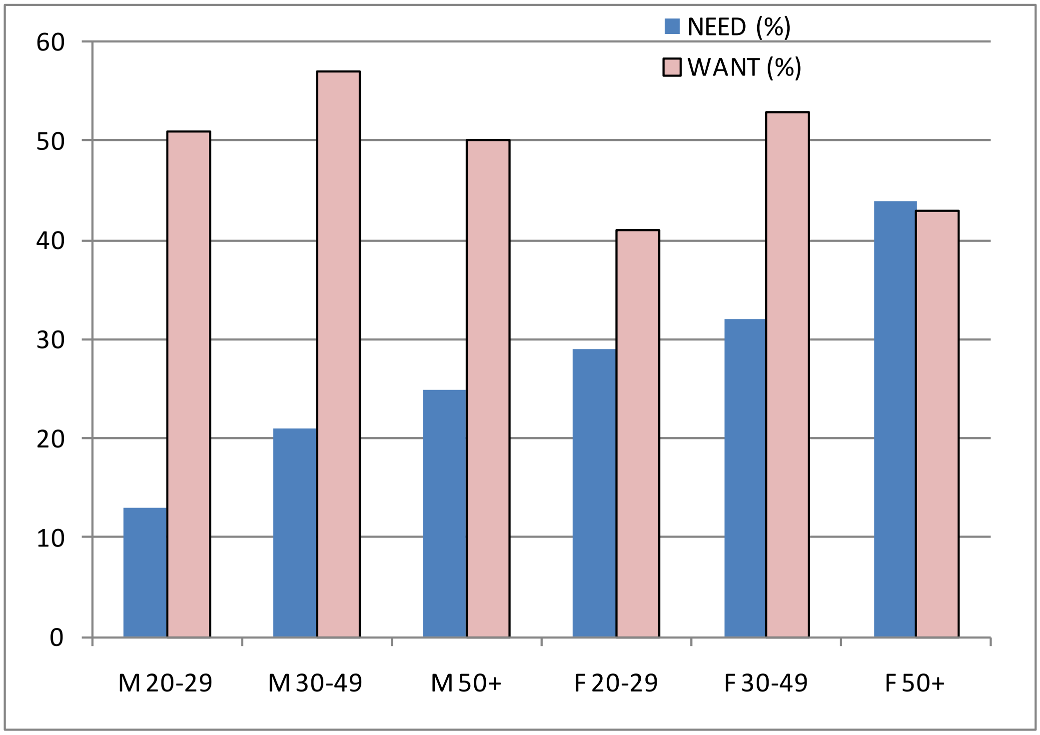

Figure 7. Preferences according to different gender and age bracket (note that students' preferences are not taken into account in this figure).

5. Ecodesign Strategy (ES)

The elements pointed out in the analysis of the design activities which have led designers to the development of the eco cell-phone were matched with the Ecodesign issues proposed at the end of Section 3. This allowed us to define a general framework for a possible strategy for Ecodesign, which we named "Ecodesign Strategy" (ES), to be implemented into the design process.

5.1. Characteristics of the ES

Based on the four perspectives suggested in Section 3, the proposed ES is composed of the following five elements, which are mutually interwoven:

- *Value*
  Here, value is whatever a customer needs or wants from the product, which is in line with one type of definition by Zeithaml [58]. Value can be economic, functional, or emotional. In ES, it is a vitally important aspect, since value lies at the core of business activities and all design activities should be based on it.
- *Customer*
  Following the necessity of value, it is immediately necessary to address characteristics of customers. Here, it is possible to adopt the Persona concept [37, 38].

- *System*
  Here, "system" means a composition of the product and its surrounding products, including users' activities. The system concept should be a part of ES, because the design of the system at an early stage can affect decision making at later stages. Moreover, this is beneficial, because it allows designers to work from a broader perspective than simply that of the target product itself. The system differs from that of Product-Service Systems [59, 60], as the system here includes no service activities [61] offered by the company (e.g. maintenance service). ES focuses on referring to physical products, not to services.
- *Function and Component*
  These are needed, as they play an important role in traditional engineering design (e.g. [28, 41, 42]) as well.
- *Environmental characteristics*
  It is taken for granted that environmental characteristics of a product are important in ES and constitute a fundamental input to the Ecodesign activities. They are chosen e.g. from environmental impact categories or inventory parameters in life cycle assessment (LCA), or from some peculiar parameters of the product. Examples are an amount of consumed energy/material or CO_2 emission, impact on resource depletion, and recyclability. As the design team is supposed to include a person with environmental knowledge, it should not be difficult to capture appropriate environmental characteristics from the product properties.

