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MASS CUSTOMIZATION ISSUES FOR ENVIRONMENTALLY CONSCIOUS DESIGN

T. Sakao and M. Fargnoli

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1. Introduction

In recent years, a great attention has been paid to development of so-called "environmentally friendly products" by industries and governments around the world. In fact, a great effort has been made to make more sustainable from the environmental viewpoints both the production and the use (consumption) of industrial products. As a result, there are a huge number of environmentally conscious products (eco-products) available on the market. Accordingly, industries have obtained a number of design methods for the purpose.

Thus, such activities of Ecodesign (environmentally conscious design) by industries today could be regarded as successful. However, this is true only if the supply side alone is focused. Namely, those activities are not necessarily successful if seen from the demand side. Actually, ecodesigned products are not well accepted by consumers at present. This means that commercial business activities with Ecodesign as a whole are not necessarily successful.

One problem is that current Ecodesign lacks effective identification of target customer categories appropriate for a product to be ecodesigned [Hora 2004, Sakao 2005]. Another problem consists in emerging difficulty to embed environmental competitiveness on products just by following current Ecodesign methods as is suggested by [Stevels 2005]. Many of the environmental properties of products which those methods support to be implemented on products are becoming established as part of regulations or legislations that for manufacturers have to be in compliance with. Thus, current Ecodesign methods support manufacturers to satisfy necessary conditions but not sufficient conditions for competitiveness in business. For these reasons, Ecodesign "strategies" must be investigated in order to achieve successful business with Ecodesign. It has to be underlined that the word strategy here is intended as the way manufacturers decide to adopt for the aim of selling their products to be ecodesigned. It includes to whom their products will be sold either or not by appealing environmental characteristics. It also should answer to the question of the way how the product will be competitive. The strategy should be the input to the following design activities later on. Actually, these "later" activities have been the target of most current Ecodesign methods.

Now, one can pose a question that nothing even similar to such a strategy is available or not. Indeed, it is broadly accepted that manufactures must somehow contribute to more sustainability of our society. Hence, most manufactures have a philosophy in accordance with such a belief. However, the company's philosophy is normally too vague to affect sensitive decisions in product design activities. Thus, the philosophy can not play a role of what is regarded as a strategy here.

In such a context, there is a noteworthy and wide spread concept, Mass Customization (MC). MC connotes both marketing and product development issues in its scope. It is based on increasing differentiation levels of products and services depending on customers' needs, while reducing

production costs and keeping levels of customer relationships [Anderson 1997]. MC could contribute to solve the problems of current Ecodesign but has never been applied to Ecodesign.
The paper aims at analyzing the compatibility between MC and the strategies of Ecodesign. Especially, application of an idea from MC is investigated in the field of Ecodesign. Here, it should be noted that Ecodesign nowadays is being affected by the latest implementation of environmental legislations, as well as must confirm with the market including green consciousness of partial consumers. The final objective of this research work is development of a design approach able to match the MC paradigm together with the requisites for an environmentally conscious development of industrial products. More in detail, in Section 2 an overview of the current Ecodesign in industries is presented. In Section 3 the different aspects that should be taken into account in ecodesigning new products are discussed. After Section 4 briefly introduces MC's concerns, Section 5 analyzes how to incorporate MC into Ecodesign. Section 6 summarizes the paper.

2. Current Ecodesign

Industrial products with relatively low environmental burdens are indeed developed nowadays. This represents in most cases a path which companies have to follow in order to comply with the recent international environmental policies and regulations. This also sometimes aims at satisfying green consciousness of customers. Figure 1 shows a schematic view of the concerns that manufacturers of green products have to face.

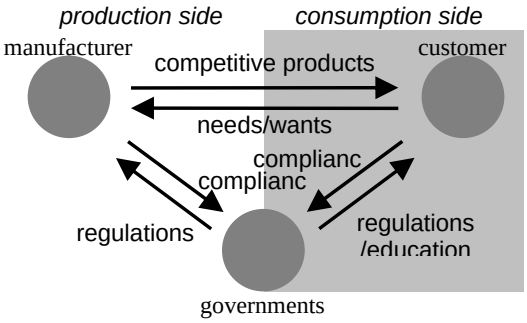


Figure 1. Ecodesign surroundings of a manufacturer

On the spur of the strict regulations in the field of the environment, companies are more and more obliged to consider production of eco-products, i.e. products developed taking into account the impact during their whole life cycle. These activities must be regular ones, not project-based ones. Thus, they are forced to modify somehow their technological background.
Indeed, environmental performances of industrial products are becoming the target of an ever greater number of laws and regulations in most countries. In particular, the efforts made by both the European Community and the Japanese government in recent years have to be underlined. As a matter of fact, these two legislative approaches can be considered quite similar. Indeed some of the European regulations are inspired to the Japanese ones. Of course, this is also due to the globalization of the modern markets, and to the intensive import/export activities between Europe and Japan. Among them, we can distinguish the following aspects as what significantly characterize the environmental legislation in those countries;

