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THE CUSTOMER'S VALUE IN THE SUSTAINABLE DESIGN

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Abstract

Design and manufacture of sustainable products has implications for manufacturers, for customers and for the rest of the society as well. Despite of the fact concerning to the decisions that companies take to follow maximum profit strategy, part of the environmental costs generated are assigned to the manufacturer. The rest of the environmental costs, (external costs) are assumed by the society. It has been traditionally considered that the revenues of a company producing sustainable products depend on the relationship between cost, price and value for the customer. However, the considerations in this relationship of 'externalities' or 'costs for the society' are seldom realised in practice. This paper aims to illustrate how additional product value may be gained by encouraging the design of sustainable products (which reduces the environmental impact and the external costs). In consequence, customers recognise the added value of the product by increasing their willingness to pay for it. For some ecological products, the higher amount of money that the customer is able to pay covers sufficiently the higher costs of the sustainable product design and even may increase the company profits.

Keywords: sustainable design, life cycle assessment, life cycle costing, environmental requirements, behaviour aspects on sustainability

1. Introduction

The economic goals of manufacturing companies are often in conflict with environmental improvements of their products. This situation has brought the need of integrate both economic and environmental requirements in the product development process. Some models have been proposed to integrate economic and environment requirements with customers requirements using different approaches of the Quality Function Deployment method (QFD) [1-3].

This paper proposes a new model to enable the consideration of environmental requirements and cost estimation together with customer's requirements through the customer's willingness to pay for a product that includes certain environmental improvements. The model is based on the integration of three methodologies: Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Contingent Valuation (CV) respectively.

2. Methodology

The LCA methodology [4] is applied to obtain the environmental performance of office tables by the identification and quantification of the energy, the materials and the pollutants produced. The assessment goes through the entire life-cycle of the product. This includes extraction and processing of raw material, manufacturing, distribution, use, recycling and final disposal. The model uses a Life Cycle Inventory (LCI) composed by several databases, BUWAL [5], Idemat [6], and IVAM LCA [7], together with own recompiled data [8].

Working data was obtained directly from local enterprises of the furniture sector. The information gathered included: a) manufacturing process description; b) flow of materials in all the stages of the process including their description and quantities; c) energy consumption during the manufacturing process; d) quantities of finished products and co-products and outputs (atmospheric emissions, water effluents and solid waste). All this information was allocated to the functional unit of each of the materials or processes using cause-effect criteria.

No agreement exists on the use of a single method to evaluate environmental impact. Consequently, a number of combined sets of methods has been developed. The most noticeable are the following ones: Eco-Indicator’95 [9], Eco-Indicator’99 [10], Environmental Priority System (EPS) [11, 12] or Tellus [13], among others. Regarding to the evaluation methods, the ISO 14042 (2000) standard states that in an LCA study it is advisable to make use of different methods of assessment and to carry out a sensitivity analysis that allows a correct interpretation of the results obtained.

LCC methodology considers all the costs incurred throughout the entire life cycle of a product [14]. They may be divided into two categories: Internal Costs (IC) and External Costs (EC). Internal costs provide the sum of the total costs for which a company is responsible, and can be classified into conventional, hidden and less tangible costs [15]. External costs (or social costs) are costs for which a company is not responsible at a specific time. It means that neither the marketplace nor regulations assign them to the firm.

Working data for the study of internal costs was obtained from the common company's accountancy. On the other hand, the study of external costs involves the compilation of different economic indicators to quantify the negative effects of the damage caused by the environmental impacts and the transport. Economic parameter values for external costs have been estimated for some atmospheric pollutants (CO_2, CO, CH_4, SO_2, NO_x, N_2O), road congestion and noise caused by transportation [16, 17].

Contingent Valuation methods (CV) have been broadly used to estimate willingness to pay (WTP) for products and services whose market prices does not reflect their value to the society. Different studies of CV especially focused on public infrastructures, natural spaces and in the effect of very pollutant activities over the environment are reviewed in [18-20]. However, the literature lacks of similar surveys related to ecological friendly products.

An innovative questionnaire has been designed to obtain directly the amount of money that customers are willing to pay for a product that incorporates specific environmental improvements. The built-in question support an alternative format to the open-ended, dichotomous choice or referendum formats used frequently in CV surveys.