It is crucial that every item above be identified, if available, when an ES is structured. In addition, there must be a systematic connection and no contradictions between items. Environmental characteristics must also be organically connected to the value for the customer (on the other hand, the function and component, and the system are adopted to provide the value). For example, consider a high ratio of recycled material (*environmental characteristics*) that is expected to generate value for *customers* not concerned about recyclability: companies should avoid such an ES with these two elements, as they are not *connected* to each other. An example of a *contradiction* would be a copier with a mode to save energy (*function*): this reduces energy consumption (*environmental characteristics*), but if the shift from energy-saving to normal mode requires a long time, it is in conflict with the instant response (*value*) expected by customers who hate to wait for a copier to switch to a normal mode.

The ES can be represented by a morphological scheme [62, 63, 64][9], which is used to present crucial elements in a qualitative manner, and allows designers to know the appropriateness of a blueprint of Ecodesign at an early stage of Ecodesign.

The ES of the eco cell phone is described in Table 2: it has to be underlined that the items appear systematically connected and have no conflicts with each other. For a different category of customers, who do not appreciate the value of feeling nature, a different type of product other than Eco cell-phone was foreseen: a chassis made from another material, i.e. ordinary plastic.

[9] The morphological-scheme approach is widely used in order to generate new design solutions allowing designers to "force divergent thinking and to safeguard overlooking novel solutions to a design problem" [62]; its use in the Conceptual phase of the design process is underlined in Pahl and Beitz [63] and in Hubka and Eder [64].

Table 2. Representation of an ES for the eco cell phone

Customer	Businesswomen over 50
Environmental characteristics	♦ Less CO_2 emission ♦ Less resource depletion
Component	Shell made of bioplastics with plant fiber
Function	Provide communication (for the whole product) and protect the contents (for the component)
Value	The above-mentioned environmental characteristics and "feel of a natural material" as a *need*
System	Customization of the shell through exchanging with ordinary plastic material

5.2. Steps for Creating the ES

Summarizing the activities described in Section 4, it emerged a procedure, which could be incorporated in the earliest design stages of the design process, which we called "Ecodesign Strategy", which precedes the traditional Ecodesign phases[10]. The ES phase consists of the following steps:

Step 1. Considering environmental characteristics of the product:

The product development team takes into account *environmental characteristics* (captured by environmental engineers), which can be *value,* of the concerned product. If possible, *components* or *function* relevant for the *environmental characteristics* are also identified.

Step 2. Investigating feasibility and modifying the product concept:

The designers further identify or generate *function* and *components*. The first goal is to meet the functional requirements of the product in a feasible manner, while the second is to make sure the product could realize *value* without any conflict. If necessary or effective, the utilizing *system* is considered. If a new *function* or *components* are generated at this moment, the team goes back to Step 1.

Step 3. Grounding the product on customer value:

The team targets *customers* who appreciate the *value* of the *environmental characteristics* and *function* (based on market information). If this creates the need to modify the product concept, the team goes back to Step 2.

At this new stage, the design team is able to generate an ES so that it meets the properties described above, with the aim of clarifying the specifications the manufacturer should follow when addressing the product's Ecodesign and its introduction to the market. This will be a part of how the company conducts business with the product. A scheme of the ES procedure is shown in Figure 8.

Because a product has a certain number of environmental characteristics, the proposed three steps have to be conducted for all of the concerned characteristics. Thus, designers can determine which ones will be prioritized depending on the target customers and the company's strategy. In order to incorporate

[10] In this context, traditional phases of the design process are considered the ones proposed by most of Authors in the engineering design literature: 1. Design Task Analysis; 2. Conceptual Design;3. Embodiment Design; 4. Testing and Prototyping. Examples can be found in Pahl and Beitz [63] or in Hubka and Eder [64]; similarly, the reference for the design process applied in Ecodesign can be considered the one proposed by the technical report [2].

the quantitative preferences of the target customers, conjoint analysis [65] could be employed (see an example in [66]).