- reduction of waste of electrical and electronic equipment (e.g. home appliances) by means of increasing re-use and recycling opportunities, improving the environmental performances of these products, and promoting a take-back policy offered by companies;
- control of the products with hazardous substances, and the producers' responsibility also from the economic point of view;
- obligation for manufacturers to consider the whole products' life cycle, as well as to assure their compliance with regulations by internal design control, by implementation of an environmental management system, by use of eco-labels, etc.; and

- procurement of relatively environmentally friendly products under the Green Purchasing Law in Japan.

It is significant to consider the fact that, as a result, these laws effectively make “design for recycling”, “design for waste reduction”, “design for reuse”, etc. forced for a wide range of products. These activities have greatly influenced designers’ choices. Such a new trend modifies companies’ perspectives concerning the opportunity to enter the so called “eco-market” and influences their marketing analyses. It also significantly influences the company strategies for the whole product development process, spanning from the product planning and design to its production and distribution. In spite of such growth of environmental consciousness, the eco-products are still considered as belonging to a niche market when distinguished from the “traditional” products [Chen 2001]. Namely, it is impossible to conceive separate meaningful market segments (i.e. one for the “normal” products and another for the environmentally friendly ones) for most of the enterprises that want to maintain or improve their competitiveness. This is reasonable because this requires further efforts and significant investments that companies have to bear. On the other hand, one should notice that there is also a positive effect: There is a fact that the benefits for companies in a market regulated by stricter environmental regulations are higher [Chen 2001].

Regarding product design, in fact, the necessity to put on the market competitive products reducing as much as possible the “time to market” has brought most of the companies to optimize activities of developing new and innovative products. They even have to offer diversified production possible to satisfy different customer needs. Actually, it has to be underlined that traditional product development processes (e.g. the approach by Pahl and Beitz or that by Roozenburg and Eekels) do not directly incorporate environmental concerns except for the final phases, when most of the characteristics of the product are already defined. In addition, environmental properties have been often considered being in contrast with achievement of optimal performances of products. Namely, they have been regarded to give a negative impact on the “traditional” properties, such as safety, reliability, aesthetics, etc., as well as increase the costs that companies have to bear. This situation has been partially caused both by application of the “end-of-pipe” approaches (i.e. after design and develop the product, and then think how to reduce its impact on the environment), as well as by an often-adopted strategy of upgrading already-existing products (e.g. improving performances) rather than rethinking the concept of a new product from scratch.

These situations have resulted in “Ecodesign by makeup”, which makes products more eco-friendly only after the product structure is determined. Even with such a design solution, manufacturers almost always send a message about environmental consciousness to their customers in their environmental communication. This will not be effective, since they lack a product concept and a business strategy appropriate with the environmental consciousness. In other words, this will only reach “cosmetic Ecodesign”. For instance, let us consider a notebook made of recycled papers. This is an ecodesigned product due to environmentally conscious material selection. This type of a notebook sometimes consists of papers so weak that the notebook is quite easily worn to shreds. Will this be a good Ecodesign? No, for the purpose of a long term use and preserve. However, this will be a good solution for a memo pad keeping information just for a temporal period. This vague solution of Ecodesign in this case is caused from the absence of effective customer identification.

Considering these situations and numerous available methodologies and tools for Ecodesign of products, a crucial problem to be solved in Ecodesign exists in the earliest stage of the design process, namely the product’s strategies identification. With this aim in mind, in order to investigate possibility to elevate current Ecodesign to a higher level, it will be analyzed how Ecodesign should be from business perspectives under these circumstances.