The main body of the questionnaire includes questions that are directly related to the WTP for a product that incorporates certain environmental improvements. For instance, the respondent person is asked to choose between seven pairs of prices for each of the environmental advantages. For each pair of prices the respondent person has to decide which item he or she would pay for. The pairs include the currently available version of the product (at its present market price) and an ecological alternative to the same product (at a price above the current market price). By progressively increasing the price of the ecological alternative in each choice, respondent persons are provided with a simple way to decide the maximum price they would be willing to pay for the environmentally improved product. Figure 1 shows an example of these questions.

Photography of current product (A)	Photography of ecological alternative (B)
Characteristics of current product	Characteristics of the ecological alternative

For each pair of prices, WOULD YOU BUY PRODUCT A or B?

If the price were:	Price of product A	Price of product B	I'd buy:	
	300.5 €	279.5 €	A	B
	300.5 €	300.5 €	A	B
	300.5 €	321.5 €	A	B
	300.5 €	342.6 €	A	B
	300.5 €	363.6 €	A	B
	300.5 €	384.6 €	A	B
	300.5 €	405.7 €	A	B

Figure 1 Example of a question based on contingent valuation.

Incentive compatible experiments in which subjects reveal their preferences by acting in a controlled scenario were used to validate survey data [8].

The questionnaire was repeated for three different models of office tables corresponding to different styles and prices. The results were similar [8].

By means of the integration of the three methodologies described above, it is proposed a model to redesign products with a better environmental behaviour, satisfying, also, the objectives of profitability for the manufacturing company and sustainability for the society.

3. Integration model

The integration of the methodologies described above brings up a model to support the redesign of products that show better environmental performance. At the same time, the products redesigned by the use of the model are expected to be profitable for the enterprise and for the society as well. This model is divided in four steps (Figure 2):

1. Initial analysis of the product: environmental and economic. Those components or life cycle stages with a higher value of this index are identified as priority targets for improvement.
2. Generation of alternatives, obtaining environmental information of similar products and information about alternative materials/processes to those used in the initial design.
3. Analysis of alternatives from three different points of view: environmental, economic and from the customer's perspective.
4. Selection of the best alternative. The selection of the best alternative comes from the analysis of the following performance indicators:
   - Sustainability for the society, which implies lower environmental impact and reduced external costs of the improvement alternative in respect the initial design.
   - Profitability for the company, which implies maximum sales benefits of the improved alternative.

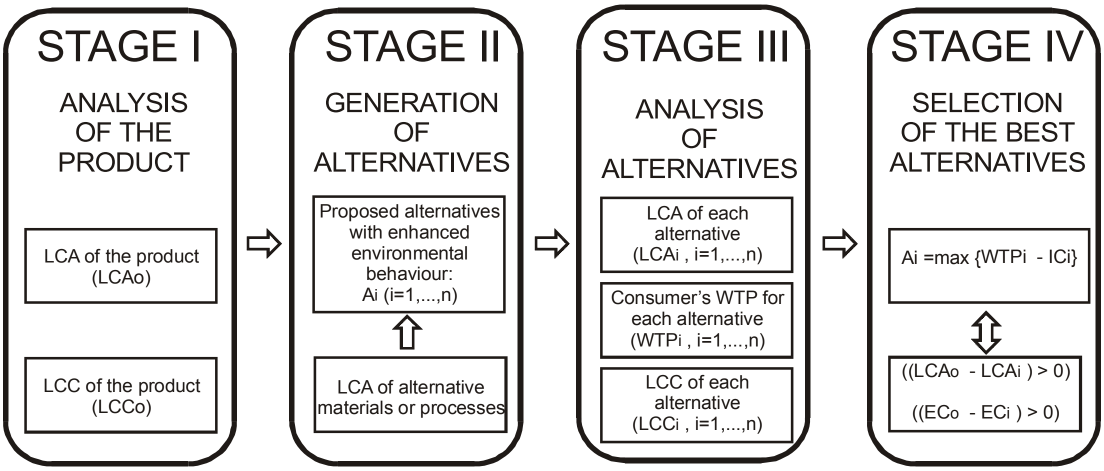

Figure 2 Integration model.