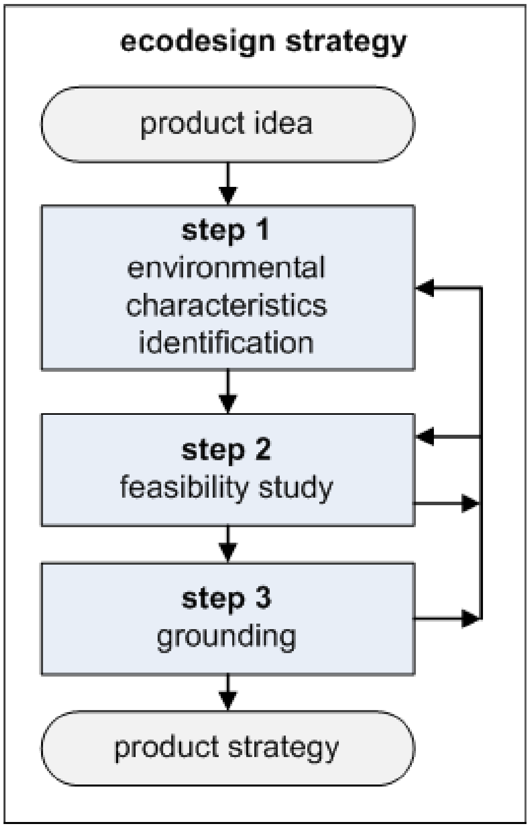

Figure 8. Scheme of the ES procedure

In addition, how to create the ES is also proposed: as an example, in Table 2 a representation of the ES emerged from the eco cell-phone case study is shown. Nevertheless, it is obvious that various environmental characteristics should be considered in the ES: it is insufficient to improve only one environmental characteristic in the proposed Ecodesign process, since the more characteristics addressed in establishing an ES, the more effective the ES is produced with respect to environmental performances of the product. However, the design team has to bear in mind that reducing the number of characteristics addressed simultaneously makes design more efficient from the viewpoint of problem solving in general (e.g. [67]).

In Figure 9 the use of the ES is represented, i.e. its integration into the design process. Needless to say, the implementation of the ES elements can be foreseen even after the planning stages of the design process. In fact, depending on the nature of the product which is analyzed, some elements have more or less importance (as implied by [68]) at different stages of its design process. For instance, in the case of the eco-phone, the product's value appears significant in the product planning stage; at this stage, the product's components and parts have less influence. The opposite situation can be found in the "embodiment design" stage, i.e. the design stage where, beginning with the product concept, the product layout is defined (including dimensions, materials, tolerances, etc.).