3. Characteristics of Environmentally Conscious Products

Nowadays, in deciding whether a certain product can be considered “environmentally friendly” or not, we should take into consideration that the various attributes of a certain product are usually intended in different ways by all the stakeholders involved with the product’s life cycle. Hence, the same attributes of a product are evaluated using different weights of importance. It is clear then that depending on who is assessing the environmental quality level of a product (designers, producers,

customers, sellers, etc.), the aspects underlined are sometimes in conflict with one another. Furthermore, certain attributes condition in a rather considerable manner evaluation of a product, leaving the objectives out of consideration. Therefore, before analyzing the main properties that characterize eco-products, we have to distinguish different typologies of industrial products; durable products, consumer goods and the so-called "time zero" products proposed by Manzini and Wimmer. In fact, each of these categories has a different environmental profile. Durable goods are related to the manufacturing and handcrafters industry. In this case, the length of their life span represents the main environmental performance. Thus, use and maintenance are the most delicate phases of the product's life cycle. As far as consumption goods are concerned, we can classify them into two sub-categories; the goods consumed generally during the use phase and the "throw-away" goods. In the former case, the most significant aspects from the environmental point of view are represented by the choice of materials and production processes. The latter goods, instead, include numerous sub-categories of products that have various environmental profiles. In general, the level of disassembling and recycling, as well as the standardization of components is the most significant aspects.
The "time zero" products are characterized by complete dematerialization issues: Customers do not own the product, they just use it. Typical examples of such an address are represented by car-sharing initiatives or by the take-back policies. Needless to say, use of these products requires a significant change in the mind-set of both customers and manufacturers. At the same time, on the basis of the experiences from companies that have already implemented such approaches, it is clear that numerous benefits can be achieved:

- Customers can always have updated products at their disposal (particularly, those containing high technology components, which are indeed designed for a short life cycle).
- Manufacturers can make a profit of reuse of parts or components, as well as of recycle of materials.

On the basis of these considerations, we can analyze the characteristics of eco-products considering the environmental sustainability as the sum (and the combination) of numerous products properties such as reliability, safety, maintenance, manufacturing, durability, modularity, etc. As a matter of fact, the "green" level of a product is influenced by numerous attributes. "External properties" can be distinguished for any kind of industrial product from the engineers' viewpoint, in accordance with the methodical design theory. All such properties influence the product's environmental performances in a more or less direct way. Apparently, assessment of such properties both allows designers to develop a measure of the product's sustainability and at the same time shows which characteristics have to be modified in order to improve the whole product's life cycle.
Furthermore, it is necessary to define some criteria for each of such properties in order to obtain a more precise and objective evaluation of the product. Note that all of them are not of the equivalent relevance to the sustainability of the product. In fact, some of them ought to be considered as more important than others depending on the nature of the product as well as the specific needs of the stakeholders.
Bearing this in mind, according to the Ecodesign issues, design and development of eco-products should be carried out taking the following different perspectives into account;

- the product considered as a system, and thus considering the improvement of its end-of-life (e.g. by means of optimizing disassembling, reusing, recycling, etc.), as well as of its life span (e.g. reliability, maintainability, modularity, etc.);
- product's value, i.e. the value that customers recognize on a certain product, or in other words the product's qualities that producers have to look for in order to meet customers' needs and expectations;
- product's function, i.e. the function the physical product is designed for; and
- product's components and parts, focusing on choice of materials, etc.

These represent different aspects of product planning and development that manufacturers should consider. They could be seen as the trade union between the traditional Ecodesign approaches (more focused on technical aspects) and the MC ones (that allow engineers to take into account marketing and company's strategies).

In order to address such issues in companies' practices, several design approaches have been developed by researchers and companies in this field. Nevertheless, with the aim of integrating the life cycle thinking within the traditional design activities, the lack of a well defined design framework is seen. This must solve the design hindrances and limitations caused by the many different requirements both from a technical nature and from the customers' point of view, as well as the need to respect environmental standards and regulations.

4. Techniques and benefits of Mass Customization

In a competitive market, customization has been one of the promising strategies for manufacturers to attract their customers. Actually, the concept of Mass Customization (MC), which is defined, for instance, as "design and manufacture of customized products at mass production efficiency and speed" [Anderson 1997], is already widespread. MC is based on increasing differentiation levels of products and services depending on customers' needs, while reducing production costs and keeping levels of customer relationships. The variation handled by MC of products includes structures or functions of products. In addition, product MC can also include developing products whose outer colours are able to be opted by a customer. There is MC of services, too. For example, customization of a travel service bureau allows customers to build elements such as transportation measures to fit their needs and wants.

If applied to later stages of product design, MC in most cases incorporates partial variation on physical products employing the mass production technologies, through an intermediate method lying somewhere between mass and customized production. Many theories and practices of MC presented so far have focused on the customization of properties of physical products. For instance, a well known practice in industry is adjustment of a shape of shoes depending on a shape of customers' feet. In relation to this, there are several theories on how to prepare a common "platform" and exchangeable modules in a product. On the other hand, there are relatively fewer theories and practices of customization applied to earlier stages of design. As briefly reviewed above, such an activity realizes tailoring products or services depending on customers' requirements, so that a solution better matches the requirements.