3.1 Stage I: Initial analysis of the product

This stage is carried out through study of the environmental profile of the initial product to identify the parts or stages of its life cycle that display the worst environmental performance: At this point, the required steps are:

- Definition of the structure of the product throughout its whole life cycle.
- Execution of a life cycle inventory of all the components in the structure of the product.
- Analysis of the product life cycle following the steps proposed by SETAC.

This stage shows the environmental impact of the product being evaluated in units of an environmental indicator, depending on the impact assessment method chosen for use (LCA_0). Components or stages with a higher indicator value are identified as priority environmental improvement objectives.

Life Cycle Costing method is used as the tool to estimate both internal and external costs.

3.2 Stage II: Generation of alternatives

At this point, the product components or stages of its life cycle that need to be enhanced from an environmental point of view have been identified. The next step is to define improvement alternatives. Thus, it is necessary to collect all the environmental information about similar products and about alternative materials/processes to those used in the initial design that allows the fulfilment of the same functions. The relevant steps to follow in this stage are:

- A life cycle of the materials/processes that perform the same function as the identified target components subject to improvement.
- The generation of more ecological alternative versions of the product by replacing the target components, processes or materials with others that have a lower environmental impact.

The result of this stage is a proposal consisting of *n*-alternatives that improve the environmental performance of the initial product.

3.3 Stage III: Analysis of the alternatives

In this stage, the alternatives generated previously are analysed from three different points of view:

- Analysis of the alternatives from an environmental perspective. After the application of a LCA methodology to each of the environmentally improved alternatives generated, a list of environmental assessment values in units of an environmental indicator (LCA_i) is obtained, where i = 1, ..., n are the environmentally improved alternatives generated.
- The analysis of the alternatives from an economic perspective. As a result of applying the LCC methodology to each of the improvement alternatives generated, we obtain the economic evaluation for each of them (LCC_i) divided into internal and external costs.
- The analysis of the alternatives from the consumer's point of view. The application of the CV methodology-based questionnaire results in the consumer's willingness to pay for each of the environmentally improved alternatives (WTP_i).

3.4 Stage IV: Selection of the optimal alternatives

Two decision criteria are used to select the optimal environmentally improved alternatives from the enterprise and society point of view:

- From society's point of view, any product catalogued as an ecological product must satisfy the condition that both impact on the environment and the external costs are lower when compared with the initial product.
- From the firm's perspective, if the decision to manufacture an ecological product is not imposed by outside conditioning factors (e.g. by law), then the product, apart from fulfilling the above conditions, has to be profitable for the manufacturing company. The money benefits gained with the product have to be at least equal to those obtained from initial product sales.

The application of the nomenclature used in the previous stage to assess each alternative provides insights to derive the equations that need to be fulfilled to select the most profitable and ecological redesign alternative:

$$A_i = \max\{\mathrm{WTP_i} - IC_i\} \leftrightarrow [(\mathrm{LCA_0} - LCA_i) > 0] \wedge [\mathrm{EC_0} - EC_i) > 0] \quad (1)$$

where 0 is the initial product and i = 1, ..., n are the ecological alternatives generated.

4. Results

The proposed model has been applied to different products in the furniture industry. Several environmental improvements have been considered:

- Use of particleboard with low formaldehyde content.
- Design for recycling.
- Minimise energy consumption.
- Use of paint without organic solvents.
- Use of varnish without solvents.
- New packaging systems.
- Minimise the amount of materials.
- Recycled materials.

In all cases, the customers' questionnaire answers have shown concerns on environmental issues. The most noticeable results are summarised here:

- The product sustainability attributes can be divided into two main categories: those related to the vertical differentiation of the product and, those related to the concept of horizontal differentiation. In the former, customers differ in their willingness-to-pay for certain attribute. In the latter, customers have heterogeneous preferences in relation to certain attribute.
- Customers give more value to sustainable products, although differences appear depending on the environmental attribute included in the product.
- The value that customers give to a sustainable product shows relative independence of the externality reduction.

The environmental evaluation of each product improvements reveals disagreements in the results obtained from different methods (Eco-Indicator'95, Eco-Indicator'99, EPS and Tellus). This issue makes harder the calculation of the externalities.