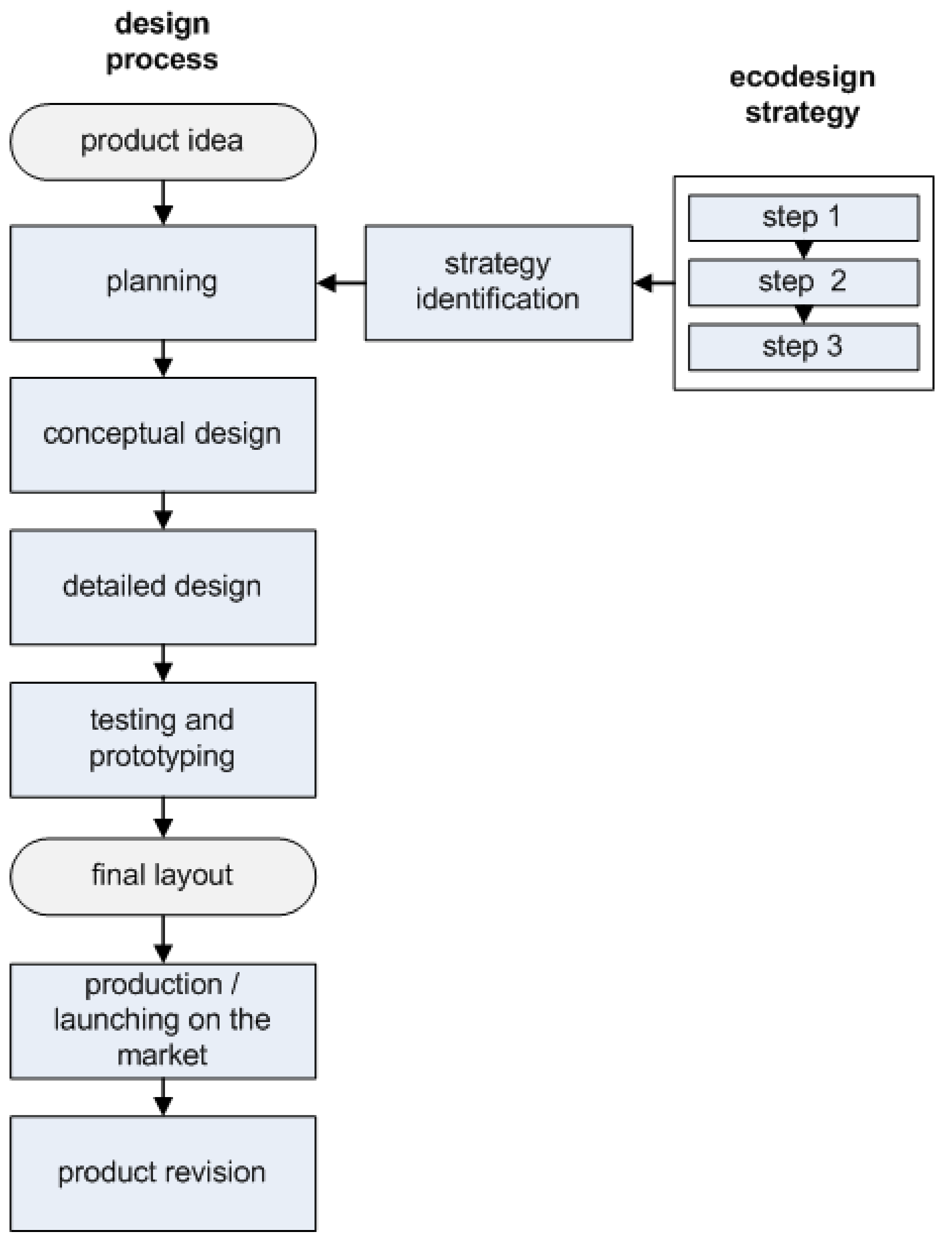

Figure 9. Integration of the ES procedure within the design process

At this point it is important to underline the fact that the difference between an ES and a traditional design strategy lies in the approaches: the ES provides environmental characteristics organically connected to other design elements, addressing designers while considering environmental aspects during design activities. Traditional design strategy, which does not explicitly consider ecological concerns from the beginning, could lead designers to develop a product with a higher impact on the environment. In this case, “end-of-pipe” design solutions may not produce the same results as those generated with ES. At the same time, it should be considered from a practical point-of-view (i.e. taking into account operative needs of manufacturers) that a support framework like the one proposed in this section is effective, especially for small and medium-sized companies with limited resources at their disposal.

5.3. How to optimize the ES

In order to improve the efficiency of the ES phase of the design process, engineers might have difficulties in facing with non technical issues, e.g. marketing aspects, especially in the case of small and medium sized companies (SMEs) which rarely have at their disposal enough resources to be supported by marketing specialists. Moreover, the definition of the *value* might be yet too vague for designers to refer to as a source of information for customers' buying decisions in later stages, especially in the case of environmental characteristics. Therefore, with the aim of helping designers to classify the concerned value, the following four types of *needs* and *wants* are introduced: responding to these would enrich the information about strength of value in ES.

1. Indications from environmental regulations

These are concerned with mandatory requirements of environmental legislation (e.g. directives mentioned in Section 2), which manufacturers cannot avoid. In this case, compliance itself is the entire issue: e.g., HARL in Japan requires a manufacturer of TV sets to recycle 55 % of the product, but it does not require further environmental improvements.

2. Needs from customers

These are requirements from customers, excluding those that are related to the environmental concerns (these belong to the third category): some concern product functionality, while others might include the reduction of the cost of ownership. It is crucial to determine whether they really refer to environmental issues. For example, energy saving belongs to this category when customers are only interested in saving money; on the other hand, it belongs to the third category when they are concerned about resource depletion.

3. Needs on the environment from customers

These elements are the ones customers request with respect to the environment. It is important to distinguish them from the elements which belong to the fourth type: these needs reflect product's characteristics for obtaining which customers are willing to pay. Influential customer parameters may include gender, age, and country of residence. With respect to country, for example, in [69] it was shown that those in the USA place a considerably higher marginal utility (incremental worth) on the recyclability of a milk package than the Dutch do.

4. Wants from the environmental viewpoint

This category refers to features that are preferred from an environmental standpoint, but that customers would not directly pay for (note that a practical method for discriminating a given characteristic between need, want and something else is available [57][11]). This set can be obtained by subtracting the first and third categories above from "all" of the environmental concerns on the product. The wants in this category are expected to vary among customers as well. An example would be the use of recycled aluminum for drinking cans. A concerned customer does not want to pay to recycle materials, but prefers to buy recycled cans. Note that the company, however, could benefit in the long run from incorporating this type of property into products, since it can be evaluated as a part of the overall image of the company. In other words, this category should be considered from the standpoint of companies' virtues, of which McAloone et al. have proposed the environmental consciousness to be a part [70].

Hence, the weighting for each request in this category should be determined depending on corporate strategies with respect to the environment.

It has to be noted that the latter two types of needs and wants are focused with priority in Step 3 of the ES procedure, because the first is mandatory anyway, and the second can be addressed by an existing design procedure.

6. Discussion of Results

The five elements of the ES were extracted to realize the balance of environmental issues with customer (i.e. market) demand. Sufficiency of the elements cannot be guaranteed in principle through one example, but can rely on the discussion of existing and newly-proposed important elements in carrying out Ecodesign. The effectiveness of the ES can also be supported by the fact that the product based on this ES was actually developed and introduced in the Japanese market in late 2005, and the ES contents also coincide with most of the actual product development [71][12].