MC lets manufacturers provide customer-dependent value with bearing costs a little higher than those in mass production of unified products. Because MC is one of the potential ways to sell their products, keeping MC as a strategy is beneficial for manufacturers. Importantly and obviously, manufacturers must understand a product's value which depends on customer types in order to carry out MC effectively.

5. Incorporating Mass Customization into Ecodesign

The research work carried out began with a detailed study of Ecodesign tools, which take into account environmental aspects throughout the product life cycle. Then, it analyzed how to integrate them together with the MC techniques mentioned above. This resulted in identification of the following main aspects.

5.1 Stage for customization

As stated in Section 2, one of the problems of current Ecodesign consists in the proper development of the earliest stages of the product design process. Namely, lacking identification of strategies of Ecodesign before the so-called task clarification stage is the problem. Thus, it is in this stage that application of customization works relatively more effectively. Namely, applying MC technologies to the earliest stage of Ecodesign will be effective to solve the problems of the current Ecodesign.

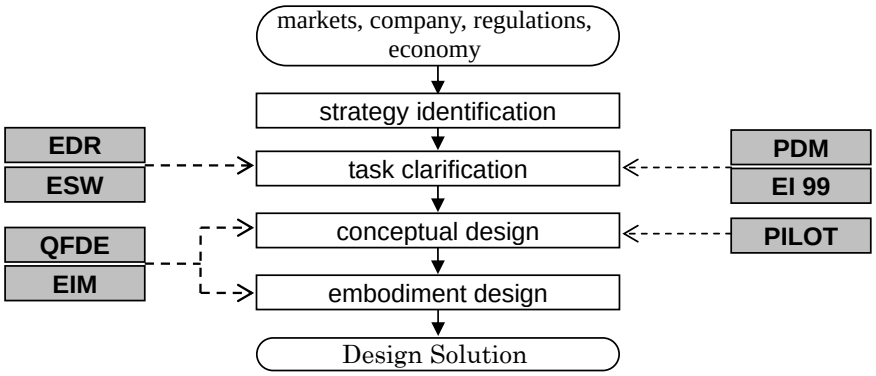
5.2 Existing methods

A number of methodologies and tools for Ecodesign of products are available. Among them, the authors [Fargnoli 2005a] have proposed an integrated design approach to effective Ecodesign employing several methods and tools such as Ecodesign Strategy Wheel (ESW) by Brezet and Hemel, Quality Function Deployment for Environment (QFDE) by Masui et al., and Ecodesign PILOT by

Wimmer and Züst according to their applicable stages. In order to take into account the requisites of the environmental legislations, Environmental Design Review (EDR) [Fargnoli 2005b] is available. Among existing MC methods, an application of QFD (Quality Function Deployment) to MC is available [Pulm 2003]. This allows designers to specify what must be realized and what can be optional on QFD matrices, by introducing a table representing properties of parts such as easiness to integrate with a platform. It should be also noted that product modularization or product family organization using MC technologies has also potential.

5.3 Integration

In Figure 2, the general scheme of the Ecodesign flow proposed here is shown. This has been obtained by augmenting the integrated design approach proposed by the authors [Fargnoli 2005a] with a newly added stage of identifying the strategy of the Ecodesign.



Legend:

EDR: Environmental Design Review (JEMAI, 2000; Fargnoli & Sakao, 2005).
ESW: Ecodesign Strategy Wheel (Brezet & Hemel, 1997).
QFDE: Quality Function Deployment for Environment by (Masui et al., 2003)
EIM: Eco-Impact Matrix (Fargnoli et al., 2005).
PDM: Product Design Matrix (Graedel & Allenby, 1995).
EI 99: Eco Indicator 99 (Goedkoop et al., 1999).
PILOT: Ecodesign PILOT (Wimmer & Züst, 2003).

Figure 2. General scheme of the augmented Ecodesign flow

On the basis of the considerations in Section 3, the analysis of the different perspectives concerning the product development has to be implemented in the whole design process. Of course, depending on the stage, some aspects have more or less importance. For instance, the product's value appears significant in the "strategy identification" stage; in such a stage, instead, "product's components and parts" have less influence. The opposite situation can be found in the "embodiment design" stage. The correct definition of such aspects and their combination in a proper and effective way can be supported by the use of methods and techniques, as indicated in Figure 2.
More in detail, as far as the stage called "strategy identification" is concerned, it clarifies the specifications the manufacturer has to follow when dealing with the product's Ecodesign and its introduction in the market. This will be a part of how the company achieves business with the product. For this purpose, the target customers are identified first. Then, the specifications for the product have to be defined, considering all the following four types of needs and wants from the environmental viewpoint. It should be noted that this classification among the four types, except for the first one, depends on the targeted customers.