The internal cost data used in the calculations performed to obtain the life cycle cost of every environmentally improved alternative was directly reported by the product's manufacturing company. These costs ratios considered the necessary manufacturing process variations introduced by each ecological alternative. This research work assumed that such cost data is independent from the number of units produced.

Table 1 shows the results for two of the alternatives, compared with initial product, A_0:

$\mathbf{A_1}$ Substitution of the board by another equivalent with low formaldehyde content.

$\mathbf{A_2}$ Substitution of the solvent-based treatment of the metallic surfaces by powdered paint.

Table 1. Analysis of alternatives

		A_0	A_1	A_2
LCA_i	EI'95 (mPt)	314.3	313.8	297.8
	EI'99 (mPt)	7692.5	7602.5	7690.5
	EPS'00 (elu)	46.6	45.5	46.4
	Tellus ($)	16.3	16.2	16.1
LCC_i	IC (€)	136.87	138.17	137.27
	EC (€)	22.15	21.78	21.77
WTP_i	(€)	300.5	342.6	342.6
WTP_i - IC_i	(€)	163.6	180.2	187.7

It can be noticed that all the alternatives satisfy the requirements that makes it an ecological product from the point of view of sustainability for society (environmental impact reduction and external cost reduction). The WTP expressed in Table 1 is the value that maximises the benefits for an enterprise that manufacture the initial product and the ecological alternative [8]. The difference within WTP and IC includes the benefits for the manufacturer, the benefits for the seller and taxes (Figure 3).

The benefits for the enterprise are also a function of the number of units sold. Figure 3 shows the hypothetical sales benefits for an enterprise that manufacture two versions of the product (the initial product and one of the ecological alternatives, A_1 or A_2) and the total number of units demanded is constant. Thus if the price of the ecological alternative is higher, the number of units of this alternative demanded will be lower and the number of units of the initial product demanded will be higher. The monetary unit expressed in Figure 3 considers the percentage of units demanded of each version. In the two alternatives, the highest benefits are obtained for the same WTP (fourth pair of prices of Figure 1).

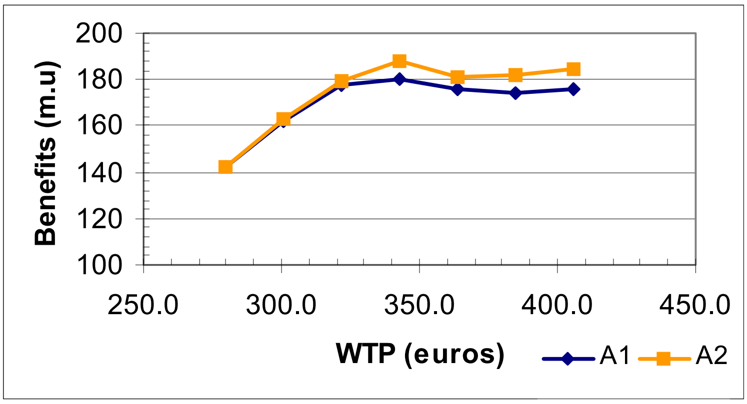

Figure 3 Sales benefits as a function of the WTP

Furthermore, the condition that the profits the firm obtains must be higher than those obtained from the sale of each item of the initial product is also met, since none of the environmental improvements incorporated in the product increases its internal cost more than the willingness to pay increases.

5. Conclusions

A new model is proposed that highlight the importance that the customers give to the different environmental requirements of a product, in order to promote the design and manufacturing of sustainable products.

The model expressed in the equation 1 combines the findings of three methodologies: LCA, LCC and CV, which were used to evaluate the impact on the environment, the life cycle cost and the consumer's willingness to pay, respectively, of different environmentally improved alternatives of a product.

The model tries to integrate two opposite criteria. From society's point of view, the condition that must be satisfied by an ecological product is a reduction in impact on the environment and in its external costs, in relation to the initial product. These conditions, however, are in conflict with the interest of any firm, since the aim of any firm is to maximise the profits it obtains from the sale of its products, regardless of the impact they may have on the environment.

In conclusion, the model states that the decision to manufacture an ecological product has to be profitable for the manufacturing company and any product catalogued as an ecological product must satisfy the condition that both impact on the environment and the external costs are lower when compared with the initial product.

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