The ES can be considered as a supportive tool for designers when searching for effective solutions within design stages. In other words, without a proper Strategy for Ecodesign, designers are more likely to reach ineffective solutions: for instance, in the eco-cell phone case study, they might come up with the shell that doesn't make the kenaf fibers visible on the surface and fails to provide the *value* of "feel of a natural material". On the other hand, the reason why the segment of women ranging from their 20-49 (see Table 1) was actually targeted could also be explained by their potentially higher frequencies of changing cell phones. Note that there are other unhandled constraints in this case, for instance economic ones. For example, the mass of the potential buyers was not estimated.

In other words, the use of a Strategy for Ecodesign should be seen as an input for companies to decrease the possibility of failing in the markets, and can be drafted iteratively based on some feedbacks. The ES we proposed is an attempt to find a solution to such a problem from practical point of view (i.e. the ES represents a possible tool for putting into practice the concept of SfE).

The method to represent value was proposed to reveal subtle differences between need and want for different customers. A related approach is seen in [72], whose motivation to harmonize Ecodesign in business activities is included in our research. However, our approach is new, introducing strict distinctions between different types of value, since they are critical for customers' buying decisions.

It should be mentioned that the case study concerning the eco-cell phone showed an example of Ecodesign that took into account only a few environmental aspects of the product. In principle, the ES should cover as many environmental aspects as possible. However, depending on the situation, it can also

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[11] In sum, this method reveals willingness to pay for a concerned characteristic in a qualitative manner through asking a question of comparison between two products with and without the characteristic.

[12] More in detail, the design project began with the motivation to develop an environmentally-friendly cellular phone. During the initial step, there was a risk of forgetting about customers' value (in comparison with the value that customers perceive in traditional products) when making the product environmentally friendly. However, they avoided losing customer value or having to use "environmentally-consciousness excuses". In the end, they adopted a shell made of bioplastics with kenaf fibers. Although 10 % was still from ordinary plastic based on fossil fuel and natural gas, the other main ingredients were from renewable resources. This solution was designed especially for a segment of women ranging from their 20s to 40s. The texture of the material was also an appealing point to the customers. For another category of customers, a different type of shell, made out of ordinary plastic, was prepared, but the two phones shared other parts as a platform.

be used partially, i.e., as a tool for obtaining specifications' input for further product design, since a product should satisfy not only green requirements, but also other aspects (such as current and emerging customer expectations, technical performances in terms of functionality, safety, reliability, etc.). Thus, it is clear that usually in practice not all the environmental properties of a product can be optimized simultaneously, without risking launching a product that is unlikely to compete well in the market.

7. Conclusions

The analysis of current Ecodesign in Section 2 concluded the problem of the lack of a strategy that could affect the whole product development process. As explained using the example in Section 4, the strategy identification (i.e. the definition of a proper Strategy for Ecodesign) can allow us to understand the intended ecodesigned products more effectively. In addition, it could help designers to generate product ideas in the earliest stages of Ecodesign. Thus, the present investigation found the ES being a promising approach for the development of environmentally conscious products. On the other hand, disconnection and/or contradiction with each other in a general SfE would make "bad design", as described in the notebook example in Section 2. This means that recognizing the relationships among the items characterizing a SfE is an important prerequisite to the success of Ecodesign on the market. For this reason, we tried to structure a SfE by means of the ES, which appears to be an effective answer to our research question.

In the case study, only a few aspects are addressed for an illustrative purpose, pointing out the relationships between a few environmental characteristics and value issues. Improvement could be achieved by considering the relative importance of the selected environmental characteristics within the whole environmental impact of the product.

Moreover, it should be noted that the ES is generated early in the design process and more quantitative and concrete specifications are determined later on. Therefore, it is not feasible to discuss environmental performance of the concerned product quantitatively in the ES framework. Rather, designers are urged to make a decision with semi-quantitative information.

The present article introduces the consideration of value, as judged by the target customers, to conventional mechanical design methodologies, based on the ES. This means that designers must search for solutions within a smaller design space. It has to be mentioned that there are numerous examples of highly functional products, whose value was missing indeed by customers, making them unsuccessful products. This risk is always present for designers. However, it should be emphasized that the ES can reduce the occurrence of such situations, providing a new parameter for designers, the "system". Adding this new parameter provides the opportunity to control the link between value and function, as implied in the example.

In conclusion, this article proposed a method of strategy identification aimed at solving the problems of current Ecodesign involving marketing issues in product development activities. It was found that this approach has the potential to work effectively; one key component of the ES was the inclusion of environmental characteristics as one important element organically connected to the other elements such as value, system, and customer. The novelty exists in the representation of the ES at the early stage of Ecodesign, enabling designers to deepen and enrich the information of concerned customers so that they accept the product.