1. *Indications from environmental regulations*
   These are concerned about directives, for instance, RoHS, WEEE, EuP Directives in Europe, and laws such as Home Appliance Recycling Law (HARL) in Japan. These are the prerequisites that a manufacturer cannot get away of. At the same time, compliance itself is

the thing. For instance, in the case of HARL in Japan, which requires a manufacturer of TV sets to get 55 % of the products recycled, a manufacturer must achieve a score higher than the threshold (55 %) but need not increase it any more after the threshold is cleared.

2. *Requests from customers*
   These are requirements from customers, excluding what are related to the environmental issues (these belong to the third category). Some are related to product functionality, while others include the reduction of utility cost. It is crucial that some requests which seem environmental ones are investigated whether they really refer to environmental issues. For instance, "energy saving" belongs to this category when customers are only careful about the money to be paid. On the contrary, it belongs to the third category when they wish the resource depletion to be prevented.
3. *Requests on the environment from customers*
   These are what customers request on the environment. It is expected that a higher variety exists in this category among customers than in the second category. An instance is exclusion of a toxic substance such as lead; this request is well likely raised for kids' toys by parents, who are worried about children's swallowing them unintentionally. Influential parameters of customers may include genders, ages, and countries they live in. In the case of countries, for example, it was demonstrated that people in the USA put a considerably higher part-worth on the recyclability of a milk package than Dutch people [Sriram 1993].
4. *Wants from the environmental viewpoints*
   This category refers to what are preferred from the environmental viewpoints but customers would not directly pay for. This set can be obtained by subtracting the three categories above from "all" the environmental concerns on the product. The wants in this category are also expected to vary much among customers than in the second category. An example is usage of recycled Aluminium for drinking cans, if the target customers care nothing about the recyclability of the material. This is not appreciated directly by the concerned customers. However, the company could benefit in the long run from incorporating this type of property into products, since it can be evaluated as a part of the whole corporate activities. In other words, this category should be dealt with from the viewpoints of companies' virtues, which McAloone et al. have proposed the environmental consciousness to be a part of. Hence, the weighting for each request of this category should be determined depending on corporate strategies on the environment.

Having identified the potential requirements in each type of requirements above, designers have to determine which ones will be prioritized depending on the target customers and the company's strategy. In order to incorporate the quantitative preferences of the target customers, Conjoint Analysis can be employed. In case multiple types of products are needed, Product Family Architecture [Jiao 2003] and the method based on the QFD [Pulm 2003] can be effective to identify what should be a platform and what an optional part.

6. Summary

This paper pulled the trigger of discussing MC in the context of Ecodesign. This research has been motivated by the current situation in which business with Ecodesign is not so successful. In other words, Ecodesign still has space for manufacturers to improve. The problem of absence of an Ecodesign strategy before the product development was addressed. First, understanding customers from the viewpoint of environmental preferences is crucial. Second, manufacturers should make a clear distinction between what is needed and what is wanted in Ecodesign as quite a few environmental regulations and legislations for manufacturers to comply has been becoming effective.
This means that Ecodesign should tackle also issues which were addressed in the marketing territory. Furthermore, this implies that it may be beneficial for the academic and the industries to shift from the paradigm of the so-called integrated product development, which the current Ecodesign belongs to, to a new paradigm together with the marketing discipline.
Some preliminary investigations on how MC techniques bring benefits to making an Ecodesign strategy were presented. Although development of the proposed research approach is still in an initial

stage, incorporating MC into the earliest stage of Ecodesign is proposed. This is relatively a challenge also as MC, since there are fewer theories and practices of MC in that stage as shown in Section 4. Further works concerning both development of methods able to support Ecodesign with MC and their validation throughout industrial case studies, are being carried out.

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Tomohiko Sakao, Ph.D.
Guest Reseaercher
Institute for Product Development and Machine Elements (*pmd*) / Darmstadt University of Technology
Magdalenenstrasse 4, 64289 Darmstadt, Germany
Tel.: +49-(0)6151-16-5155
Fax.: +49-(0)6151-16-3355
Email: sakao@pmd.tu-darmstadt.de
URL: http://www.pmd.tu-darmstadt.de