Results presented in this article suggest that Ecodesign could benefit from tackling issues that have been addressed in the realm of marketing. For instance, customization was used in the example to match more with customer demands, and this may be interesting to investigate within Ecodesign. Actually, mass customization, which takes into account both marketing and product development issues [73], could be part of a solution to the Ecodesign problems, but it has yet to be directly applied to Ecodesign [9].

In addition, it would become more important to address trade-offs and to solve contradictions, due to the greater number of information types to be addressed. For the latter, one promising approach is the application of TRIZ (Theory of Inventive Problem Solving) [74] as shown in the existing literature [75, 76]. Furthermore, research work on what kinds of environmental value is appreciated by different types of consumers would be interesting and useful in order to optimize the ES approach.

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References

[1] IEC (2005): Guide 114, Environmentally conscious design – Integrating environmental aspects into design and development of electrotechnical products, International Electrotechnical Commission.
[2] ISO (2002): ISO/TR 14062, Environmental management - Integrating environmental aspects into product design and development, International Organization for Standardization.
[3] Simon, M., Evans, S., McAloone, T., Sweatman, A., Poole, S. (1998). Ecodesign Navigator. England, Manchester Metropolitan University, Cranfield University, EPSRC.
[4] UNEP (1997). ECODESIGN: a promising approach to sustainable production and consumption, United Nations Publication.
[5] University of Michigan (1992). Design For The Environment (Product Life Cycle Design Guidance Manual). Rockville, MD, Government Institutes Incorporation.
[6] Fiksel, J., Ed. (1996): Design for Environment. New York, Mc Graw Hill.
[7] Abele, E., Anderl, R., Birkhofer, H., Eds. (2005): Environmentally Friendly Product Development, Methods and Tools. London, Springer.
[8] Hora, M., Tischner, U. (2004): Successful design and marketing of Eco- and Sustainable Goods. 9th European Roundtable on Sustainable Consumption and Production.
[9] Sakao, T., Fargnoli, M. (2010): Customization in Ecodesign: A Demand-side Approach Bringing New Opportunities?, The Journal of Industrial Ecology. Vol.14, No.4, pp. 529 - 532.
[10] Peattie, K. (2001): Golden Goose or Wild Goose? The Hunt for the Green Consumer, Business Strategy and the Environment. Vol.10, pp. 187-199.
[11] Sakao, T., Shimomura, Y. (2007): Service Engineering: A Novel Engineering Discipline for Producers to Increase Value Combining Service and Product, Journal of Cleaner Production. Vol.15, No.6, pp. 590-604.
[12] Stevels, A. (2005): Traditional EcoDesign in Proactive Electronic Companies will be soon Dead! Long live Ecovalue! 10th International Conference Towards Sustainable Product Design.
[13] Fargnoli, M., Bisillo, S., Costantino, F., Geraci, D. (2010): Eco-Virtuosity: Management of Ecodesign Issues. 11th International Design Conference, Dubrovnik.
[14] Hertwich, E. G. (2005): Special issue on consumption and industrial ecology, Journal of Industrial Ecology. Vol.9, No.1-2, pp. 1-287.
[15] Luskin, J., Blackman, A. B. (2007): Special issue "Sustainable Production and Consumption—Making the Connection", Journal of Cleaner Production. Vol.15, No.6, pp. 489-606.
[16] EU (2003): Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE), Official Journal of the European Union. Vol. L 37, pp. 24-39.
[17] EU (2003): Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances (RoHS) in electrical and electronic equipment, Official Journal of the European Union. Vol. L 37, pp. 19-23.

[18] EU (2009): 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 and amending Council Directive 92/42/EEC, Official Journal of the European Union. Vol. L 285, pp. 10-35.

[19] EU (2005): Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council, Official Journal of the European Union. Vol. L 191, pp. 29–58.

[20] Akao, Y. (1990). Quality Function Deployment. Portland, OR, Productivity Press.

[21] Cristofari, M., Deshmukh, A., Wang, B. (1996): Green Quality Function Deployment, International Journal of Environmentally Conscious Design & Manufacturing. Vol.5, No.2, pp. 13-18.

[22] Zhang, Y., Wang, P., Zhang, C. (1998): Product Concept Evaluation Using GQFD-II and AHP, International Journal of Environmentally Conscious Design & Manufacturing. Vol.7, No.3, pp. 1-15.

[23] Olesen, J. (1997): Environmental QFD – The Creation of Project Focus. Proceedings of International Conferences on Engineering Design, Volume 1, Tampere, Tampere University of Technology.

[24] Masui, K., Sakao, T., Kobayashi, M., Inaba, A. (2003): Applying Quality Function Deployment to Environmentally Conscious Design, International Journal of Quality and Reliability Management. Vol.20, No.1, pp. 90-106.

[25] Fargnoli, M., Kimura, F. (2007): An Integrated Approach for the Sustainability Measure of Industrial Products in Design Stages, 16th International Conference on Engineering Design (ICED 07). Paris.

[26] Fargnoli, M., Sakao, T., Notarnicola, S. (2005): A Procedure to Identify Effective Redesign Options in Ecodesign. International Conference on Engineering Design (ICED 05), Melbourne.

[27] Boxwell, R. J. (1994). Benchmarking for Competitive Advantage. New York, McGraw-Hill.

[28] Pahl, G., Beitz, W. (1988). Engineering Design: A Systematic Approach. London, Springer-Verlag.

[29] Roozenburg, N. J. M., Eekels, J. (1995). Product Design: Fundamentals and Methods. Chichester, MA, John Wiley & Sons.

[30] Halog, A., Schultmann, F., Rentz, O. (2001): Using quality function deployment for technique selection for optimum environmental performance improvement, Journal of Cleaner Production. Vol.9, No.5, pp. 387-394.

[31] Pighini, U., Fargnoli, M., Accinni, S. (2002): An integrated procedure for the design of sustainable products, International Design Conference on Design. Dubrovnik. pp. 1351-1356.

[32] Kljajin, M. (2000): Design for Environment using life cycle assessment, International Design Conference on Design. Dubrovnik. pp. 175-180.

[33] Polonsky, M. J., Mintu-Wimsatt, A. T., Eds. (1997): Environmental Marketing. Binghamton, NY, Haworh Press.

[34] Belz, F.-M. (2006): Marketing in the 21st Century, Business Strategy and the Environment. Vol.15, No.3, pp. 139–144.

[35] Sharma, A., Iyer, G. R., Mehrotra, A., Krishnan, R. (2010): Sustainability and business-to-business marketing: A framework and implications, Industrial Marketing Management. Vol.39, pp. 330-341.

[36] Meyer, A. (2001): What's in it for the Customers? Successfully Marketing Green Clothes, Business Strategy and the Environment. Vol.10, pp. 317-330.

[37] Cooper, A. (1999). The Inmates Are Running the Asylum. USA, Sams.

[38] Pruitt, J., Adlin, T. (2006). The Persona Lifecycle: Keeping People in Mind Throughout Product Design. San Francisco, Morgan Kaufmann.

[39] Sakao, T., Shimomura, Y., Sundin, E., Comstock, M. (2009): Modeling Design Objects in CAD System for Service/Product Engineering, Computer-Aided Design. Vol.41, No.3, pp. 197-213.

[40] Manzini, C., Vezzoli, L. (1998). sviluppo di prodotti sostenibili (Sustainable products development), Maggioli editore.

[41] Hubka, V., Andreasen, M. M., Eder, W. (1998). Practical studies in Systematic Design. London, Butterworth.

[42] Hubka, V., Eder, W. E. (1992). Engineering Design. Zurich, Heurista.

[43] OIDC (2006). "Osaka Intelligent Design Center, Hair Dryer HD-S1283 by Hitachi, Ltd.". Retrieved on May 4, 2007, from http://web.pref.osaka.jp/oidc/ie/case/dryer.html.

[44] Fargnoli, M., Bisillo, S., Costantino, F., Tronci, M. (2010): The assessment of ecological profile of industrial products. TMCE 2010, Ancona, Italy.

[45] Bialetti (2011). Retrieved April 29, 2011, from www.bialettishop.com/CWGreenPlanetFryPansMain.htm.

[46] NEC (2006). "Interview on the product planning." Retrieved on May 4, 2007, from http://www.nec.co.jp/eco/ja/annual2006/02/2-1.html.

[47] Emmenegger, M. F., Frischknecht, R., Stutz, M., Guggisberg, M., Witschi, R., Otto, T. (2006): Life Cycle Assessment of the Mobile Communication System UMTS: Towards Eco-efficient Systems, International Journal of Life Cycle Assessment. Vol.11, No.4, pp. 265-276.
[48] Scharnhorst, W., Althaus, H.-J., Hilty, L. M., Jolliet, O. (2006): Environmental Assessment of End-of-Life Treatment Options for a GSM 900 Antenna Rack, International Journal of Life Cycle Assessment. Vol.11, No.6, pp. 425-436.
[49] Skerlos, S. J., Michalek, J., Morrow, W. R. (2006). Sustainable Design Engineering and Science: Selected Challenges and Case Studies. Sustainability Science and Engineering. M. A. Abraham. Amsterdam, Elsevier. 1**:** 467-516.
[50] NEC (2006): Product Brochure: FOMA N701iECO.
[51] Bioplastics, E. (2008): Position Paper: Life Cycle Assessment of Bioplastics, European Bioplastics.
[52] Kurdikar, D., Fournet, L., Slater, S. C., Paster, M., Gruys, K. J., Gerngross, T. U., Coulon, R. (2000): Greenhouse Gas Profile of a Plastic Material Derived from a Genetically Modified Plant, Journal of Industrial Ecology. Vol.4, No.3, pp. 107-122.
[53] Groot, W. J., Borén, T. (2010): Life cycle assessment of the manufacture of lactide and PLA biopolymers from sugarcane in Thailand, International Journal of Life Cycle Assessment. Vol.15, No.9, pp. 970-984.
[54] Detzel, A., Krueger, M. (2006): Life cycle assessment of polylactide (PLA) - A comparison of food packaging made from NatureWorks(R) PLA and alternative materials. Heidelberg, IFEU. pp. 146.
[55] Serizawa, S., Inoue, K., Iji, M. (2006): Kenaf-Fiber-Reinforced Poly(lactic acid) Used for Electronic Products, Journal of Applied Polymer Science. Vol.100, pp. 618-624.
[56] Iji, M. (2010): Environmental impact of PLA with kenaf fibers, Personal Communication with T. Sakao, Green Innovation Research Laboratories, NEC.
[57] Sakao, T. (2009): Quality Engineering for Early Stage of Environmentally Conscious Design, The TQM Journal. Vol.21, No.2, pp. 182-193.
[58] Zeithaml, V. A. (1988): Consumer Perceptions of Price, Quality, and Value: A Means-End Model and Synthesis of Evidence, Journal of Marketing. Vol.52, No.July, pp. 2-22.
[59] Tukker, A., Tischner, U. (2006). New Business for Old Europe. Sheffield, Greenleaf Publishing.
[60] Mont, O., Tukker, A. (2006): Product-Service Systems: reviewing achievements and refining the research agenda, Journal of Cleaner Production. Vol.14, No.17, pp. 1451-1454
[61] Vargo, S. L., Lusch, R. F. (2008): From Goods to Service(s): Divergences and Convergences of Logics, Industrial Marketing Management. Vol.37, pp. 254-259.
[62] Jones, J. C. (1978). Design Methods: seeds of human futures, John Wiley & Sons**:** 295.
[63] Pahl, G., Beitz, W. (1984). Engineering Design: A Systematic Approach. London, Springer-Verlag**:** 95.
[64] Hubka, V., Eder, W. E. (1992). Engineering Design. Zurich, Heurista: pp. 62.
[65] Green, E., Srinivasan, V. (1978): Conjoint Analysis in Consumer Research: Issues and Outlook, Journal of Consumer Research. Vol.5, pp. 103-123.
[66] Van der Haar, J. W., Kemp, R. G. M., Omta, O. (2001): Creating value that cannot be copied, Industrial Marketing Management. Vol.30, pp. 627-636.
[67] Eder, W. E., Hosnedl, S. (2007). Design Engineering: A Manual for Enhanced Creativity. Boca Raton, FL, CRC Press.
[68] Boks, C. (2006): The soft side of ecodesign, Journal of Cleaner Production. Vol.14, No.15-16, pp. 1346-1356.
[69] Sriram, V., Forman, A. (1993): The relative importance of products' environmental attributes: A cross cultural comparison, International Marketing Review. Vol.10, No.3, pp. 51- 70.
[70] McAloone, T. C., Andreason, M. M. (2004): Design for Utility, Sustainability and Social Virtues, Developing Product Service Systems. International Design Conference, Dubrovnik.
[71] NEC (2006). "The Eco Mobile Debut!". Retrieved on May 1, 2009, from http://www.nec.co.jp/eco/en/annual2006/02/2-1.html.
[72] Finster, M., Eagan, P., Hussey, D. (2001): Linking Industrial Ecology with Business Strategy -Creating Value for Green Product Design-, Journal of Industrial Ecology. Vol.5, No.3, pp. 107-125.
[73] Anderson, D. (1997). Agile Product Development for Mass Customization. Chicago, IL, Irwin.
[74] Altshuller, G., Altov, H. (1996). And suddenly the inventor appeared-TRIZ, the theory of inventive problem solving. Worcester: MA, Technical Innovation Center.
[75] Chang, H., Chen, L. (2004): The conflict-problem-solving CAD software integrating TRIZ into eco-innovation, Advances in Engineering Software. Vol.35, pp. 553–566.
[76] Sakao, T. (2007): A QFD-Centred Design Methodology for Environmentally Conscious Product Design, International Journal of Production Research. Vol.45, No.18-19, pp. 4143-4162.

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